# WHICH FACTORS CAN INFLUENCE CHANGES IN THE PERFORMANCE OF STATION AREAS?

*A LONGITUDINAL STUDY*

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# Colophon


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# Glossary

This chapter states the definitions of terms used in this study.

## Nodes

In typical transport modelling networks are modelled as lines (transport connections) and nodes. Nodes refer to intersections or entrances of the transportation network. Examples are road intersections or public transport stations.

The term node can also refer to the node and the area around it, i.e. a station area. An area with both highway and high quality public transport access are called multimodal nodes.

## Node development

Node development refers to the concentration of urbanization near nodes (with at least high quality public transport access). Creating urbanization around nodes will bring housing, jobs, facilities, shops, and leisure within reach of more people, contribute to a better utilization of existing infrastructure, and provide the traveller with a travel mode choice.

## Cross-section research

In cross-section research every object (i.e. a person or location) is represented by one observation. The observations are done at the same point of time. An example of a dataset designed for cross-section research is shown below.

| Object | Year of measurement | Observation of variable 1 | Observation of variable 2 | Observation of variable 3 |
|---|---|---|---|---|
| **Station A** | 2004 | 1 | 1 | 1 |
| **Station B** | 2004 | 2 | 2 | 2 |
| **Station C** | 2004 | 3 | 3 | 3 |

## Longitudinal research

Longitudinal research uses multiple, successfully measured, observations per object. Due to the multiple observations per object, longitudinal research is more time consuming and therefore more expensive than cross-section research. A dataset designed for longitudinal research is shown below. Such a dataset is called a panel dataset.

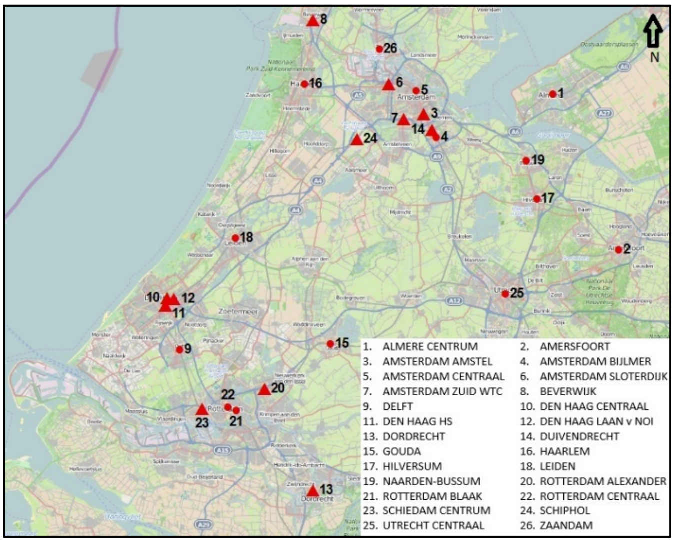
| Object | Year of measurement | Observation of variable 1 | Observation of variable 2 | Observation of variable 3 |
|---|---|---|---|---|
| **Station A** | 2004 | 1 | 1 | 1 |
| **Station A** | 2005 | 2 | 2 | 2 |
| **Station A** | 2006 | 3 | 3 | 3 |
| **Station B** | 2004 | 1 | 1 | 1 |
| **Station B** | 2005 | 2 | 2 | 2 |
| **Station B** | 2006 | 3 | 3 | 3 |
| **Station C** | 2004 | 1 | 1 | 1 |
| **Station C** | 2005 | 2 | 2 | 2 |
| **Station C** | 2006 | 3 | 3 | 3 |

# Samenvatting (Dutch Summary)

In Nederland is er de afgelopen tijd steeds meer aandacht gekomen voor knooppuntontwikkeling. Deze aandacht is terug te zien in het aantal studies uitgevoerd door overheden, gemaakte allianties en de vele werkzaamheden aan stations en rails. Knooppunten worden gezien als de locaties voor toekomstige (economische) ontwikkelingen, omdat ze door hun van oorsprong goede bereikbaarheid Nederland in beweging houden. Als toevoeging kunnen OV knooppunten toevoegen aan het meer duurzaam maken van onze dagelijkse transport behoefte. In deze studie zullen stations locaties centraal staan bij de discussie over knooppuntontwikkeling. Voor het aanjagen van (economische) ontwikkelingen bij stationslocaties en het stimuleren van OV gebruik gebruiken lokale beleidsmakers veelal maatregelen in het domein van ruimtelijke planning en transport. Voorbeelden hiervan zijn het verdichten van de huidige bebouwde contouren, het plannen van nieuwe woonwijken nabij bestaande stations of het aanpakken van verkeersknelpunten. Dit zijn immers de instrumenten die lokale beleidsmakers hebben.

Daarnaast laat onderzoek zien dat er een verband is tussen zowel ruimtelijke ordening en persoonlijke mobiliteitspatronen en bereikbaarheid en ruimtelijke economische ontwikkelingen. Er zijn echter ook onderzoeken die geen of minder sterke relaties laten zien. Wat opvalt is dat onderzoek met sterke relaties vaak gebaseerd is op cross-sectioneel onderzoek. De weinige onderzoeken met minder sterke relaties zijn gebaseerd op longitudinaal onderzoek. Het verschil in gevonden relaties wordt wellicht veroorzaakt door het verschil in onderzoeksmethodiek.

Een ander punt is dat cross-sectioneel onderzoek gebaseerd is op één observatie in de tijd per variabele per locatie. Als er met cross-sectioneel onderzoek een relatie wordt gevonden tussen, bijvoorbeeld, bebouwde dichtheid en OV gebruik, dan geeft dit onderzoek geen causale relatie aan. Deze resultaten worden echter vaak wel zo geïnterpreteerd, onder meer door (lokale) beleidsmakers. Om causale relaties aan te tonen is het aantonen van relaties tussen de verandering van deze variabelen nodig. Dus in het geval van het voorbeeld: is er een verband tussen de toename van bebouwde dichtheid en een toename in OV gebruik? Longitudinaal onderzoek is hier meer voor geschikt doordat het meerdere observaties in de tijd per variabele per locatie meeneemt waardoor de variatie van een variabele kan worden geanalyseerd. Er is een gebrek aan goed Nederlands longitudinaal onderzoek die de interactie tussen ruimtegebruik en transport beschrijft. Hierdoor is het niet duidelijk welke causale relaties er nu echt zijn.



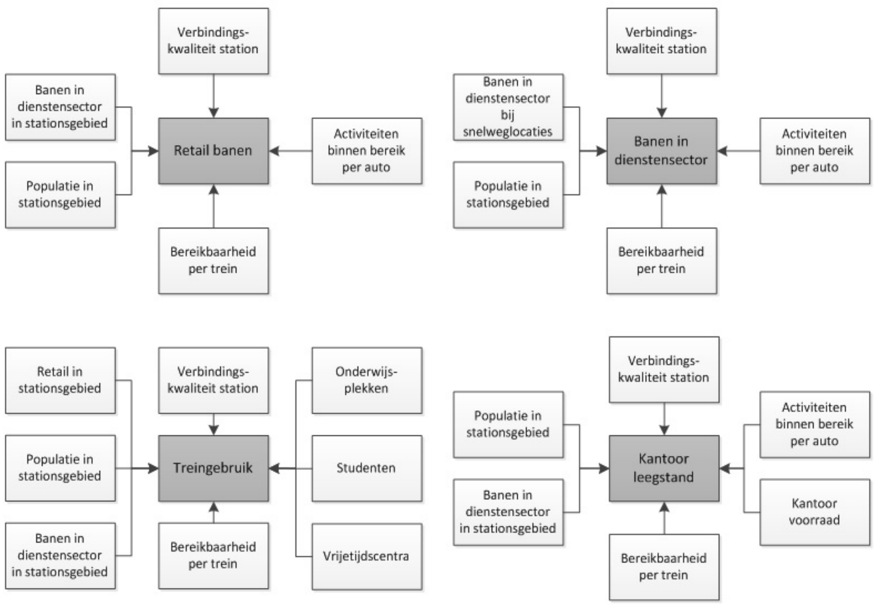

**FIGUUR 1: GESELECTEERDE STATIONS EN DE RANDSTAD.**

Het doel van deze studie is tweeledig:

1. *Het onderzoeken van interacties tussen landgebruik en transport in stationsgebieden gebruik makend van een longitudinale onderzoeksmethode in vergelijking met de cross-sectionele onderzoeksmethode.*
2. *Het bepalen welke factoren, beïnvloedbaar door lokale beleidsmakers, de verandering in de prestaties van stationsgebieden verklaren.*

Voor het beantwoorden van het onderzoeksdoel zijn eerst modellen opgesteld die beogen de prestaties van stationslocaties te verklaren. Aan de hand van bestaande literatuur over de interactie tussen landgebruik en transport zijn deze modellen opgesteld. De verklaarde variabelen (prestatie indicatoren genoemd) in deze modellen zijn retail banen, banen in de dienstensector, treingebruik en kantoorleegstand. De verklarende variabelen komen allen uit de het domein van ruimtelijke planning en transport. De vier gebruikte modellen zijn te zien in figuur 2. Voor operationalisatie van deze modellen zijn 26 stations uit de Randstad geselecteerd. Deze zijn te zien in figuur 1. Door het gebrek aan aanwezigheid van enkele variabelen is er echter voor gekozen om station Schiphol niet mee te nemen. Er is voor de Randstad gekozen omdat de meerderheid van de stationslocaties die aandacht krijgen in overheidsdocumenten hier te vinden zijn. Om binnen de Randstad tot een behapbare selectie te komen zijn alleen alle stations gekozen die door minimaal twee treindiensten worden aangedaan, waarvan minimaal een intercitydienst.

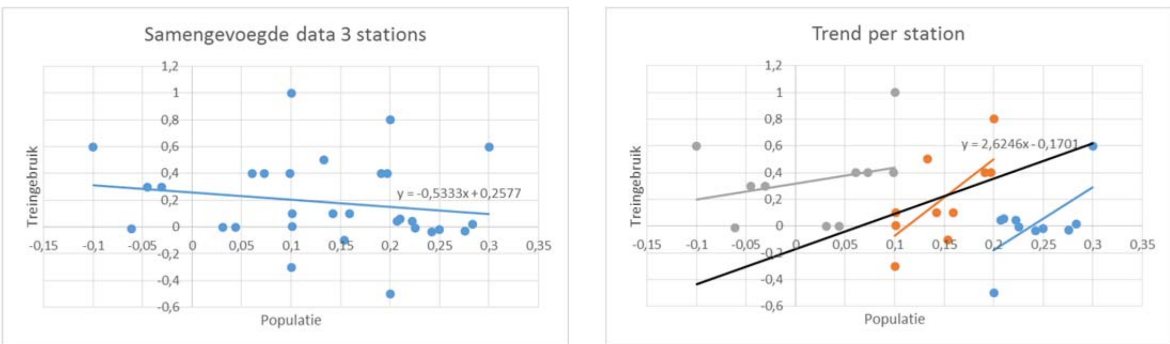
Voor het operationaliseren van de modellen dienen een aantal variabelen te worden gemeten in het stationsgebied. Hierom is eerst een stationsgebied gedefinieerd als het invloedsgebied van het station. Er dient hierbij onderscheid te worden gemaakt tussen herkomststations en bestemming stations. Door het gebruik van de fiets als voortransportmiddel ligt het invloedsgebied van een trein station aan de herkomstzijde van de reis veel hoger. Daarnaast is ook de geboden vervoerskwaliteit bij het station van invloed op het invloedsgebied. Mensen zijn bereid verder te reizen voor een IC station met nationale dekking dan een bushalte bijvoorbeeld. Gebaseerd op het IC karakter van de gekozen stations is het invloedsgebied bepaald op 3.000 meter aan de herkomstzijde en 1.500 meter aan de bestemming zijde. Voor alle variabelen data is gebruikt van de periode 2004-2012.




**FIGUUR 2: CONCEPTUELE MODELLEN.**

Tijdens inspectie van de data viel het op dat ruimtelijke economische activiteiten, zoals banen in de retail en dienstensector, een duidelijke trendbreuk laten zien rond 2008. Aangenomen is dat dit heeft zeer waarschijnlijk te maken met de financiële crisis. Niet-economische data, zoals bereikbaarheid per trein, laten tijdens de gehele periode in het algemeen een stijgende trend zien. Omdat verwacht wordt dat de trendbreuk van ruimtelijk economische data een sterke invloed heeft op de resultaten is er voor gekozen de data op te splitsen in een pre-crisis dataset (2004-2008) en een post-crisis dataset (2008-2012).

De statistische analyse van de modellen is gedaan aan de hand van meervoudige lineaire regressie modellen. Deze analyse is eerst uitgevoerd met de conventionele cross-sectie methode. Om het effect van voor en na de financiële crisis mee te nemen is de cross-sectie analyse uitgevoerd voor de jaren 2004, 2008 en 2012. De longitudinale methode is uitgebreid met nog enkele theoretische verbeteringen die bij cross-sectioneel onderzoek niet mogelijk zijn door de beperkte hoeveelheid data. Om duidelijk te hebben welke veranderingen in variabelen welke veranderingen in resultaten teweeg brengen is het cross-sectie model stap voor stap uitgebreid met een theoretische verbetering. In totaal zijn er vijf stappen, waarbij de conventionele cross-sectie methode stap 1 is. De tweede stap behelst het standaardiseren van de data. Standaardisatie maakt variabelen dimensieloos en stelt de onderzoeker in staat om de invloed van variabelen met elkaar te vergelijken op basis van de grootte van de gevonden regressiecoëfficiënt. Hierdoor is de onderzoeker in staat om niet alleen aan te tonen dat er een relatie is tussen variabelen, maar kan hij ook aangeven welke variabele het grootste aandeel heeft. Bij de derde stap is er afgestapt van het gebruik van absolute data. In stap 3 wordt de ontwikkeling van variabelen tussen 2004 & 2008 en 2008 & 2012 gebruikt in de analyse. Hierdoor wordt er onderzoek gedaan naar de relatie tussen de ontwikkelingen van variabelen. In de vierde stap wordt alle verzamelde data gebruikt en wordt het geanalyseerde model een longitudinaal onderzoek. Hierbij zijn de jaar op jaar verschillen van de variabelen gebruikt. Eenmaal voor de periode 2004-2008 en eenmaal voor de periode 2009-2012. Door de verhoging van het aantal meetpunten is het nu ook mogelijk een vertraging tussen prestatie indicatoren en verklarende variabelen in te bouwen. Het is namelijk niet te verwachten dat de toename van de bereikbaarheid per trein onmiddellijk leidt tot een toename in trein gebruik bijvoorbeeld. Om die reden is er in de relatie tussen de verklarende variabelen en de prestatie indicatoren een vertraging van minimaal 1 en maximaal 2 jaar gesimuleerd. In de vijfde en laatste stap is het model uitgebreid met een fixed effects model. In voorgaande analyses is data van verschillende stationslocaties samengevoegd voor één analyse. Om verschillende redenen (bijvoorbeeld vanwege socio-demografische verschillen in populatie in het stationsgebied) is het niet mogelijk om verschillende stationslocaties zomaar met elkaar te vergelijken. Daarnaast hoort in een regressieanalyse data onafhankelijk te zijn. De data per station is afhankelijk door de opeenvolgende metingen. Bovendien kan het samenvoegen van data leiden tot misinterpretatie van resultaten. Dit is weergegeven in figuur 3. Links is de fictieve dataset van drie stations te zien. Normale lineaire regressie vind een negatieve trend tussen populatie en treingebruik. Rechts in de figuur is de dezelfde data weergegeven met een aparte kleur per station. Het is duidelijk te zien dat elk station een positieve trend laat zien en dat de gevonden trend met normale regressie niet kan kloppen.




**Figuur 3: Misinterpretatie van samengevoegde data en normale regressie (links). Echte trend per station en gevonden trend door middel van fixed effects (rechts).**

Het toepassen van een fixed effects model zorgt ervoor dat er gecorrigeerd wordt voor de verschillen tussen stations door middel van het toevoegen van dummy variabelen. Hierdoor wordt het mogelijk de repetitieve metingen per station te gebruiken om tot betere schattingen van regressiecoëfficiënten te komen. In figuur 3 is de gevonden trend middels een fixed effects model weergegeven met de zwarte lijn. Dit keer wordt er wel een positieve trend gevonden.

Het uitvoeren van de analyses heeft een duidelijk verschil tussen de methodieken cross-sectioneel en longitudinaal onderzoek laten zien. Dit is terug te zien in zowel verschillende $R^2$ waarden als verschillende significante variabelen die gevonden werden. De longitudinale methode laat consistent lagere $R^2$ waarden zien. Dit betekent dat de jaar op jaar verschillen van de verklarende variabelen niet in staat zijn veel variatie van de jaar op jaar verschillen van de prestatie indicatoren te verklaren. Dit impliceert dat bij het beïnvloeden van deze verklarende variabelen beleidsmakers geen resultaten op de korte termijn kunnen verwachten. Dit wordt onderbouwd door de resultaten van stap 3 (ontwikkeling tussen 2004 & 2008 en 2008 & 2012), hier zijn de genomen tijdstappen veel groter (namelijk 5 jaar) en deze modellen laten veel hogere $R^2$ waarden zien. De gevonden resultaten in stap 3 dat het verschil tussen de cross-sectionele en longitudinale onderzoeksmethode wordt veroorzaakt door het verschil in tijdsstappen en niet door het verschil in absolute waarden (cross-sectie) en variatie in data (longitudinaal). In andere woorden betekent dit dat er wel een relatie tussen de prestatie indicatoren en de verklaarde variabelen is, maar dat het tijd kost voordat deze kunnen worden waargenomen.

Een ander belangrijk verschil tussen cross-sectioneel en longitudinaal onderzoek is dat cross-sectioneel onderzoek consistente resultaten laat zien voor zowel 2004, 2008 en 2012 uitgedrukt in zowel de gevonden significante variabelen als $R^2$ waarden. Longitudinaal onderzoek laat juist een sterk verschil zien tussen pre- en post-crisis modellen. Pre-crisis modellen laten verscheidene significante variabelen zien terwijl post-crisis modellen nauwelijks significante variabelen laten zien. Zo wordt pre-crisis consequent een relatie gevonden tussen banen in de retail en dienstensector en activiteiten binnen bereik per auto. Post-crisis worden geen significante variabelen gevonden. Uitzondering is overigens kantoorleegstand waar kantoorvoorraad consequent zowel pre- als post-crisis als significante variabele wordt gevonden. Het is opvallend dat longitudinaal onderzoek duidelijke verschillen laat zien terwijl cross-sectioneel onderzoek voor en na de crisis consistente resultaten toont. Dit komt waarschijnlijk doordat ook na de financiële crisis in een dichtbevolkter stationsgebied waarschijnlijk meer banen zijn dan in een dunbevolkt stationsgebied. Cross-sectioneel zal daarom in beide gevallen een verband tussen populatie en aantal banen in het stationsgebied laten zien. Longitudinaal onderzoek laat post-crisis geen verband zien tussen populatie en banen in het stationsgebied, wat betekent dat er geen relatie is tussen de verandering in populatie de afname van het aantal banen in het stationsgebied. Het lijkt er daarom op dat men met cross-sectioneel onderzoek de verbanden tussen verklarende variabelen en prestatie indicatoren in tijden van economische afname overschat.

Tabel 1 laat de gevonden significante variabelen zien per prestatie indicator. Hierbij is onderscheid gemaakt tussen cross-sectionele (absolute data) en longitudinale (variatie van data) resultaten. Variabelen met een negatieve relatie zijn cursief weergegeven. Voor implicaties in beleid betekent dit het volgende. Cross-sectioneel onderzoek laat vooral positieve sterke relaties zien tussen verschillende vormen landgebruik; banen in de retail en dienstensector en populatie in het stationsgebied. De longitudinale methodiek laat hier juist negatieve verbanden zien. Deze negatieve relatie kan waarschijnlijk verklaard worden doordat de geselecteerde stationsgebieden reeds bebouwd zijn. Ontwikkeling van een type landgebruik gaat daarom wellicht ten koste van een ander type landgebruik. Longitudinaal onderzoek laat een positieve relatie zien tussen banen in de retail en dienstensector en activiteiten binnen bereik per auto. Tevens is er een positieve relatie tussen banen in de dienstensector en verbindingskwaliteit station. Gebaseerd op $R^2$ waarden kan echter geconcludeerd worden dat deze relaties niet erg sterk zijn. Er moet niet te veel verwacht worden van het aantrekken van banen in de retail en dienstensector door middel van het verbeteren van bereikbaarheid. Een ander interessant resultaat is de negatieve relatie tussen banen in de dienstensector in het stationsgebied en banen in de dienstensector bij snelweglocaties. Recent onderzoek van het PBL (2014) heeft aangetoond dat in het afgelopen decennium de meerderheid van de banen bij snelweglocaties terecht is gekomen. Dit onderzoek bevestigt dat deze locaties een ware concurrent voor de ontwikkeling van banen in de dienstensector in het stationsgebied zijn geweest. Dit impliceert dat wanneer het doel is om het stationsgebied te ontwikkelen, men concurrentie met andere locaties moet voorkomen door schaarste te creëren en ontwikkelmogelijkheden op andere locaties te beperken.

Cross-sectioneel onderzoek naar trein gebruik laat een sterke positieve relatie zien met stedelijke dichtheid verbindingskwaliteit station. Stedelijke dichtheid is hier een gecombineerde variabele van banen in de retail en dienstensector, populatie, vrijetijdscentra en onderwijsplekken in het stationsgebied. Het combineren van deze variabelen was nodig door de hoge correlatie tussen deze variabelen. Longitudinaal onderzoek laat enkel populatie in het stationsgebied consistent als positief gecorreleerd met trein gebruik zien. Andere gevonden variabelen met longitudinaal onderzoek die een positieve relatie hebben met treingebruik zijn bereikbaarheid per trein, onderwijsplekken in het stationsgebied en studenten binnen de gemeente.

Het is opvallend dat zowel cross-sectioneel als longitudinaal onderzoek een positieve relatie laten zien tussen kantoorleegstand en kantoorvoorraad. Echter, dat deze variabele wordt gevonden als belangrijke factor is niet nieuw en in lijn met eerder onderzoek (Geurs, Koster & de Visser, 2013). Het maakt in ieder geval duidelijk dat de hoeveelheid toegevoegde kantoorruimte niet in lijn was met de vraag. De positieve relatie van kantoorleegstand met bereikbaarheid per trein en activiteiten binnen bereik per auto zijn ook door dit overaanbod te verklaren. Een verhoging van deze variabelen betekenen een verhoging van bereikbaarheid en daarmee agglomeratievoordelen. Echter een verhoging van de bereikbaarheid (per trein) betekent ook een verhoogde concurrentie met andere plekken (en knopen). In combinatie met het overaanbod van kantoorruimte heeft dit waarschijnlijk geleid tot meer leegstand. Het overaanbod van kantoorruimte betekent dat toevoegen van nieuwe kantoorruimte beperkt moet worden. Focus moet liggen op het (her)ontwikkelen van bestaande leegstaande kantoren. Het gevonden verband tussen bereikbaarheid en leegstand geeft aan dat er niet genoeg vraag is naar (economische) ruimtelijke activiteiten om alle knopen te ontwikkelen. Er moeten duidelijke keuzes gemaakt worden in wat te ontwikkelen en wat niet.

TABEL 1: SAMENVATTING SIGNIFICANTE VARIABELEN.

| | Cross-sectie | Longitudinaal |
|---|---|---|
| **Retail banen** | Populatie<br>Banen in de dienstensector | Activiteit binnen bereik per auto<br>*Populatie*<br>*Banen in de dienstensector* |
| **Banen in de dienstensector** | Populatie | Activiteit binnen bereik per auto<br>Verbindingskwaliteit station<br>*Banen in de dienstensector bij snelweglocaties*<br>*Populatie* |
| **Treingebruik** | Stedelijke dichtheid<br>Verbindingskwaliteit station<br>*Bereikbaarheid per trein* | Bereikbaarheid per trein<br>Populatie<br>Onderwijsplekken |
| **Kantoorleegstand** | Kantoorvoorraad<br>Activiteit binnen bereik per auto | Kantoorvoorraad<br>Banen in de dienstensector |

# Summary

In the past years in the Netherlands more and more attention arose for node development. This is reflected in the number of studies performed for governments, alliances to realize development, and the facility upgrades of several train stations. Nodes are seen as the locations for future (economic) developments while ensuring the accessibility of the Netherlands. In addition, the fact that these station areas are well-accessible by public transport makes it important to use the potential of these nodes to make the Dutch transportation system more sustainable. This study will focus on the station areas. In order to boost development at these station areas and to stimulate public transport use, local policymakers use measures from the domain of spatial planning and transport. Examples are densifying current urban areas, planning housing near existing train stations or upgrading infrastructure. These are measures within the means of local policy makers.

In addition, research has shown a relation between spatial planning and mobility or accessibility and spatial (economic) developments. However, there also studies that indicate weak or no relations. It is apparent that research indicating strong relation often are based on cross-section research while (the small number of) studies indicating weak relations are based on longitudinal research. The difference in results might be contributable to the difference in research methodology.

Another remark is that cross-section research is based on one observation in time per variable per location. Therefore, a found relation using cross-section research between, for example, density and public transport use, this relation is not a causal relation. However, these results are interpret in such a way. In order to indicate a causal relation one needs to find the relation between the variation in two variables. Hence, in the mentioned example one should find a relation between the increase in density and increase in public transport use. Longitudinal research is more suitable for this due to its use of multiple observations in time per variable per location. This makes it possible to analyse the variation of variables. There is a lack of good Dutch longitudinal research describing the interaction between land-use and transport. Therefore it is not clear which causal relations are present.

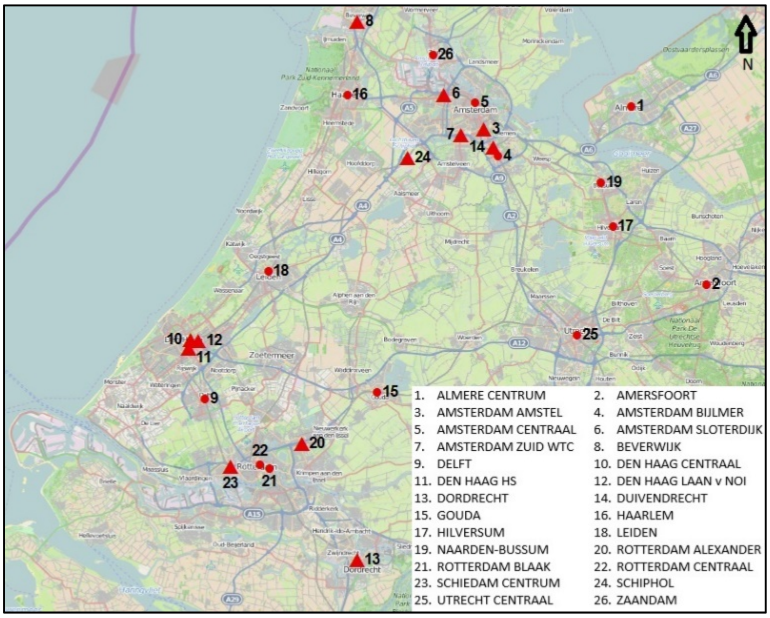



**FIGURE 1: SELECTED STATIONS AND THE RANDSTAD AREA.**

The goal of this study is twofold:

1. *Investigate land-use transport interactions for station areas using a longitudinal research method in comparison to the more conventional cross-section approach.*
2. *Determine which factors, adaptable by local policymakers, influence the changes in the performance of station areas.*

To answer the research goal, models have been developed aiming at explaining the performance of station areas. Based on existing literature describing the land-use transport interaction these models have been developed. The explained variables (called performance indicators) in these models are retail jobs, service jobs, train use and office vacancy. The explanatory variables have been selected from the domain of spatial planning and transport. The four used models are shown in figure 2 below. For operation, 26 stations have been selected from the Randstad area. These stations are shown in figure 1. Due to a lack of presence of some variables at the Schiphol station, this station has been removed from the dataset. The Randstad areas has been chosen because a majority of the train stations associated with node development are located here. To create a manageable selection of stations within the Randstad area only station serviced by at least two train service from which at least an interregional service have been selected.

To operationalise the models some variables have to be measured in the station area. Therefore, first, a station area is defined as the catchment area of a station. One needs to make a distinction between the catchment area of a origin station and a destination station. Due to the use of the bicycle as a popular access mode in the Netherlands, the catchment area of the origin station is much bigger. In addition the quality of the station will influence the catchment area. People are willing to travel further to a train station with national coverage than to a local bus stop. Based on the interregional character of the selected train stations the catchment areas has been defined as 3.000 meters for origin stations and 1.500 for destination stations. For all variables, data was used from the 2004-2012 period.

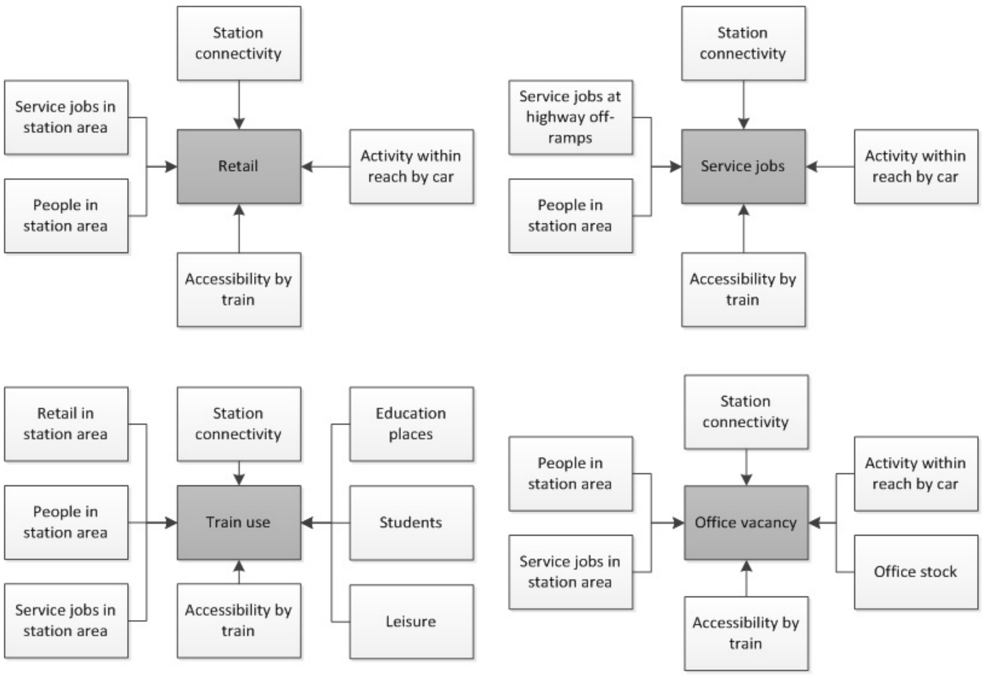
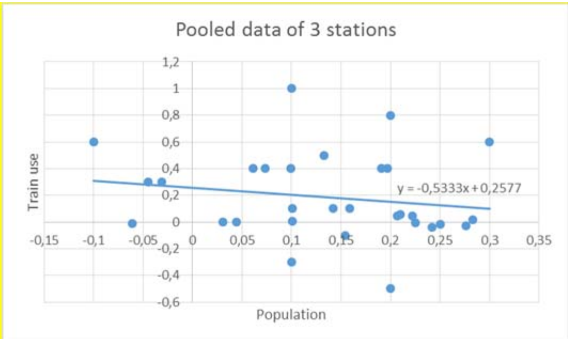



FIGURE 2: CONCEPTUAL MODELS.

During inspection of the data it was apparent that typical spatial economic activities, like jobs and retail, had a clear change of trend around 2008. It is assumed that this is caused by the financial crisis of 2008. Non-economic variables, like accessibility by train, did not show a change of trend. Because it is expected that the change of trend of the spatial economic activities will have a significant influence on results, the used dataset is split into a pre-crisis dataset (2004-2008) and a post-crisis dataset (2008-2012).

The statistical analysis of the models is performed using multiple linear regression models. The analysis is firstly done using the conventional cross-section method. In order to incorporate the effect of the financial crisis the cross-section analysis has been performed for the years 2004, 2008, and 2012. The longitudinal method has been expanded with several other theoretical improvements that are not possible using a cross-section method. To have a clear overview of the change of results caused by what improvement, the cross-section model has been expanded step by step. In total five steps have been used and the plain cross-section method is step 1. In step 2 data has been standardised. Standardisation enables the researcher to not only indicate a relation between explanatory variable and performance indicator but also which explanatory variable has the biggest influence. The third step abandons the use of absolute data and uses the development of variables in the period 2004-2008 and 2008-2012. This makes it possible to investigate the relation between the development of variables. These result should be more suitable for policy goals. The fourth step uses all collected data and turns the model into a longitudinal model. Year-to-year differences of variables have been analysed. Due to the increase of used observations, it is also possible to apply a lag. It is, for example, not assumable that the increase of accessibility by train will immediately affect the number of jobs. Therefore a lag of minimal 1 and maximum 2 years has been simulated between explanatory variables and performance indicators. In the fifth and last step the model has been expanded with a fixed effects model. In previous analyses data of different station areas has been pooled for analysis. Due to several reason (i.e. the difference of socio-demographic characteristics of population) it is not possible to simply compare different station areas. In addition, data for regression analysis should be independent. Data per station is not independent due to the repetitive measurements. In addition, pooling data might lead to misinterpretation of results. This has been shown in figure 3. Left, the fictive data of three stations has been pooled. Using a normal linear regression fins a negative trend between population and train use. Right the data has been indicated per station. It becomes clear that every station shows a positive trend between population and train use. Therefore it can be concluded that the trend in the left figure is a misinterpretation. Using a fixed effects model corrects for the differences between different stations by adding dummy variables. This makes it possible to use the extra data and the repetitive character of data to estimate better regression coefficients. In figure 3, right the trend using a fixed effects model has been indicated in black. This time a positive trend is found.



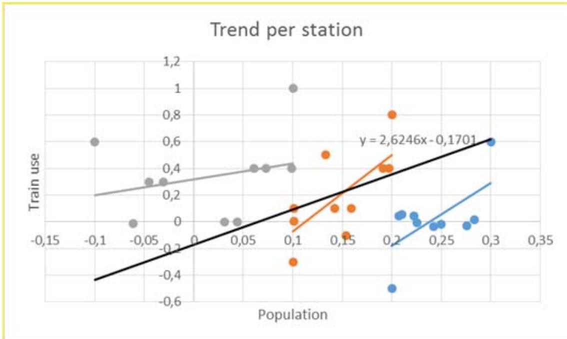




**FIGURE 3: MISINTERPRETATION OF NORMAL REGRESSION WITH POOLED DATA (LEFT). ACTUAL TREND PER STATION AND TREND FOUND USING A FIXED EFFECTS MODEL (RIGHT).**

Analysing model results it becomes clear that the longitudinal method with fixed effects returns different results than the cross-section method. This is expressed in both the $R^2$ values as the significant variables found. The longitudinal method consistently returns lower $R^2$ values than the cross-section method. This means that these models explained less variation than the cross-section models. The found $R^2$ values of the longitudinal method are considered to be very low. This means that the year-to-year differences of explanatory variables in the domain of spatial planning and transport are not suitable to explain the year-to-year differences of the performance indicators. This implies that changing the explanatory variables, through policy, one should not expect changes in the performance indicators as well on the short term. This implication is founded by the findings of the semi cross-section model were development over four and five year in explanatory variables and performance indicators was investigated. These models found relative high $R^2$ values comparable to the cross-section models. This also supports that the found differences between cross-section and longitudinal research methods are not caused by the difference in data input (absolute data vs. variation of data). In other words: there are relationships between the performance indicators and the explanatory variables, but they take time to surface.

Another distinction is found in the different models per research methodology. The 2004, 2008, and 2012 cross-section models all consistently return the same variables to be significant. In addition, the $R^2$ values are comparable as well. The longitudinal method clearly shows a distinction between the pre- and post-crisis models. Pre-crisis models return several significant variables, while post-crisis model return almost none significant variables. In example, the pre-crisis model finds a positive relation between both retail and service jobs and activity within reach by car. Post-crisis no significant relations are found. An exception is office vacancy where office stock in consistently found as an explaining variable. It is remarkable that the longitudinal results show a clear distinction in pre-crisis and post-crisis results, while the cross-section model consistently returns similar results. This is probably caused because even after the financial crisis a densely populated area will contain more office jobs than a less dense populated area. Hence, cross-section research will indicate a positive relation in both cases. However, longitudinal research shows that post-crisis there is no relation between population and service jobs. It seems that due to cross-section research relations between explanatory and explained variables might be overestimated.

Table 1 shows the found significant variables in this study per performance indicator. A distinction is made between cross-section (absolute data) and longitudinal (variation of data) results. Variables with a negative relation are shown italic.

The cross-section methods found a strong and positive relation between different forms of land-use. The cross-section methods returned population to be positively related to both retail and service jobs. Service jobs was also found to be positively related to retail jobs. The longitudinal methods found the same related variables, but negative. This can be explained by the fact that the selected station areas are already built-up. Hence, development of one activity (population, retail or service jobs) will probably happen at the expense of another activity. The longitudinal methods found a positive relation between activity within reach by car and retail and service jobs. There is also a positive relation between station connectivity and service jobs. However, based on the $R^2$ values of the longitudinal models, it should be pointed out that these relations are not very strong. Expectations of attracting development due to accessibility improvements should not be too high. Another interesting relation is the negative relation between service jobs in the station area and service jobs at highway off-ramps. A recent study of the PBL Netherlands Environmental Assessment Agency (2014) has indicated that the majority of new jobs in the previous decade has been located a highway locations. This study supports that those locations have been serious competition for the development of service jobs in station areas. This implies that that if one has the ambition to develop its station area, scarcity should be created by limiting offices to locate at other locations.

For the train use performance indicator cross-section research consistently found a positive relation with urban intensity and station connectivity. Here, urban intensity was a combined variable consisting of retail, leisure and service jobs, population and education places. These variables were combined due to high mutual correlation. Longitudinal research only consistently indicates population of the station area to be related to train use in a positive way. Other variables that were found to have a positive relation with the variation in trains use are accessibility by train, education places and the number of students in de municipality. These results imply that train use can be influenced by increasing demand at the origin side of train trips (population of station area and students). That accessibility by train has a positive relation is perfectly in line with the principles of TOD and Cervero & Ewing's two D's: distance to transit and destination accessibility.

For the office vacancy models it is remarkable that both the cross-section methods as the longitudinal methods consistently returned office stock to be positively correlated with office vacancy. However, that this variable is found to be an important factor in explaining office vacancy is not a surprise. The importance of this factor was already recognized by Geurs, Koster & de Visser (2013). It makes clear that the number of $m^2$ of office space constructed was not in line with the demand for office space. That the models also consistently return a positive relation between both activity within reach by car and accessibility by train and office vacancy can also be explained by this oversupply of office space. The increase of activity within reach by car and accessibility by train increase accessibility. The increased accessibility levels also increase competition between locations. In combination with the oversupply of office space this has led to high levels of office vacancy. The oversupply of office space implies that in future policy the construction of new office space should be restricted. Focus should be on (re)developing existing, vacant, office space in order to cope with the high vacancy levels. Demand for development is too low to development all nodes, therefore clear choices have to be made to decide which locations to develop and which not.

**TABLE 1: SUMMARY SIGNIFICANT VARIABLES PER MODEL.**

| | Cross-section | Longitudinal with fixed effects |
|---|---|---|
| **Retail jobs** | Population+service jobs | Activity within reach by car<br>*Population*<br>*Service jobs* |
| **Service jobs** | Population | Activity within reach by car<br>Station connectivity<br>*Service jobs at highway off-ramps*<br>*Population* |
| **Train use** | Urban intensity<br>Station connectivity<br>*Accessibility by train* | Accessibility by train<br>Population<br>Education places |
| **Office vacancy** | Office stock<br>Activity within reach by car | Office stock<br>Service jobs |

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# 1 Introduction

In the Netherlands, node development (knooppuntontwikkeling) is becoming more and more an important topic on political agendas. It is used to create a better coordination between space and infrastructure. Node development is considered to be important to accommodate (economic) growth, while ensuring accessibility and to create a more sustainable transportation system. An example of the policy attention is the formed alliance in the Southwing of the Randstad, 'Stedenbaan', aiming to stimulate future developments in station catchment areas and to increase transit frequencies (Atelier Zuidvleugel, 2006). Other examples are the recent facility (hall, tracks etc.) upgrades of most of the major train stations, and the study conducted in North-Holland aiming at a better utilization of station areas (Deltametropool, 2013). The importance of node development is recognized in the policy documents of ministries as well. Node development addresses both spatial and infrastructure planning. These two topics were traditionally addressed by two separate ministries, both publishing their own policy strategy. However, both documents were created after close consultation. In 2004 the Ministry of Housing, Spatial Planning and the Environment (Ministerie VROM) released the Paper on Spatial Planning (Nota Ruimte (Ministerie VROM, 2004)). The Ministry of VROM refers to nodes as locations for (potential) development. In 2004 the Ministry of Transport (Ministerie V&W) released the Mobility Paper (Ministerie V&W, 2004). This document states that accessibility should be reliable and predictable. A strong economy requires accessibility. The Dutch should be kept mobile by accommodating the forecasted growth in traffic and transport. This should lead to acceptable and predictable travel times. In 2009, the council of the VROM ministry released a document discussing the current state of nodes in the Netherlands and their possibilities. They state that (re-)development of nodes increases the value of the transport network and the national economy (VROM-council, 2009). The transport network, however, is sensitive for disruptions due to its intensive use. In the period of 2000-2007 the personal mobility increased 13%, while losses in travel time increased 53% (KiM, 2008). In order to decrease the vulnerability of the mobility network, redundancy is necessary. Redundancy in the network can be accomplished in two ways; parallel connections or a back-up system. Due to a lack of parallel connections in the secondary road network, the public transport and road network are seen as a back-up system for each other. Together, they provide sufficient capacity for mobility, which ensures accessibility. In the Netherlands all urbanized areas are well connected by roads. Providing redundancy therefore means developing nodes with access to high quality public transport. The VROM-council (2009) recommends that, for urbanization, the government selects these locations (nodes) based on their position in the network: inter-city train stations which are also well-accessible by car (VROM-council, 2009). These locations have the highest potential to accommodate economic growth while ensuring accessibility. In 2010 the Ministry of VROM has merged with the Ministry of Infrastructure to the Ministry of Infrastructure and the Environment (Ministerie I&M). Their most recent policy strategy states that the central government wants to make the Netherlands competitive, accessible, liveable, and safe. To be competitive, we must ensure that the Netherlands is an attractive base for international companies with a first-class climate for companies and knowledge workers thanks to its excellent spatial and economic infrastructure. One of the proposed strategies concerns linking spatial developments and infrastructure. To provide accessibility, a robust and comprehensive mobility system, featuring multimodal hubs, offers choices and will provide adequate capacity for the projected growth in mobility (Ministerie I&M, 2012). The discussion of these recent papers on spatial and infrastructure planning make clear that the government has an interest in node development to pursue accessibility and economic goals.

Node development will also create a more sustainable transportation system. A recent study of the Netherlands Environmental Assessment Agency (2014) has indicated that between 2000 and 2010 new dwellings and job locations mostly have been realized at locations with an inadequate accessibility; automobile dependent locations such as suburban locations and locations near highways (PBL, 2014). The automobile is not considered as a sustainable mode of transport. In order to define sustainable transportation, Black (2010) defined the factors that make transportation unsustainable. He recognizes nine aspects that cause an unsustainable transport system: diminishing petroleum reserves, global atmospheric impacts, local air quality impacts, fatalities & injuries, congestion, noise, mobility, biological impacts and equity (Black, 2010). In addition to those nine aspects I would like to add a tenth: use of space, which is an important topic in the Netherlands where arable land is scarce. Off all common modes used for daily transportation the automobile contributes the most to the aforementioned aspects. Hence, creating less automobile dependent urban areas will contribute to more sustainable modes of transport. Research has shown that there is a relationship between land-use and the demand for mobility and mode choice. For example dense, diverse, and well-designed areas result in shorter trips and less car use (Cervero & Ewing, 2010). Thus creating high urbanized (walkable) communities interlinked with high quality transit will make people less automobile dependent. From this perspective, all public transport station areas are of interest.

## Ambition of Policy

To develop nodes, (local) policymakers often use measures to boost development. The goals of these measures can be to attract spatial (economic) developments or to increase public transport use. The measures they use are usually from the domains of spatial planning and infrastructure. These measures are within the means of local policy makers. Typical Dutch measures are planning housing within the catchment area of existing public transport nodes (Stedenbaan) or upgrading infrastructure. These typical measures will make the considered node more accessible which makes it a more attractive location for spatial (economic) development. On their turn, an increase in spatial (economic) developments around public transport nodes will probably increase public transport use.

# 2 Problem Identification / Motivation

Research has shown the relation between accessibility and spatial (economic) developments. Other research has shown the link between spatial planning and the mobility it will result in. Therefore it is not strange that policy makers try to boost spatial (economic) developments or change mobility patterns with measures from the domain of spatial planning and infrastructure. An example is the work of Cervero and Kockelman (1997). They found a relation between urban density, diversity, and design and personal car use. Among other results, they found a positive relation between urban density and public transport use. For their research they analysed the land-use characteristics of 50 neighbourhoods in the San Francisco Bay Area and the mobility in those neighbourhoods based on BATS (Bay Area Travel Survey). Data was obtained from the 1990-1991 period and per neighbourhood the land-use characteristics were linked to a mobility pattern. Another example of research in the field of land-use transport interactions is the negative relation found between private passenger transport related energy use and density (Newman & Kenworthy, 2006). Newman and Kenworthy found a negative exponential relation between private passenger transport energy use and activity intensity of a city (persons+jobs/ha). For their research, data was collected from 58 higher-income cities for the year 1995. Both studies are cross-section research. Due to the characteristics of cross-section research this type of research does only indicate a relation between variable 1 and variable 2, i.e. urban density and public transport use. Cross-section research does not indicate a causal relation. Hence, it does not prove that increasing urban density will automatically increase public transport use. Despite, results of cross-section research are often interpret in such a way.

A lot of research on the topic of land-use transport interactions is cross-section research. Due to its minimal number of observations needed, cross-section research is relatively quick and cheap. There is nothing wrong with the relations found using cross-section research, but these relations should not be mistaken for causal relations. However, having knowledge on the causal relations between land-use and transport is interesting and important for policy makers trying to boost development or influence personal mobility.

Longitudinal research is able to return causal relations due to using multiple observations per object. By having multiple observations per object one is able to investigate the relation between the change of two variables. I.e. one can investigate whether or not there is a relation between the change in density and the change in public transport use. Due to the multiple observations per object (in this study station areas) it is also possible to analyse the change over time per location, instead of comparing differences between different locations.

Cross-section research usually finds evident relations between land-use and transport, like in the aforementioned examples. It is interesting to investigate whether or not evident causal relations can be found using longitudinal research as well. The importance of infrastructure and accessibility on land-use, in literature, are often derived from real estate values. Empirical Dutch studies found evident relations between the proximity of train stations and rent of offices. It was found that tenants are willing to pay more rent in the proximity of train stations (Weterings et al., 2009; De Graaff, Debrezion, & Rietveld, 2007; Debrezion & Willigers, 2007). However, these are all cross-section research studies. A recent longitudinal research analysing temporal variations found weak results for the relation between the distance to a train station and office rent (Koster, 2012). Another study analysing the effects of the opening of new train stations on housing prices found no effects (Koster, 2013). Differences in research results are probably contributable to different research methodologies.

As mentioned, a lot of research in the field of land-use transport interactions is cross-section research. Multiple good (Dutch) longitudinal research studies are lacking in the discussion. This thesis tries to make a contribution to the knowledge on causal relations in land-use transport interactions.

# 3 Research Goal

Based on the introduction and problem identification the goal of this research is twofold and formulated below. Goal of this study is to:

I. ***Investigate land-use transport interactions for station areas using a longitudinal research method in comparison to the more conventional cross-section approach.***
II. ***Determine which factors, adaptable by local policymakers, influence the changes in the performance of station areas.***

## Research Questions

To achieve the stated research goals above, five research questions have been formulated. The research questions and their explanation are shown below.

**RQ1. Which indicators can be used to assess the performance of station areas?**

In order to investigate which factors influence the change in performance of station areas, it has to be clear which indicators can be used to quantify the performance of a station area. These, measurable, indicators are called the performance indicators and stand for the desirable characteristics of stations areas that policy makers try to achieve. These performance indicators will be the explained variables in the statistical analyses. Example of such a performance indicator is the number of train users.

**RQ2. Which measurable indicators can be explanatory variables for the actual development of station areas?**

Traditionally, policy makers try to influence the performance of station areas through characteristics of these areas. Factors that might influence the performance indicators are called explanatory variables and will be the explanatory variables in the statistical analyses. A large set of factors that might influence the performance of station areas are discussed in this study, yet only factors from the domain of spatial planning or infrastructure will be included in the analyses. Examples are the size of the population in the station areas or the accessibility by train.

**RQ3. What has been the actual development of station areas, measured in these performance indicators and explanatory variables?**

For every performance indicator and its explanatory variables a dataset needs to be created with the actual development in the past years. This dataset will form the input for the analyses assessing the relation between the explanatory variables and the performance indicator. This dataset will also provide a clear overview of the actual development of the analysed stations areas over time.

**RQ4. Which relations between the change in explanatory variables and performance indicators are found?**

The developed dataset can be used to investigate the relation(s) between the explanatory variables and performance indicators. Both the conventional cross-section method and a longitudinal method are used for analyses and results are compared. The analyses should assess the significant relationships between the changes occurring in explanatory variables and changes occurring in associated performance indicators.

**RQ5. What are the implications for future policy based on the results?**

The results of this study will be translated to implications for future policy. The new insights in causal relations in the field of land-use transport interactions might lead to new recommendations.

# 4 Theoretical Framework

This chapter describes the theoretical framework used in this study. It will provide the reader with a background in the topic of land-use transport interaction. Furthermore, the variables used in the assessed models are based on the used variables/models in existing literature. This will make the analysis in this study comparable with existing literature.

The chapter is divided into four parts. The first part discusses definitions of public transport nodes and a brief history of government policy on land-use and infrastructure. This part will make clear what is expected of public transport nodes and why they are important for society. The second part covers the land-use transport interaction. Based on existing literature it is made clear that there is a mutual relation between the domains of land-use and infrastructure. Due to the existence of this mutual relation it is assumed that one domain can be influenced by the other with, for example, policy measures. The third part states the performance indicators that will be used as explained variables in the statistical analyses. It has to be made clear that not only factors from the domains of land-use and infrastructure can influence the performance indicators. The fourth part provides the reader with a context of domains that also can influence the used performance indicators.

## 4.1 Public Transport Nodes

In typical transportation modelling the (main) transportation network is represented with links and nodes. This study will only address public transport nodes in the main transportation network, hence only station areas are discussed.

Nodes are places where one can enter the transportation network or change modes. Due to the great accessibility of these nodes the area around a node has a certain value. Table 4.1 contains several definitions of a public transport node found in literature. Incorporating the different definitions lead to the following definition for stations areas used in this research:

*A station area is a place where one can enter the public transportation system, change between different modes, where people stay and meet, and where (economical) activities take place*.

**TABLE 4.1: SEVERAL DEFINITIONS OF A PUBLIC TRANSPORT NODE (STATION AREA).**

| Source | Definition |
|---|---|
| **(VROM-council, 2009)** | *Public transport nodes are the access points to the main grid and form due to their great accessibility an attractive location for several functions.* |
| **(Bertolini, 1999, p. 201)** | *"…an area where many, different, people can come, but also where many, different, people can do many different things."* |
| **(Department of Transport and Main Roads, 2013)** | *"A public transport node usually means a bus way, rail or light rail station."* |
| **(Grontmij, 2014)** | *Public transport nodes are locations where travellers change, stay and meet, and where companies locate themselves. In short: nodes with (business) activities.* |
| **Dutch dictionary (transportation point of view)** | *A point where rails or roads come together.* |
| **(Dublinked, 2012)** | *"A transport node is defined as either a point to access the transport network or a point through which it is possible to change transport mode."* |

### The place-node model

In the used definition one can identify both a transport- and spatial-related part. It is recognized that there is an inextricable connection between the transport part and the spatial development within the station area. This relation is described in the place-node model by Bertolini (1999). Here, the place refers to the station area and the node refers to the location in the transportation network. Bertolini (1999) made a clear distinction in his research between the place and the node within the context of node development. He developed an analytical model to identify the potential for node development. According to Bertolini a node is a very accessible place and an accessible place is an area where many, different, people can come, but also where many, different, people can do many different things. Therefore the node has a certain value (the ease of getting there) and the place has a certain value (things to do there).

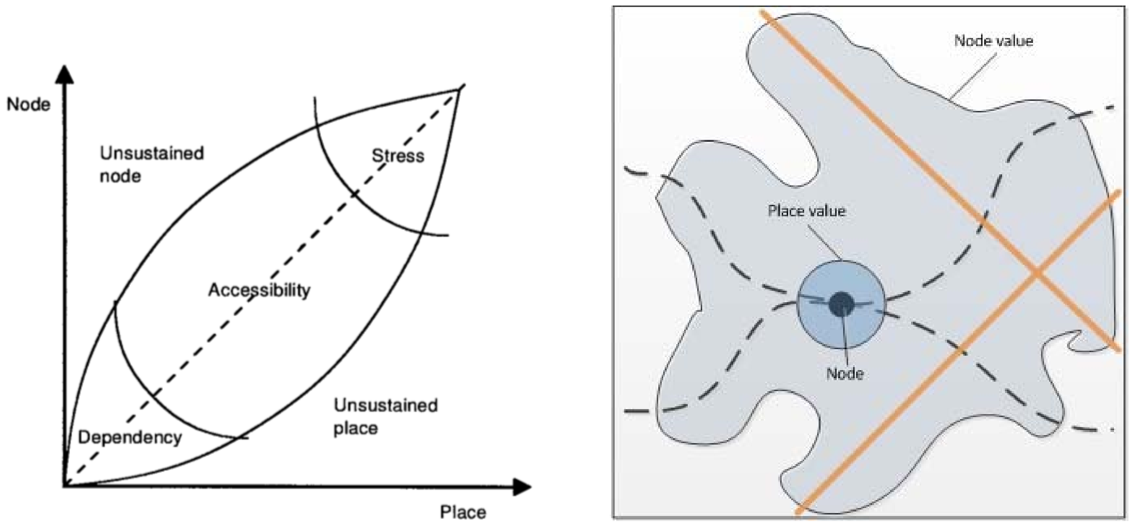
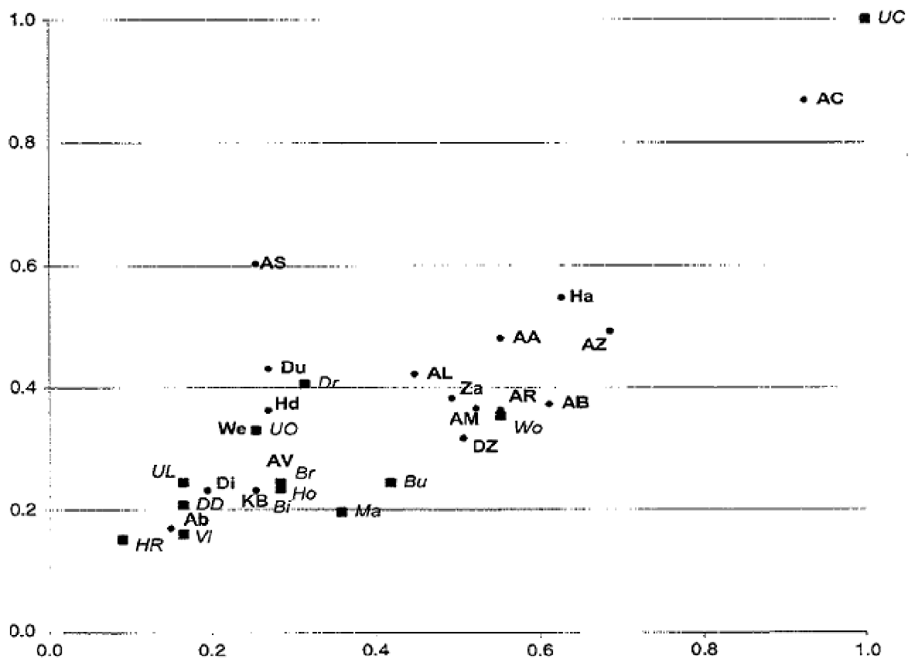



FIGURE 4.1 LEFT: THE PLACE-NODE MODEL (BERTOLINI, 1999). RIGHT: NODE VALUE VERSUS PLACE VALUE.

Both values have to be in balance in order for the node to be in balance. Figure 4.1 (right) illustrates the difference between the place and the node value graphically. The node index combines accessibility by train (number of train directions, train frequency, amount of stations within 45 min. travel.), accessibility by bus, tram and metro (BTM) (directions and frequency), accessibility by car (distance from highway and parking capacity), and the accessibility by bicycle (number of freestanding bicycle path and parking capacity). The radius around the node is the place value. The place index value is a measure of the intensity and diversity of activities in the area. Variables are the number of residents and workers in four economic clusters (retail/hotel and catering, education/health/culture, administration and services, industry and distribution) (Bertolini, 1999).

**AA** = Amsterdam Amstel
**Ab** = Abcoude
**AB** = Amsterdam Bijlmer
**AC** = Amsterdam CS
**AL** = Amsterdam Lelylaan
**AM** = Amsterdam Muiderpoort
**AR** = Amsterdam RAI
**AS** = Amsterdam Sloterdijk
**AV** = Amsterdam Vlughtlaan
**AZ** = Amsterdam Zuid
*Bi* = Bilthoven
*Br* = Breukelen
*Bu* = Bunnik
*DD* = Den Dolder
**Di** = Diemen
*Dr* = Driebergen-Zeist
**DZ** = Diemen Zuid
**Du** = Duivendrecht
**Ha** = Haarlem
**Hd** = Hoofddorp
*Ho* = Houten
*HR*= Hollandsche Rading
**KB** = Koog Bloemendijk
*Ma* = Maarssen
*UC* = Utrecht CS
*UL* = Utrecht Lunetten
*UO* = Utrecht Overvecht
*Vl* = Vleuten




**We** = Weesp
*Wo* = Woerden **Za** = Zaandam

**FIGURE 4.2: APPLICATION OF THE PLACE-NODE MODEL (BERTOLINI, 1999).**

Figure 4.1 (left) shows the place-node model. It has to be noted that the node and place index indicate the potential of a station area, it does not reflect actual use of the node. Stations with a score near the diagonal line in the centre are in balance. Stations with a score high on this diagonal are probably under stress. Here the intensity and diversity of transportation flows and urban activities are probably high. On the other side of the line intensity and diversity of transportation flows and urban activities are probably so low that other factors than demand for transportation or urban activities are keeping these stations in operation. In the top left of the diagram the unsustained nodes are categorized. Here transport facilities are much more developed than urban facilities. For the unsustained places this is the other way around. The node-place model indicates the development potential for a station area. Furthermore it will provide the reader with a clear visual representation of the development of the analysed nodes in chapter 7.

Figure 4.2 shows the application of the place-node model for stations in the Amsterdam and Utrecht agglomerations in the Netherlands at the end of the 20th century (Serlie, 1998). Stations from the Amsterdam agglomeration are indicated **bold**, while stations from the Utrecht agglomeration are indicated *italic*. It becomes clear that most nodes are relatively in balance. The only exception is Amsterdam Sloterdijk which is an unsustained node. The transport facilities here were much more developed that the urban activities in the station's area. The potential for Amsterdam Sloterdijk thus lies in strengthening the station area (place) by, for example, adding spatial development. The two city centre nodes, Amsterdam CS and Utrecht CS, are clearly under stress and have therefore less potential for growth.

## Dutch strategy documents on land-use and infrastructure

In the Netherlands the awareness that spatial developments and the need for mobility go together started to rise a long time ago. This topic was already covered in the second report on spatial planning (1966) where a population growth of 20 million people was forecasted. This forecasted growth came together with an enormous projected growth in traffic. In order to prevent the Dutch cities from becoming too big and congested, urban growth would be accommodated in designated overspill centres: concentrated deconcentration (VROM, 1966). These overspill centres had to be designed in a compact way to preserve green areas and be efficient in funding for services and infrastructure. In addition to this spatial plan the third report on spatial planning (1977) added extra arguments for the overspill areas to be designed as compact as possible; reducing energy use, car-use, and less investments in infrastructure. This policy was based on four key elements: 1) location of new developments in existing urban regions, 2) good public transport connections for new developments, 3) mixed housing, employment, and services on the scale of the urban region, and 4) location of employment in the immediate accessibility by car or railway stations (VROM, 1977).

The fourth report on spatial planning, followed by the fourth report extra, aimed even more at reducing energy use, the growth of (car) mobility, and preserving the environment. A crucial element in this report is the focus on accessibility by car of urban functions. In order to accommodate a growing population and economy, priority was first on developing inner city locations, followed by locations on the edges of existing urban areas. Only when these first two options were not possible, other locations could be considered for development. Another focus in the fourth report extra was the so called ABC-policy. The policy aimed at controlling the growth of the number of companies at highway locations and the car-use stimulated by that. The ABC-policy divided locations according to an accessibility profile. This profile had to determine were a company could locate. A-locations were locations within the bigger station areas and well accessible by public transport. These locations were meant for services and offices with lots of visitors and a low automobile dependency. B-locations were serviced by reasonable to good public transport and, in addition to that, well accessible by highway. These locations are suitable for offices with a higher automobile dependency, like business services. The C-locations are the so called highway locations. Good accessibility by car and hardly any public transport. These locations are for industries and the transport sector (VROM, 1991).

In conclusion, spatial planning policies were focused on reducing (transport-related) energy use, car-use, and mobility. The elements of these policies cover intensifying urban density (increasing accessibility by car), mixing land-use, and promoting non-car modes. Non-car modes were promoted by intensifying urbanization and increasing the role of public transport.

National policy strategy for infrastructure and planning

The latest policy strategy for infrastructure and planning also emphasizes that careful planning is necessary to protect our last nature reserves and utilize our existing built-up areas as efficient as possible. The National policy strategy for infrastructure and planning states that the central government wants to make the Netherlands competitive, accessible, liveable, and safe. To ensure the accessibility of the Netherlands the strategy is to create a robust and comprehensive mobility system featuring multimodal hubs (nodes), they offer choices and will provide adequate capacity for the projected growth in mobility. The multimodal hubs are mainly well-accessible train stations that are also well-accessible by car. These train stations play an important role in this mobility system. An important motivation for the government to focus on multimodal hubs is to ensure accessibility while (economic) growth is accommodated. Ensuring accessibility will keep the Netherlands a competitive economy. Road and railway systems can be each other's back-up system and together they provide enough capacity to ensure accessibility of the most important economic locations (VROM-council, 2009). For rail commuting, traveling is made easier for passengers; on the busiest commuter lines, train frequencies are going to be increased to at least six regional and six interregional trains an hour, making the use of a timetable unnecessary. This is an important strategy in providing a liveable environment for the inhabitant: making a transition to more sustainable modes of transport in order to cope with the diminishing supply of fossil fuels and reduce the $CO_2$-emmissions related to transport (Ministerie I&M, 2012).

Hence, Dutch government focusses on densifying existing built-up locations and to use existing (multimodal accessible) nodes as much as possible to accommodate economic growth. Multimodal accessible locations ensure accessibility and provide a back-up system for each other. It will also make the transportation system more sustainable as people will become less automobile-dependent. To cope with today's sustainability issues, government also focusses on more public transport use as opposed to car use. This will be realized by increasing public transport quality.

## 4.2 Land-use Transport Interactions

This section describes land-use transport interaction. This mutual relation has been indicated in existing literature. The relation is mutual because it has been shown that on one side personal mobility patterns are subject to land-use (characteristics of the built-up environment). On the other side is infrastructure, as part of accessibility, an important precondition for spatial (economic) development. First the relation between land-use and personal mobility is discussed. Second the relation between infrastructure and spatial (economic) development.

### The built-up environment and personal mobility

Research has found that in areas that are more densely built-up, diverse in land-use, and where slow modes of transport (walking and cycling) are promoted people are less automobile dependent and use more alternative modes of transport. These aspects were also recognized by Cervero & Kockelman (1997) and they called it the 3D's: Density, Diversity, and Design (of space and routing). In their research, Cervero & Kockelman examined how the 3D's affect trip rates and mode choice of residents in the San Francisco Bay Area. For 50 neighbourhoods, 1990 travel diary data and land-use records were obtained from the U.S. census, regional inventories, and field surveys. Next, models were estimated that relate features of the built environment to variations in vehicle miles travelled per household and mode choice, mainly for non-work trips. The research found that density, land-use diversity, pedestrian-oriented design generally reduce trip rates and encourage non-auto travel. Found elasticities between variables capturing the 3D's and various measures of travel demand were in the 0.06 and 0.18 range (I.e. they found an elasticity of -0.063 between urban intensity and person vehicle miles travelled per household for non-work trips. This elasticity means that an increase of urban intensity with 1% will decrease person vehicle miles travelled with 0.063%). Overall, the research of Cervero &

Kockelman showed that elasticities between each 'D' and travel demand are modest to moderate, but statistically significant. Hence it supports the theory that creating dens, diverse, and pedestrian-oriented neighbourhoods can influence the way we travel (Cervero & Kockelman, 1997).

Years later, Cervero & Ewing (2010) added two extra D's: Distance to public transport and Destination accessibility. Cervero & Ewing (2010) performed a meta-analysis on more than 200 studies on the built environment / land travel relation that have been conducted since 2001, the year of their previous review study. The built environment is modelled using the 5D's. The purpose of the study was to quantify effect sizes of the built environment on travel. After inspection of the more than 200 studies, eventually over 50 studies were used to compute effect sizes. The effect sizes are shown as elasticities. The effect sizes of built environment characteristics on personal car use (expressed in vehicle mileage travelled (VMT)), public transport use, and walking are shown in tables 4.2 to 4.4. Results show that increase of density, decreases VMT and increases walking and public transport use. The same holds for diversity, design, destination accessibility, and distance to public transport. Distance to public transport is measured as the shortest path to the nearest public transport stop. Note that design has a strong influence on walking and public transport use. Also note that destination accessibility by car 'degenerates' car use. This seems unlikely, but can be explained. A higher accessibility by car probably means living closer to the city centre, where density, diversity, accessibility by public transport, and the proximity of public transport stops are higher as well. All these factors reduce car use (Cervero & Ewing, 2010). A qualitative explanation of the effect of the used 5D's on travel behaviour is discussed in the next sections.

**Table 4.2: Weighted average elasticity's of VMT with respect to the 5D's (Cervero & Ewing, 2010).**

| | | # of studies | Weighted average elasticity of VMT |
|---|---|---|---|
| **Density** | Household/population density | 9 | -0.04 |
| | Job density | 6 | 0.00 |
| **Diversity** | Land-use mix (entropy) | 10 | -0.09 |
| | Jobs-housing balance | 4 | -0.02 |
| **Design** | Intersection/street density | 6 | -0.12 |
| | % 4-way intersections | 3 | -0.12 |
| **Destination accessibility** | Jobs accessible by car | 5 | -0.20 |
| | Jobs accessible by public transport | 3 | -0.05 |
| | Distance to downtown | 3 | -0.22 |
| **Distance to public transport** | Distance to nearest public transport stop | 6 | -0.05 |

**Table 4.3: Weighted average elasticity's of walking with respect to the 5D's (Cervero & Ewing, 2010).**

| | | # of studies | Weighted average elasticity of walking |
|---|---|---|---|
| **Density** | Household/population density | 10 | 0.07 |
| | Job density | 6 | 0.04 |
| | Commercial floor area ratio | 3 | 0.07 |
| **Diversity** | Land-use mix (entropy) | 8 | 0.15 |
| | Jobs-housing balance | 4 | 0.19 |
| | Distance to a store | 5 | 0.25 |
| **Design** | Intersection/street density | 7 | 0.39 |
| | % 4-way intersections | 5 | -0.06 |
| **Destination accessibility** | Jobs within one mile | 3 | 0.15 |
| **Distance to public transport** | Distance to nearest public transport stop | 3 | 0.15 |

**Table 4.4: Weighted average elasticity's of public transport use with respect to the 5D's (Cervero & Ewing, 2010).**

| | | # of studies | Weighted average elasticity of public transport use |
|---|---|---|---|
| **Density** | Household/population density | 10 | 0.07 |
| | Job density | 6 | 0.01 |
| **Diversity** | Land-use mix (entropy) | 6 | 0.12 |
| **Design** | Intersection/street density | 4 | 0.23 |
| | % 4-way intersections | 5 | 0.29 |

| | | | |
|---|---|---|---|
| **Distance to public transport** | Distance to nearest public transport stop | 3 | 0.29 |

Diversity

In everyday life people will participate in activities, such as work, school or leisure. These activities are not located in their homes, thus people have to travel to be able to participate in these activities. Within a neighbourhood with mixed land-use, everyday activities, on average, are located at a shorter distance in relation to an area with a more homogeneous land-use. Especially in combination with higher densities. In that case people have to travel outside their neighbourhood, which is often too far for walking or cycling. Hence, diversity has a positive influence on reducing automobile dependency. On a higher level of scale, like citywide or regional, diversity has a positive effect on reducing trip length, hence reducing vehicle mileage travelled (Cervero & Ewing, 2010). It is also believed that diversity will make an area more lively. Diversity will encourage the use of slow modes and public transport (Cervero & Ewing, 2010) and therefore a diverse neighbourhood will have more pedestrians and cyclists on the streets. It is assumed that this will increase safety and liveability. In a more diverse neighbourhood there is also a higher activity intensity of leisure activities like shops and bars. Activities like these attract visitors during the whole day. This might increase efficiency of the (public) transport system: the transport system is used during the whole day and not only during traditional peak hours. Increasing diversity on a city-wide or regional scale will also increase (public) transport system efficiency. Within a traditional designed city diversity is often low; the majority of jobs are located in the city centre and people live in the suburbs. Hence every peak period the direction of transport flows is mainly unilateral. Diversity will make this transport flow bilateral and this will increase the effectiveness of the (public) transport system because the transport infrastructure is intensely used in both directions instead of one. This increase of effectiveness is especially interesting for the public transport system as it will make the system more cost effective. This, for example, may make high quality public transport feasible on more locations.

Density

People living in dense neighbourhoods are found to be less automobile dependent and more frequent users of public transport. Automobile dependency in dense neighbourhoods is lower because, in combination with diversity, average trip lengths to participate in activities are lower. Lower trip lengths make the use of slow modes more attractive. In addition, dense neighbourhoods normally have more amenities for pedestrians, like wide sidewalks and shops or bars along the route, which makes walking more rewarding. Public transport use is higher in dense neighbourhoods because in dense neighbourhoods with public transport the total number of activities that will generate or attract trips is higher. Hence, the number of potential public transport trips is higher as well. Furthermore due to congestion in high dense areas slow modes and public transport become more competitive modes compared to the automobile. In addition to the higher number of potential users and congestion, quality of public transport in high dense neighbourhoods is often higher. Due to higher (potential) usage and congestion in dense areas investing in high quality public transport is more cost effective. Finally, high-dense neighbourhoods tend to have less parking facilities and higher parking tariffs. Extra factors that reduce car use (Cervero & Kockelman, 1997).

Newman and Kenworthy have conducted research on the relation between urban density and transport-related energy use and between density and automobile dependence. The first research produced a widely known result, shown in figure 4.3. It shows how the aggregated density of several cities related to their transport-related energy consumption per capita. Despite some critics (one cannot just aggregate densities and cultural differences are not incorporated), it becomes quite clear that low-dense cities use more energy per capita for transportation than high-dense cities (Newman & Kenworthy, 1988). Assuming that people in the analysed cities make the same amount of trips, the research suggests that in low-dense cities people use energy consuming modes like personal cars more often and less public transport or slow modes in comparison with high-dense cities and/or make longer trips. The second discussed study aimed at finding a relation between density and automobile dependence measured in private-transport-related energy consumption. Analysing the data of 58 higher income cities it was found that cities are significantly less automobile dependent when they have an activity intensity of at least 35 jobs and persons per hectare (Newman & Kenworthy, 2006). The result of this research is shown in figure 4.4.

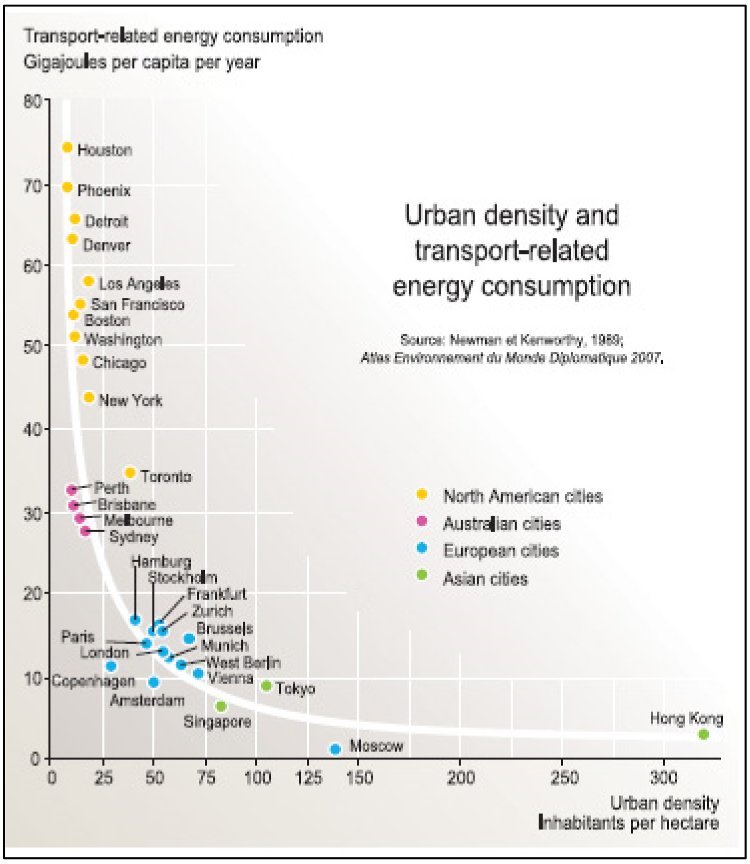



**FIGURE 4.3: URBAN DENSITY IN RELATION TO TRANSPORT-RELATED ENERGY CONSUMPTION (NEWMAN & KENWORTHY, 1988).**

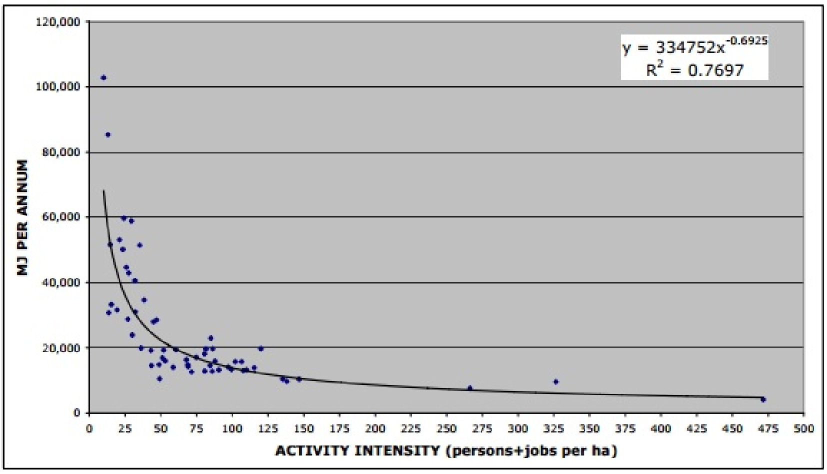



**FIGURE 4.4: URBAN INTENSITY IN RELATION TO PRIVATE-TRANSPORT-RELATED ENERGY CONSUMPTION (NEWMAN & KENWORTHY, 2006).**

<u>Design</u>

The design (of spacing and routing) of a neighbourhood is an important factor in promoting the use of slow modes. To achieve this goal it is important that within these areas the routes for pedestrians and cyclists are well facilitated. This, for example, includes the presence of sidewalks and bike paths, numerous crossing facilities, and the absence of (busy) main roads and (lots of) (visible) parking facilities. Amenities like awnings or roofed sidewalks, trees, realizing parking lots out of sight, and civic squares make destinations more accessible and convenient to reach for slow modes.

Promoting the use of slow modes is important in promoting public transport use. If one has the goal to increase public transport use, one should take the importance of the access and egress modes into account. Public transport is a transportation mode that focuses on transporting mass from one place to another. In contrary to the car, the origin and destination of the public transport trip are often not the actual origin and destination of the commuter. Therefore the commuter has to use access and egress modes. In the Netherlands, slow modes (bicycle and walking) are the most used access and egress modes with 58.4% for access and 56.7% for egress (Givoni & Rietveld, 2007). The design of the station area is therefore important to stimulate slow modes which can be seen as a precondition for the use of public transport.

Distance to public transport

Distance to public transport can be measured as the average shortest distance to the nearest public transport stop from a household or workplace. A lower distance to public transport will probably result in a higher share of public transport use (see table 4.4). This can be explained by the logic that if a public transport stop is nearby it is easier to reach and the threshold to use it is lower.

To assess the distance to public transport factor the percentage of people living within reach of a public transport stop is often calculated. The area within reach of a public transport stop is called the catchment area and its radius differs depending on the quality of service of the public transport stop, trip characteristics, and traveller characteristics. The latter is caused by the fact that for some travel motives people are willing to travel further. For instance, people are willing to travel further for their job than for grocery shopping. Particular in the Dutch case people are also willing to travel a larger distance between their home and the train station, than between their destination and the train station. The use of the bicycle as an important access mode in the Netherlands is an explanation for this. As egress mode, walking is most used and a convenient travel distance for pedestrians is less than for cyclists. In addition, when distance between destination and public transport stop is big, people might chose a different mode of transport to begin with.

Destination accessibility

Destination accessibility measures the ease of access to the place of interest. For example, it can be measured by the amount of jobs reachable within a certain amount of time (by public transport) (Cervero & Ewing, 2010). In the Netherlands this given travel time is often defined as reachable within 30 minutes car travel time and 45 minutes public transport travel time (VROM-council, 2009). It complements distance to public transport in the way that if one lives near a public transport stop, the public transport serving that stop should also bring that person to the place where he or she wants to be. Hence, the destination accessibility factor is part spatial and part infrastructural; spatial because both origin and destination should have a public transport stop nearby. However, maybe even more important is the presence of a direct connection between those stops. Otherwise it still might not be possible to reach that place within a certain amount of time and the person might choose to use an alternative mode of transport or to not make the trip. An increased destination accessibility level has a positive effect on reducing automobile dependence and increasing public transport ridership. This can be explained by the fact that a region with a high destination accessibility probably has lots of locations with a high level of the aforementioned D's: density, diversity, design, and distance to public transport. These locations are also well-connected with each other.

## Transit-Oriented Development

Designing urban areas taking the factors captured by the 5D's into account is often referred to as transit-oriented development (TOD). The concept of TOD is based on the idea to design an urban form in relatively high density, mixed land-use and efficient mass transportation services (Loo, Chen, & Chan, 2010). Node development (especially developing station areas) is often associated with the principles of TOD. TOD is turned to by policy makers more and more to address the problem of car use and the related social and environmental costs. Many factors influence the travel behaviour of people and therefore the focus of policies aiming at controlling that behaviour cannot be limited to transportation policies. As explained in this chapter the form of the urban environment might have an important influence on travel behaviour.

## Infrastructure and spatial (economic) development

The first thing to understand the relation between infrastructure and boosting spatial (economic) developments is that constructing infrastructure is not a goal on its own. Realizing new infrastructure or upgrading existing infrastructure is a way to increase the accessibility of a location. Accessibility can be measured as the number of people or jobs reachable within a certain amount of time. For companies accessibility is important because a high amount of people (employees or clients) within easy access of that location will give that location an extra value over a less-accessible location. For households this extra value by accessibility is caused by the fact that lots of jobs or shops are accessible within a certain amount of time.

<u>Agglomeration benefits</u>

Why are locations with high accessibility levels attractive for companies and households? The idea that increasing accessibility attracts new spatial developments can be derived from the fact that businesses and households like to benefit from agglomeration effects. Agglomeration effects arise between firms due to labour market pooling, input and output sharing and knowledge spill overs (Marshall, 1890). In example, it has been observed that companies cluster together at CBD's and sub centres and are prepared to pay the higher rents and wages at these locations (Koster H, 2013). Within agglomerations there are more suitable suppliers within reach which will lower the cost of supply due to competition and proximity. At the other hand, more customers or clients are nearby within agglomerations. For most companies having a large home market is attractive because this group of customers can be reached easily and cheap. Households, for example can benefit from agglomeration effects by the accessibility of services and jobs. This accessibility is interesting for people looking for a job or for households where more than one person has a job; living in a well-accessible location might be a strategic choice to minimize the commuting time for everybody. Another example is the case of losing a job; in a well-accessible location a person might not have to move to find another job.

<u>Accessibility</u>

By many persons and institutions accessibility is defined and operationalised in many ways. Table 4.5 shows some definitions of accessibility. In his dissertation, Geurs (2006) identifies four components from the several definitions and operational measures: land-use, transportation, temporal, and individual.

- The land-use component reflects on land-use, consisting of (a) the amount, quality and spatial distribution of activities (jobs, shops, health, social and recreational facilities etc.), (b) the demand for these activities at origin locations (where the people live), and (c) the confrontation of supply and demand for activities, which may lead to competition with the restriction of capacities of activities (such as job or school vacancies and hospital beds).
- The transportation component described the transport system as a disutility for an individual to travel between its origin to its destination covering the distance using a certain mode of transport. The disutility can be expressed as time (travel time, waiting, etc.), costs (tickets, parking levies etc.), and effort (reliability, comfort, safety, etc.). The supply of (public transport) infrastructure influences location and characteristics (maximum travel speeds, timetables, costs etc.).
- The temporal component relates to temporal constraints. This can contain several aspects like the availability of activities at a certain time (i.e. opening hours of activities, peak hours, or timetables of public transport) or time individuals have available to participate in certain activities.
- The individual component reflects the needs (depending on age, income, education, etc.), abilities (physical condition, availability of transport modes, etc.), and opportunities (available budget, education,

etc.) of individuals. These characteristics of individuals may strongly influence the total aggregate of accessibility result. (Geurs K. , 2006)

By having the power to determine zoning plans, grant building permits, and construct/adjust local and regional infrastructure, Dutch local policy makers can influence the first two components of accessibility the most; land-use and transportation. To a certain extent they can also influence the third component; temporal. I.e. local policy makers can regulate the maximum opening hours of activities or extent time tables of local public transport.

Accessibility and spatial (economic) developments in literature

The distribution of accessibility in space has an influence on the location of households and firms, and can therefore influence the land-use system. Many studies have indicated that accessibility levels, to a certain extent, influence the location choice of households and firms. It has been shown that the accessibility of activities such as work, shops and public services are important for households, while the accessibility of labour force is important for firms. Both revealed and stated preference studies show that accessibility influences residential choice decisions: for example, residents are more likely to move away from a location with low accessibility levels to social and economic activities than from locations with high accessibility levels (Kim, Pagliara, & Preston, 2005; Molin & Timmermans, 2002). However, it has to be noted that other factors such as demographic factors, dwelling attributes and neighbourhood amenities are more important in explaining location decisions (Molin & Timmermans, 2002; Zondag & Pieters, 2004). Research on the location preferences of entrepreneurs and the empirical analysis of firm locations in the Netherlands have indicated that distance to road and railway infrastructure is an important factor in location decisions (Bruinsma & Rietveld, 1997; de Bok, 2004).

In this research study the focus is on station areas. Hence, the question is whether or not and to what extent spatial (economic) developments can be attracted by the presence of train stations or increasing public transport quality. In their report Geurs, Koster & De Visser (2013) state the importance of infrastructure and accessibility on the location choice of companies. The choice of locations depends on many factors. First factor is the location itself, like quality of the buildings, availability of ground, and access to local infrastructure. Then there are the regional characteristics like the accessibility of the labour force, clients, and suppliers (Geurs, Koster, & de Visser, 2013). Furthermore, it seems that the importance of these different characteristics differ for different companies. Especially firms in the business services sector (banks, insurance companies, consultancies) have a real preference for locations near train stations (within 800 meters) or near highway off-ramps (within 2000 meters). This ensures the accessibility for their employees and clients and was showed with a revealed preference study based on empirical longitudinal firm data (De Bok & Van Oort, 2011; Van Oort, et al., 2007).

Other literature describes the importance of infrastructure and accessibility based on an analysis of real estate values. However, this factor depends on a lot of other factors like the contract (i.e. duration), characteristics of the building (i.e. size, age), characteristics of the location (i.e. presence of services, presence of other companies) and regional market conditions (i.e. demand-supply relation). This lies outside the scope of this research. In several Dutch empirical studies the positive effects of stations on locations expressed in real estate values have been proven (De Graaff, Debrezion, & Rietveld, 2007; Debrezion & Willigers, 2007; Weterings et al., 2009). Their results show that tenants are willing to pay a higher rents for offices in the proximity of train stations. According to De Graaff, Debrezion & Rietveld (2007) there is an increase in rent of 16% when a location is located within 500 meters of a train station, accounted for the other, earlier mentioned, factors that influence rent (and real estate value). It has to be noted that according to Wetering et al. (2009) the transport quality of the train station (train frequency, number of direct connections, and location within the network) is more important than the presence of a train station. The rent is mainly higher near the bigger (interregional) train stations that have a good (direct) connectivity with other cities. However, it also has to be noted that there are also studies available that indicated low or no effects of train stations on their locations (Koster, 2012; Koster, Van Ommeren, & Rietveld, 2013a; Koster, Van Ommeren, & Rietveld, 2013b). It is interesting to point out that some of the studies that found low or no effects of train stations on their location are based on longitudinal research; they analyse variation of variables instead of one observation of that variable. Another remark on some of those studies is that they use fixed effects models; data of different locations is not pooled without taking the difference of different locations into account. Fixed effects modelling is explained in more detail in chapter 6.

Another way to assess the importance of infrastructure and accessibility on the attractiveness of locations is assessing building vacancy levels. The hypothesis is that vacancy levels of buildings are higher at less attractive locations. Geurs, Koster & De Visser (2013) assessed office vacancy levels in relation to the proximity of a train stations. Their research goal was to assess whether or not station areas experienced lower vacancy levels. With data on office vacancy of the 2002-2009 period they estimated a regression model, where the chance that a vacant office is still vacant in the very next year is a function of its distance to a train station. To correct for building characteristics, characteristics like size, age, etc. have been incorporated as well. Model results were that vacant office buildings in the proximity of train station do not have a higher or lower chance to be occupied in the next year (Geurs, Koster, & de Visser, 2013).

## 4.3 Performance Indicators

This section describes the performance indicators used in this research and provides an answer to research question 1. Note that the selected performance indicators are comparable with explained variables in the discussed literature in the previous section. From the discussed policy documents in the previous section it can be concluded that node development is about using the (economic) potential of nodes (in this study station areas), while ensuring the accessibility of the Netherlands. By using the (economic) potential of nodes it is meant that there is a lot to do for a lot of different people (Bertolini, 1999). Hence, *activity intensity* should be high in station areas. However, developing those locations is mainly a case of market operation. The role of policy makers is to create attractive locations for (economic) development (by for example increasing accessibility levels). At those attractive locations, households and firms are willing to pay higher rents (Koster , 2013). Hence, the attractiveness of a location can be measured by its *economic value*. Using station areas ensures accessibility because the road and rail system can complement each other to ensure sufficient capacity and both systems can function as back-up systems for each other. Furthermore it will make a shift possible to a more sustainable transportation system because the use of these locations will decrease automobile dependency. Because road connectivity in the Netherlands is high (you can get pretty much anywhere by car), the performance of a station area can be assessed by its *public transport use*. In conclusion, the performance of station areas can be derived from their *activity intensity*, *public transport use*, and *economic value*.

*Activity intensity* can be measured by determining the number of population and jobs within the station area. This has been done in the discussed literature as well. However, population is not incorporated as planning of housing is mostly subject to planning by policy makers. Jobs are incorporated in this research. Jobs can be divided into four economic clusters: retail/hotel & catering, education/health/culture, administration and services, and industry and distribution. The last cluster, industry and distribution, is not incorporated because it is not desirable that these types of companies are represented in a station area. This is reflected in the ABC-policy mentioned earlier. These types of companies should be located at C-locations based on their mobility profile. The cluster of education/health/culture is also not incorporated because the development of these institutions is mostly a matter of planning by policy makers as well. Furthermore, a distinction is made between the cluster retail/hotel & catering and the cluster administration and services. This distinction is based on the geographical distinction of stations. Stations near (old) city centres typically have a large share of the retail/hotel and catering cluster (from now on called retail jobs), while stations at new centres/suburbs typically have high shares of the administration and services cluster (from now on called service jobs). Retail and service jobs are incorporated as performance indicators.

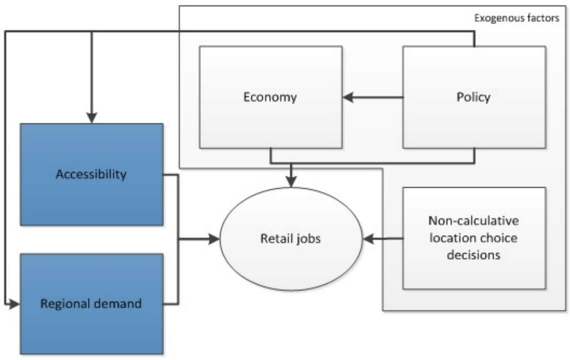
Measuring *public transport use* is straightforward by measuring the number of users. This study focusses on station areas, so a distinction of public transport use can be made between train use (with its (inter)regional character) and BTM use (with its local character). Unfortunately detailed data on BTM use was not available for this study. Train use data is available. Hence, public transport use is measured by train use.

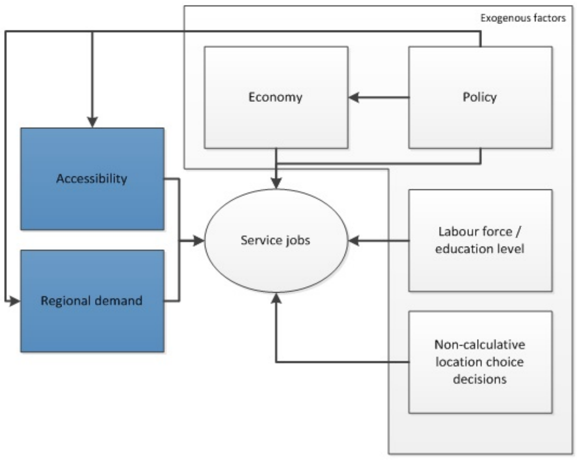
*Economic value* can be measured by real estate values and vacancy levels. Government policy aims at using stations areas (especially the multimodal accessible ones) as locations to accommodate economic growth. If entrepreneurs are eager to locate at these station areas this should be reflected by high real estate values and low vacancy levels. After a quick scan of available data it turned out that no good data on (time series of) real estate values is available for all considered station areas. For vacancy only data is available to estimate the vacancy of offices bigger than 10.000m$^2$. Only office vacancy has been incorporated as performance indicator for economic value. In summary, the following performance indicators will be incorporated in this study:

- Retail jobs;
- Service jobs;
- Train use;
- Office vacancy.

## 4.4 Explanatory Variables

In the previous section four performance indicators have been determined. These indicators will be used as explained variables in a regression model. The selected variables to explain (explanatory variables) the variation in these performance indicators are, as stated in the research goal, adaptable by policy makers. However, these selected variables are not the only factors that are believed to have an influence on the determined performance indicators. This section provides the reader with the context of all factors that are believed to influence the determined performance indicators. The factors that are not assessed in the remainder of this research study are called the external factors. Per performance indicator the complete context of factors that are believed to influence them are shown below in figure 4.5. Factors used in this research are highlighted blue. Every factor is explained in the remainder of this section.



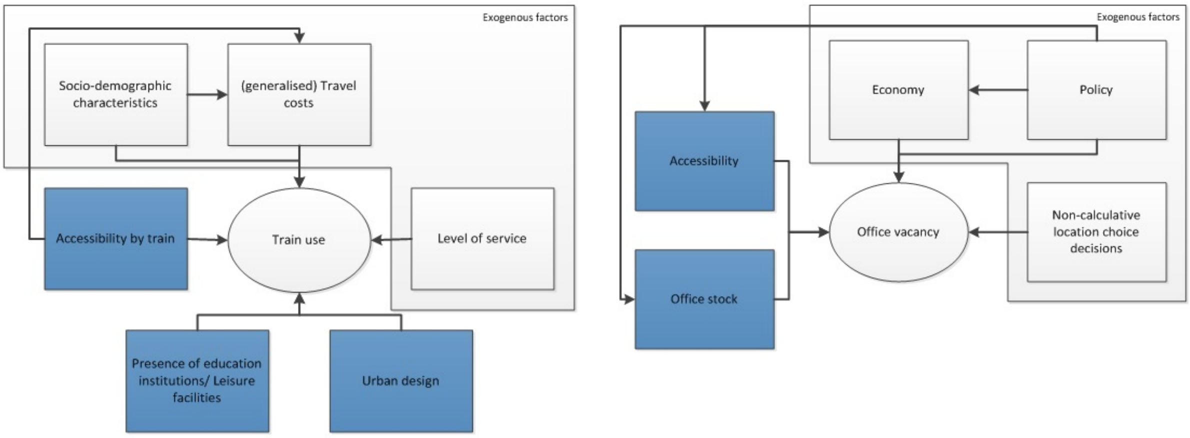



**FIGURE 4.5: CONTEXT OF FACTORS INFLUENCING PERFORMANCE INDICATORS. USED FACTORS IN THIS RESEARCH ARE HIGHLIGHTED BLUE.**

Policy

A relevant domain is policy. As indicated in figure 4.5 policy also has influence on several other factors, but policy can also have a direct influence on retail and service jobs and office vacancy. Local policy is granted the power to make zonal plans and grant building permits. Zonal plans regulate land-use and determine what sort(s) of land-use is allowed. With these powers local policy makers can control the location and amount of development. There are also some (local) municipal taxes, like property taxes. The levels of these taxes can be relevant for the location choice of companies.

There is another policy measure that might have an influence as well: new working conditions. Modernization and IT-solutions enabling working from home and flexible workplaces have decreased the demand for office space per employee. In 1996 the required office space per employee was, on average, $26m^2$. This has decreased to a required office space of $23m^2$ (Zuidema, Elp, & Schaaf, 2012). Especially working from home is promoted by government as a partial solution for the mobility problem.

Zoning plan, taxes and promoting working from home are just examples of policy measures that can influence retail and service jobs and office vacancy. There are more policy measures that can influence those performance indicators, but discussing all those policies lies outside the scope off this research.

Economy

Another relevant factor is the economic climate. The economic climate can be influenced by policy or other (national or international) events. Policies like tax levels, labour laws, international agreements etc. can influence the profitability of companies and the prosperity of a company. The profitability of companies can be related to their number of employees and prosperity can be related to what people can afford to spend in, for example, retail shops. The intention of this global and incomplete description of the relation between economy and retail and service jobs is to make clear that the economic climate should not be forgotten when assessing the development in retail and service jobs.

Accessibility (by train)

The importance of accessibility has already been explained in detail in section 4.2. For retailers and service jobs higher accessibility levels will increase the number of customers, employees, clients and suppliers within reach of that company. This might increase current businesses or attract new ones. For train use the accessibility by train is important, like explained by destination accessibility in section 4.1. The presence of a train station is not enough, the infrastructure and quality of the train service determine how many people can reach that place by train.

This factor is highlighted blue and will be used in this research study because (local) policy makers can influence the accessibility, especially by controlling land-use and transport. In the next chapter this factor will be operationalised into measurable variables to assess accessibility.

Regional demand

Regional demand is influential on retail and service jobs and office vacancy due to the fact that demand for economic activities is not infinite. Within a region (which can contain several municipalities) multiple location can be assigned for spatial (economic) development. These can be existing locations with development or complete new locations for development. However, if demand for spatial (economic) development is lower than the supply of locations, these locations will have to compete with each other. For instance, assigning a new location for spatial (economic) development might attract new businesses and/or make businesses leave the existing location. This last phenomenon might lead to office vacancy when there are no new businesses to use the exerted building. An example of this phenomenon is called node cannibalism; developing a new node might attract businesses, but at the expense of an existing node increasing vacancy levels over there (Snellen, 2013). Hence, zoning plans should be in line with demand for activities. Municipalities are in charge of making zoning plans, hence they can control the number of development allowed to build.

Certain facilities lack demand for a location in every municipality/city. A typical example is a piano shop, you will not find one of those in every village. Those facilities tend to locate in the (historically) biggest city of a region, due to the agglomeration effects of that city. This regional function can explain why two similar places (similar population for example) in two different regions can have a clear difference in the 'completeness' of the city centre. The bigger city will probably also have the most growth potential as it has, relatively, more agglomeration effects to benefit from.

Non-calculative location choice decisions

In literature it is often assumed that the location choice of companies is based on complete information and informed decisions, this is not always true. Decisions are also (maybe even most of the time) based on incomplete information and own preferences. Therefore it can be the case that an entrepreneur is happy with his current location while his business would profit more on a different location. This is because often non-economic factors play a role in location choice. It is found that proximity of the entrepreneurs' origin is important or the location of other (fellow) entrepreneurs (Geurs, Koster, & de Visser, 2013). Another subjective factor is image. The (change in) image of a location might attract location choices that otherwise cannot be explained. Research, for example, has shown that the image of high-speed trains has been influential. The actual use by business travellers of the high-speed rail between Amsterdam and Paris since its completion does not reflect the high demand for companies to settle near the stations of the high-speed rail line (Willigers & van Wee, 2011).

Labour force / education level

An important factor for location choice of companies is (presence of) the labour force, clients, and suppliers. For these reasons companies tend to stick together in urbanized areas to benefit from agglomeration effects. The education level of the potential labour force might be important for some companies as well. In his book, Marlet (2009) states that people do not always move to wherever their job is, sometimes companies move to wherever their personnel might be. Some companies look for (specific) highly educated personnel. Highly educated people tend to live in cities with a high human capital factor (cultural activities, architecture, etc.). The presence of a university might be important as well. The education level of an area is also found to be an important factor in the number enterprises started. Highly educated people tend to start more enterprises and consume more which is beneficial for local SMEs. (Marlet, 2009)

Socio-demographic characteristics

An important factor influencing train use is the socio-demographic characteristics of the population. Examples of these characteristics involve prosperity (i.e. having (access to) a personal car or not), capability (elderly are often more dependent on motorised transport), or age (juveniles are not able to drive a car yet). For short distances, the modes of walking or cycling are available to almost everybody. For longer distances the socio-demographic characteristics influence whether or not a person is a choice or a captive traveller. Captive traveller means that this person does not have an alternative mode of transport available to choose from. Hence, for the longer distances, some people are captive public transport travellers as they do not own a car or are not licensed to drive a car. The group of captive travellers often include lower income households, elderly, juveniles, and students (which also receive a free-travel card for public transport during their study in the Netherlands). For trips that exceed the range of walking or cycling these people are depending on public transport. In two neighbourhoods with comparable quality of public transport the socio-demographic characteristics of the population in that neighbourhood therefore might explain a significant difference in public transport use.

Level of service

The level of service (LOS) of a train trip is an addition to accessibility by train. Accessibility by train ensures that a person can reach their destination within a certain amount of time. This might be satisfying for a captive traveller, LOS might attract extra train use. LOS can be defined as trip quality. For example, LOS can incorporate punctuality, clean coaches, comfortable seats, friendly train personnel, etc. These examples can be seen as an extra service on top of providing basic transport and are used to attract extra (choice) travellers. The NS (Dutch railways) uses the pyramid of client wishes (see figure 4.6). The bottom of the pyramid, in red, states safety and reliability. Those are no considerations, but a necessary precondition. If making the trip is not safe, people will not make the trip. Above that, in yellow, the general wishes speed and ease are stated. These are also called dissatisfiers. All travellers are dissatisfied when their trip lacks these qualities. On top, in green, the satisfiers are stated (comfort and perception). These qualities can be seen as an extra. When they are not present it is no reason to not make the trip, but when they are present it can attract extra travellers. Choice travellers can be attracted by providing them with these satisfiers. Some examples by the NS are providing Wi-Fi in trains, offering leisure at train stations, and offering a 1st class service with extra comfort.

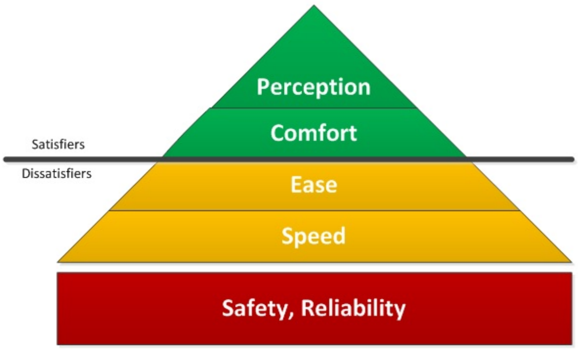



FIGURE 4.6: PYRAMID OF CLIENT WISHES USED BY THE NS (HAGEN, 2003).

(Generalised) travel costs

When people decide to make a trip, choice travellers have to decide which mode of transport to use. Factors that will influence this decisions are travel time, costs and comfort. When, for example, a person wants to travel 30 kilometres to work, this trip will probably not be comfortably made by bike. If this job is located in a busy city centre the person might choose to travel by public transport because its travel time might be lower (roads in the busy city are congested) and the person does not have to pay any parking fees.

In typical transport modelling these factors are translated into generalised costs. This is done by adding the several trip characteristics (travel time, waiting time, costs, etc.) factors using weights. Determining generalised travel costs is different because characteristics differ from trip to trip and the weighing of trip characteristics is personal and based on individual characteristics. For example, a wealthy person might weigh actual travel costs less than another person. Generalised travel costs can be very influential why people travel by train or not. Generalised travel costs (for train use) can be influenced directly by decreasing travel times, lowering prices, or increasing comfort. However, do to the personal nature of weighing those trip characteristics the travel mode choice remains an outcome dependent on individual characteristics of the traveller.

Making a trip normally has a purpose (going to work, doing groceries, visiting a friend etc.) and has therefore a certain utility. Due to generalised travel costs the trip has a certain disutility. When the disutility (of all available modes of transport) is greater than the utility one will consider not to make the trip (I.e. one will probably not travel two hours to visit a friend for an hour). Hence, improving generalised travel costs for a certain mode (i.e. lowering fare prices) might generate extra trips as well.

Urban design

Urban design has been explained in section 4.2 as design (of spacing and routing). Urban design is an important factor in promoting the use of slow modes. To achieve this goal it is important that within these areas the routes for pedestrians and cyclists are well facilitated. In the Netherlands, slow modes (bicycle and walking) are the most used access and egress modes with 58.4% for access and 56.7% for egress (Givoni & Rietveld, 2007). The design of the station area is therefore important to stimulate slow modes which can be seen as a precondition for the use of public transport.

Presence of education institutions / leisure facilities

Experience has learned the NS that the presence of facilities such as institutions for higher education have a significant effect on public transport use (Nijënstein (NS), 2014). This is explained by the fact that students mostly are captive public transport travellers. This is already explained in the socio-demographic section. The fact that students in the Netherlands also receive a free-travel card for public transport only increases public transport use by students. Therefore, the presence of students near a train station generates train trips, the presence of an educational institution will attract train trips.

In addition to these educational institutions leisure facilities might attract extra train trips as well. Research showed that 30% of all train trips have the motive of leisure. Other research shows that 20% of all medium to long range leisure trips are made by train (Limtanakool & Dijst, 2006). A recent Dutch study showed that, on average, 23% of visitors of leisure facilities near train stations used the train to reach their destination. For leisure facilities with a national catchment area this average is even higher (Kruijs, 2013). These figures are clear evidence that the presence of leisure facilities should be taken into account for explaining the variation in public transport use. Because (local) policy makers can influence the location of educational institutions and leisure facilities (by zoning plans) this factor is included in the research study as well.

Office stock

Perhaps the most important reason for vacancy is oversupply. Even the most attractive and popular locations for companies to settle will suffer from vacant offices when too much capacity is supplied. It was found by Geurs, Koster & De Visser (2013) that the Netherlands has been subject to an oversupply of the office market. Too much capacity was added without keeping demand into consideration. This can be argued considering the fact that although vacancy has been increasing since 2002, capacity kept increasing as well. Figure 4.7 shows the capacity and vacancy of the Dutch office market since 1991. The complete surface shows the number of $m^2$ (in millions) of office space and the light red surface the vacant amount of $m^2$ office space. From 1991 to 2002 the ratio between used and vacant office space was relatively constant. Since 2002, the ratio of vacant office space increased, while total capacity was still increased as well. Hence, it can be concluded that more office capacity was added than there was demand for office space.

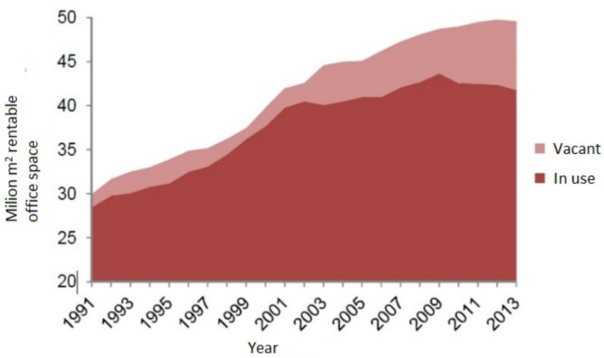



FIGURE 4.7: TOTAL CAPACITY OF OFFICE SPACE IN THE NETHERLANDS, VACANT VERSUS USED (PBL/ASRE, 2012).

# 5 Conceptual Model

This chapter will cover the operationalization of the four models of the four performance indicators shown in figure 4.5. The influential factors highlighted in blue will be covered by measurable variables. This chapter is divided in four parts. First the station areas to be analysed are determined. Second, the used definition of a station area is determined. Third, per influential factor the variables covering that factor are determined and the method of measurement. The measurement of the performance indicators is explained as well. Lastly, the collected data has been inspected for irregularities and other statistical aspects that might influence model results.

## 5.1 Selection of Train Stations

The analysed station areas are selected from the Randstad area. The Randstad area is the most (economic) developed area in the Netherlands and the busiest train stations are found in this region. Chapter 1 mentions the increased policy attention for node development stating a recent study on aiming at a better utilization of station areas in the Northwing of the Randstad, recent facility upgrades of major stations, and an alliance formed in the Southwing of the Randstad, 'Stedenbaan', aiming to stimulate future developments in station catchment areas and to increase transit frequencies. Stations mentioned in these plans are located in the Randstad area.

To narrow down the number of stations to a manageable number of stations the stations are selected based on the quality of their train service. Stations serviced by more than one train service with at least one interregional (intercity) service are selected. Following this criterion 26 stations from the Randstad area have been selected and are shown below in figure 5.1. Due to differences in size, function, urban environment, and geographical location the selected set of stations is considered to be quite diverse. Multimodal stations are indicated with a triangle, pure IC-stations are indicated with a dot. This distinction is explained in section 6.2.

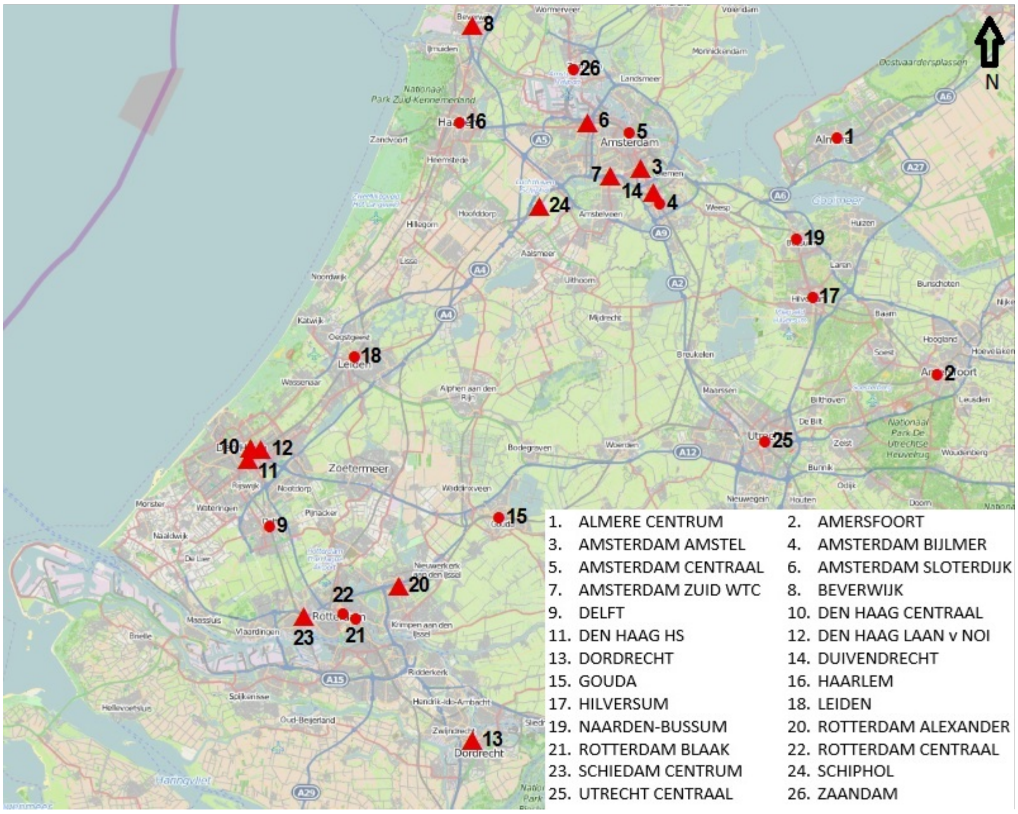



**FIGURE 5.1: THE POLY-CENTRIC URBAN AREA OF THE RANDSTAD AND THE SELECTED STATIONS.**

## 5.2 Catchment Area of a Station

Some performance indicators and explanatory variables have a spatial component, like the number of service jobs. In order to determine this number, the station area has to be defined. The station area is defined as the catchment area of the station. It is believed that people are willing to travel a maximum distance to use public transport. It is also believed that this maximum distance is subject to the quality of the station. People are willing to travel less far for a bus station than a train station with national coverage. This maximum distance is called the catchment area of a station. In addition, there is also a distinction to be made between the origin station of the public transport trip and the destination station. Especially in the Netherlands, where the bicycle is a popular access mode (Givoni & Rietveld, 2007), the catchment area of the origin station is believed to be bigger than the catchment area of the destination station, where people do not have access to their bike anymore. Another argument is that if the actual trip destination is too far from the destination station, choice travellers would have chosen another mode of transport to begin with.

In order to define the catchment area, three approaches have been used in this study. The first approach is based on a distance-decay function. Second approach is based on several defined catchment areas and the third, and used, approach is based on a defined catchment area for origin and destination activities. All three approaches are discussed below.

### Distance-decay function

The first approach is based on a distance-decay function. Applied to this type of research, such a function describes the link between the distance of an activity (i.e. jobs) to the train station and the chance that that activity at that distance will generate/attract a transit trip. For example, jobs within 500 meters of the train station are incorporated for 100%, while jobs at 4 kilometres are only incorporated for 6%. The proposed distance-decay functions are shown in figure 5.2. The functions have been developed based on revealed data from the 2004-2009 Dutch National Mobility Survey (MON). The MON survey is conducted on a yearly basis and contains over 10.000 households that keep a travel journey for a couple of days. Based on socio-demographic data collected of the households, population that is underrepresented is balanced using multipliers. The MON data from 2004 and on is selected because since 2004 the 4 digit zip code is added to the cases in the survey. The 4 digit zip code adds geographical information on made trips. After 2009 the MON survey is replaced by the OVIN survey. This new method is organized in a different way making easy aggregation of data not possible. The 2004-2009 MON data has been aggregated for a better averaged outcome. Within MON, a movement (i.e. going to work) might contain several trips (i.e. cycling to station, riding the train, walking to office). Per movement a main transport mode is allocated to the movement. In the example the main mode would be train. To determine the functions, all movements with motive ‘commute’, ‘business’, and ‘education’ have been selected with main mode train. From the remaining cases all trips with the modes of mopeds, cycling, and walking have been used to determine the access distance-decay curve. The egress distance-decay curve is only based on all trips with the mode of walking.

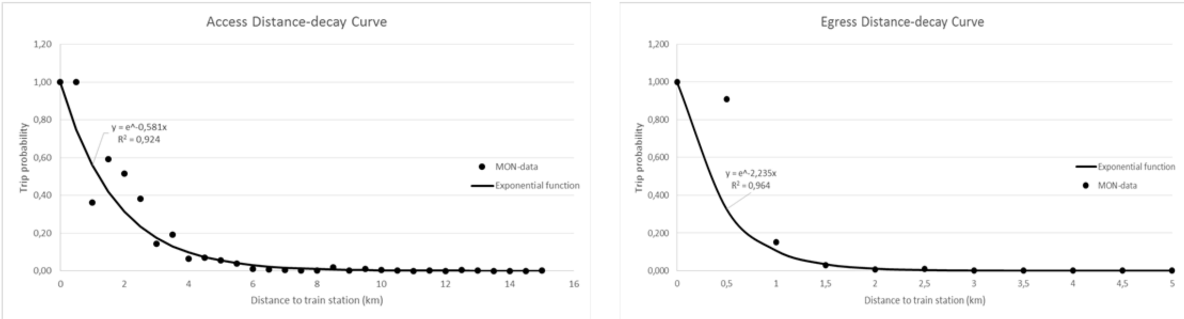



**FIGURE 5.2: PROPOSED DISTANCE-DECAY FUNCTION FOR ACCESS TRIPS (LEFT) AND EGRESS TRIPS (RIGHT).**

Because the MON data also contains the 4 digit zip code the origin and destination of a trip are known. By multiplying the population of the origin neighbourhood with the number of jobs in the destination neighbourhood the total number of possible trips between those neighbourhoods can be determined. From the MON data the actual number of trips between two neighbourhoods can be determined. The length of a trip is recorded as well. Aggregating all trips based on length classes results in a dataset with data on the number of possible trips per length class and the number of actual trips per length class. Dividing the actual number of trips by the total number of possible trips per length class results in a chance that a trip with that length will be made. This results in the trip length – trip probability distribution as shown in figure 5.2. For trip distance ‘0’ the probability has been set to 100%. A negative exponential function fitted the determined distribution the best.

The distance-decay functions were used to quantify the variables of the conceptual models. For typical activities that generate trips (population) the access function was used and for typical activities that attract trips (i.e. jobs) the egress function was used. A more detailed explanation of the data collection can be found later on in this chapter. Inspection of the developed dataset showed that most of the variables with a spatial component were highly correlated. This is shown in table 5.1, correlations higher than 0.5 are indicated bold and italic. Due to the many cases of correlation model results, using regression analysis, might be affected. This might result in under- or overestimating of explanatory variables. This phenomenon lays in the fact that the model tries to explain the variance of the explained variable with the variance of all the selected explanatory variables. Whenever two explanatory variables are strongly correlated they explain the same variance and this is directly reflected in the found regression coefficients. It is expected that the phenomenon of correlating variables is caused by the fact that activities near the station are incorporated more than activities further away. It is also expected that near the station the density of activities is the highest. Hence using a distance-decay functioning to define the station area will mainly incorporate the high densities of activities very near to the station.

**TABLE 5.1: CORRELATION MATRIX OF ACTIVITIES WITHIN THE STATION AREA USING A DISTANCE-DECAY FUNCTION.**

| | Retail | Service jobs | Leisure | Population | Education places | Students |
|---|---|---|---|---|---|---|
| **Retail** | 1 | | | | | |
| **Service jobs** | ***0.553*** | 1 | | | | |
| **Leisure** | 0.491 | ***0.743*** | 1 | | | |
| **Population** | ***0.534*** | ***0.581*** | ***0.532*** | 1 | | |
| **Education places** | 0.216 | 0.481 | 0.338 | ***0.534*** | 1 | |
| **Students** | 0.350 | ***0.517*** | 0.258 | ***0.611*** | 0.438 | 1 |

### Several defined catchment areas

The second approach to define the station area is based on a 'hard' definition of the station area. However, to incorporated the distinction between origin and destination stations and the fact that different activities might have a different catchment area, several catchment areas have been defined. In literature several definitions for the catchment area are used as well. After a quick scan of literature catchment areas were found in the range of 500 to 5000 meters (Van der Blij, Veger, & Slebos, 2010; VROM-council, 2009; Atelier Zuidvleugel, 2006; Snellen, 2013; Bertolini, 1999). Based on this range, the selected catchment areas are 500, 1000, 1500, 3000, and 5000 meters. For every variable with a spatial component five variants were determined; one for every defined catchment area. With the aid of a simple regression analysis the best variant of the explanatory variable per model was determined. For every conceptual model the five variants of the performance indicator are combined with the five variants of one of the explanatory variables. This will lead to 25 simple regression models. Incorporating a one or two year lag as well (the incorporation of lag will be discussed later in this chapter) brings the total number to 50 simple regression models. The variant of the explanatory variable with the highest $R^2$ value is considered as the best fitting variant and would be chosen to use in the actual model. After the variants of all explanatory variables are determined, the variant of the performance indicator was determined with a multiple regression analysis. Every conceptual model was analysed five times; once for every variant of the performance indicator. The multiple linear regression (MLR) returning the highest $R^2$ value was considered to be best variant for the performance indicator. It was apparent that the three performance indicators with a spatial component (retail, service jobs, and office vacancy) all returned the 5000 meters catchment area as the best variant. Because the three activities are considered to be trip attractors, this result was found to be illogical: no commuter would walk 5000 meters for egress. Hence, this method to define the catchment area was eventually not used as well.

### One defined catchment area

Because the first two attempts to determine the catchment area did not return satisfying results, it was chosen to use one defined 'hard' catchment area. One defined catchment area for activities attracting trips and one defined area for activities generating trips. The used definition is based on the fact that all selected stations are serviced by interregional trains. Based on the expert experience of the PBL Netherlands Environmental Assessment Agency the following catchment areas for train stations with interregional service are used: 1.500 meters for trip-attracting activities and 3.000 meters for trip-generating activities (Snellen, 2013). These definitions of a catchment area are used in the remainder of this study.

## 5.3 Data Collection

This section covers which variables are used and how they are measured. This is done first for the performance indicators as it is already clear which variables are used for those (retail and service jobs, train use, and office vacancy). For the influential factors, discussed in section 4.4, on those performance indicators the explanatory variables covering those factors still have to be determined. After this is done, the measurement of those variables can be explained as well.

This section covers the data collection of the performance indicators. Besides train use data all data was available at the PBL Netherlands Environmental Assessment Agency. Train use data has been provided by the NS. Based on the availability of data, data is collected for the 2001-2012 time period.

## Data for performance indicators

Retail and Service jobs

As typical trip attracters, the considered catchment area for these performance indicators is 1.500 meters. Source for the number of employees is the LISA-database, available at PBL Netherlands Environmental Assessment Agency. In the LISA-database all workplaces in the Netherlands are registered. Among others, the 6 digit zip code and the number of (part-time) jobs is registered. Due to the known location of all workplaces, and the number of employees, it is possible to calculate the total number of employees within a 1.500 meter radius of an analysed station. This is done by loading the database into the software package of ArcGIS. To make a distinction between retail employees and non-retail employees the SBI 2008 codes are used. The SBI 2008 categorization with 4 or 5 digits is based on the European (NACE Rev 2) and United Nations' (ISIC Rev 4) categorization. It categorizes businesses based on their economic activity, every business type has its own unique code. The total list of business types included as retail jobs is too big to show, instead a summary grouping the business types is shown in table 5.2. Business types included as service jobs are insurance companies, financial institutions, consultancies, services, administration, NPO's, and government. To cope with part-time jobs, these jobs are accounted for as one third jobs.

On retail jobs, the following note has to be made: the retail jobs indicator consists of several forms of shops. Considering the variety of shops and their trip attraction a distinction is made between different type of shops. The RPB (2005) study makes a distinction between three types of shops based on motive of the customer: 'Run' (errands), 'Fun' (recreational shopping), and 'Purpose' (focused shopping (i.e. buying a new kitchen)). Because people are not willing to travel far for the Run motive (RPB, 2005), only Fun and Purpose are considered in this research as retail. Hence, no supermarkets are incorporated in the retail jobs indicator.

**TABLE 5.2: INCLUDED BUSINESS GROUPS IN THE RETAIL JOBS INDICATOR.**

| | | | | |
|---|---|---|---|---|
| Malls | Pet shops | Restaurants | Fashion stores | Hotels |
| Non-daily provisions | Jewellers | Bars | Drugstores | Beauty salons |
| Hardware stores | Opticians | Laundry rooms | Art shops | Spa's |

Train Use

The train use indicator makes use of data provided by the Dutch Railways (NS). The used data contains the number of daily users per train station. Per station only people entering or leaving the train network are included. People changing trains are not included.

This indicator requires extra attention. To construct this data the NS uses several sources. People buying tickets at the ticket machines provide the NS with excellent data by entering their origin and destination. However, the majority of the travellers, commuters and students, have special (trajectory) tickets that do not provide the NS with origin and destination data every time used. Therefore the NS has to estimate usage of the latter groups. The estimation is based on the subscriptions sold and periodic in-train surveys. Combining the estimation and ticket machine data leads to an estimation of the total number of train users per station. This estimate is usable for having an indication of the order of magnitude per train station. Due to its estimation method, however, the data per station is less usable for year-to-year analysis. The year-to-year data contains, due to estimation, random variation that might not be explained by real world events. Therefore, one should be careful drawing conclusions based on these data.

Office vacancy

As offices being trip attractors, the vacancy within a 1.500 meter radius of the analysed station is determined. Office vacancy is determined using BAK-data, available at PBL Netherlands Environmental Assessment Agency. The BAK-database registers the number of $m^2$ of office space per building. It also registers the number of $m^2$

available on the market. BAK only registers offices with a rentable surface bigger than 10.000m$^2$, which is 90% of the total office capacity in the Netherlands. In the Randstad area the BAK-data even covers 95% of the total capacity, therefore this dataset gives a good overview of office capacity and supply around the selected stations (EIB, 2011). It has to be noted that the BAK-database provides the number of m$^2$ offered to the market, hence this does not always mean the office space actual vacant. In order to estimate vacancy, this study defines vacant office space as office space that is offered to the market for more than one consecutive year. BAK-data also consists detailed office information like the location of the offices based on their 6 digit zip code. With the aid of ArcGIS the total amount of vacant office space around stations can be determined.

## Data for explanatory variables

This section covers the data collection of all explanatory variables. First explanatory variables covering the highlighted factors shown in figure 4.5 in the previous chapter. This is done per factor. Second the measurement per explanatory variable is explained.

### Accessibility

Recall that accessibility can be influenced by (local) policy makers by influencing land-use and/or transport. From the perspective of the station area, the activities within the station area are directly accessible and therefore have a big influence on the accessibility of the station area as a whole. The measured activities in the station area are jobs and population. Jobs (retail and service) are already discussed at the performance indicators. Population of the station area is added. Activities outside of the station area have been measured as well. These are measured as the number of activities reachable within a certain amount of time. A distinction is made between accessibility by train and car, furthermore, a distinction is made per activity. As recognized by Wetering et al. (2009), the transport quality of the train station is more important than the presence of a train station. This quality is called station connectivity and can be measured by three quantified variables: train frequency, the number of directions, and the number of stations within reach.

#### Population

This variable describes the population in the station area. As residents are typical trip generators, the station area is defined as a 3.000 meter radius. CBS data contains the number of inhabitants per household. For a 6 digit zip code resolution this data is available for even years and every year since 2010. To calculate the missing years the average increase/decrease was taken, hence:

$$Population\ 2005 = Population\ 2004 + (Population\ 2006 - Population\ 2004)/2$$

#### Accessibility by car

As explained before, accessibility is a result of both spatial distribution of activities and infrastructure quality, determining travel times. As a result, accessibility, in literature, is often measured as the number of activities reachable within a certain amount of time. Unfortunately data on travel times is not available as traffic models are not available for every year in the considered time period. To incorporate travel times a distance-decay function has been developed. Such a function incorporates the distance between the considered station area and a certain activity. Based on that distance there is a certain chance that people will make that trip. A more detailed explanation of the used distance-decay function is shown below. Assuming that within the analysed time period, travel times by road have not significantly changed, this method can be used to provide a proxy for accessibility by car. For activities a distinction has been made between jobs and residents. Note that for this variable jobs in all economic sectors have been incorporated as the considered jobs are not necessarily located near train stations. The proxy variables for accessibility by car are called jobs / population within reach by car.

The distance between activities and station area can be determined using the LISA-database and the population database. To develop a relation between distance a chance (the distance-decay function) 2004-2009 MON-data has been used. MON-data has already been explained in section 5.2. For this distance-decay function all movements with motive ‘commute’, ’business’, and ‘education’ and the main mode ‘personal car’ have been used. The development of a distance-decay function has already been explained at the catchment area section. The used distance decay function is shown in figure 5.5. A Box-Cox function was found to fit the data in the best way.

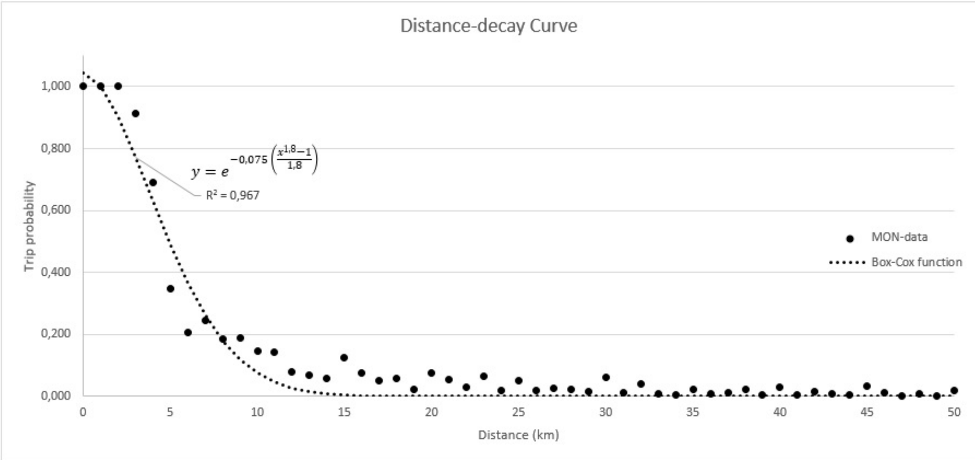



**FIGURE 5.3: DISTANCE-DECAY FUNCTION FOR INCORPORATING PERSONAL CAR TRAVEL TIMES.**

Train frequency

The train frequency has been determined by counting the number of departing trains with the aid of the yearly timetables. The train frequency is the number of departing trains between 7:30 and 9:30 (morning peak). The reason why only the morning peak is considered is because determining the frequency for the complete day would have taken too much time. No distinction has been made between interregional trains (InterCity's) and regional trains (Sprinters). The reason for this that all analysed nodes are situated in the Randstad which is a densely populated area. Therefore both regional as interregional trains have an important role in servicing the regional travel demand.


**FIGURE 5.4: NUMBER OF DIRECT TRAIN CONNECTIONS FROM GOUDA.**

Direct Train Connections

The direct train connections variable is defined as the number of unique end-stops a traveller can reach from the considered node with no transfers. This is also determined with the aid of the yearly timetables. An example is given in figure 5.6. Travelling from Gouda in 2012, one could use one of the highlighted train services. Counting all the unique end-stops, the number of direct train connections from Gouda is eight.

Stations within reach by train

The number of stations within reach is defined as the number of stations within a 45 minute train trip with no transfers. The 45 minute threshold is also used by the Dutch government to determine accessibility by transit (VROM-council, 2009). The number of stations within 45 minutes is determined using the NS trip planner. Assuming that no significant changes have taken place in train travel speeds, the number of station within 45 minutes is based on the 2014 travel times. Hence, year-to-year changes are mainly caused by the opening or closing of stations. Only big infrastructural changes are taken into account. Examples are the completion of the high-speed rail line connecting Amsterdam-Schiphol-Rotterdam-Breda and the construction of connecting arcs. In 2003 the 'Gooiboog' was completed. This connection arc realized a direct connection between Almere and Utrecht. Nowadays it is possible to travel from Hilversum to Almere Centrum within 45 minutes and no transfers, making the stations of Almere Poort, Almere Muziekwijk, and Almere Centrum reachable from Hilversum. Before 2003 these stations are not considered as reachable from Hilversum.

Accessibility by train

The accessibility by train has been determined by determining the number of population, retail, and service jobs within the station area of all stations within reach of the considered station. For example, the population within reach by train for Utrecht Centraal is the aggregation of the population within the catchment area of all stations within reach by train from Utrecht Centraal. Note that the population, number of service jobs, and retail of the considered node is not included in this indicator. These are already included in the model as separate variables.

In conclusion: retail, service jobs, and population within reach by train are used as proxy variables for the accessibility by train.

## Regional demand

Regional demand is measured by the development of retail and service jobs at other stations. These variables are already discussed at the accessibility by train variables. In addition, the number of service jobs at highway off-ramps are measured as well. A recent study of the PBL Netherlands Environmental Assessment Agency (2014) has indicated that between 2000 and 2010 the number of jobs had grew the most at highway locations. Almost 60% of the increase of jobs in that period occurred at locations near highways (not including locations near both highway and public transport) (PBL, 2014). Therefore it is believed that these locations have been a serious competitor for the development of office jobs near train stations that should be taken into account.

Service jobs at highway off-ramps

This explanatory variable has been calculated by determining the number of service jobs within a 2.000 meter radius of highway off-ramps. To define the region, the number of service jobs at highway off-ramps has been determined within a 5, 10, and 15km radius of the analysed stations. A simple regression analysis between the service jobs indicator and the service jobs at highway off-ramps variable has indicated that a 5 km radius describes the variation in service jobs at the considered node the best. It should be noted that if the analysed station area was within a 2.000 meter radius of a highway off-ramp, these office jobs were not included in this variable.

## Urban design

Design (of space and routing) is hard to quantify and therefore it is hard to come up with an indicator. A common method is to develop a list with neighbourhood characteristics that promote/discourage the use of slow modes. Quantification is achieved by scoring the neighbourhood characteristics. However, to apply this method detailed year-to-year map material is required. This is not the case. The variable design has therefore been left out of the model due to a lack of data.

## Educational institutions / leisure

Due to the fact that students are captive public transport travellers with a free-travel card for public transport, the presence of an educational institution or students can significantly influence train use. This factor will be measured by the number of educational institution jobs and the number of students in a municipality. The supply of leisure is also measured based on the number of jobs in that sector.

### Students

Students are typical trip generators and should therefore be determined using a catchment area of 3.000 meters. However, the most detailed year-to-year data describing the number of students that was found describes the number of students per municipality (CBS, 2014). This data describes the number of higher education students (in Dutch: HBO & WO). Because it is expected that the number of students will have a significant influence on the number of transit users this data has been used to determine the number of students per station. Therefore, the number of students at station area *A* in year *X* is equal to the number of students in municipality *A* in year *X*.

### Educational places

With students being trip generators, educational institutions are typical trip attractors. Therefore this variable is determined using a 1.500 meter catchment area. The number of education places an institution offers will influences trip attraction. However, no detailed data was available describing the year-to-year education places per location of an institution. Assuming that the number of education places at an institution is positively correlated with the number of employees of an institution, the number of employees can be used as a proxy for education places. The aforementioned LISA-database also distinguishes jobs at education institutions. With the aid of the LISA-database the number of employees per educational institution has been determined for every year in the analysed time period.

### Leisure

The leisure variable is added because it is believed that leisure facilities within the station area can have a significant influence on daily train use. Therefore it is important to quantify this explanatory variable by visitor number of those leisure facilities. However, this data is not available for all leisure facilities and not for every year. Therefore the assumption has been made that, similar to retail, the number of jobs at leisure facilities gives a good indication of the number of visitors. The number of jobs at leisure facilities can be determined using the LISA-database. Being a typical attractor of trips, a 1.500 meter radius is used to define the station area. Business types included in the leisure variable are museums, cinemas, theatres, and sports facilities. Note that retailers like big outlet shops are already included in the retail jobs variable.

## Office stock

Office stock data is obtained by the BAK-database as well. This database also contains the total number of $m^2$ of office space per building. Based on this data the total number of $m^2$ of office space can be determined per station area.

## Inspection of the data

After collection of the data, data has been inspected. First, data will be checked for null-values. With null-values it is meant that a variable for a station area has only null values. Stations with null-values will be removed from the dataset because they make standardization not possible (standardization is explained in the methodology chapter). Second, the correlation between all explanatory variables will be checked. Too strongly correlated variables might lead to under- or overestimation of results, because those variables explain the same variation.

It turned that the Schiphol station area was subject to multiple null-values (both education places and leisure have only null-values). Therefore this station has been removed from the dataset.

The correlation matrix is shown in table 5.3. All cases with a correlation higher than 0.5 have been indicated bold and italic. Analysing the correlation matrix one finds that there is a strong correlation between some clusters of variables. Retail jobs/service jobs/population within reach by train are strongly correlated with each other for example. The same holds for the variables for jobs/population within reach by car and train frequency, train directions and stations within reach. Although there are more cases of correlation, most correlating variables do not have a qualitative argument that they are too related.

**Table 5.3: Correlation matrix of explanatory variables.**

| | Leisure | Population | Retail jobs within reach by train | Population within reach by train | Service jobs within reach by train | Population within reach by car | Jobs within reach by car | Education places | Students | Train frequency | Train directions | Station within reach | Service jobs at highway off-ramps | Office stock |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Leisure** | 1 | | | | | | | | | | | | | |
| **Population** | ***0,731*** | 1 | | | | | | | | | | | | |
| **Retail jobs within reach by train** | 0,337 | 0,348 | 1 | | | | | | | | | | | |
| **Population within reach by train** | 0,489 | 0,452 | ***0,948*** | 1 | | | | | | | | | | |
| **Service jobs within reach by train** | 0,360 | 0,348 | ***0,968*** | ***0,928*** | 1 | | | | | | | | | |
| **Population within reach by car** | 0,313 | 0,411 | 0,138 | 0,245 | 0,162 | 1 | | | | | | | | |
| **Jobs within reach by car** | 0,319 | 0,431 | 0,225 | 0,315 | 0,214 | ***0,968*** | 1 | | | | | | | |
| **Education places** | ***0,595*** | ***0,538*** | 0,307 | 0,350 | 0,359 | 0,294 | 0,286 | 1 | | | | | | |
| **Students** | 0,449 | 0,490 | 0,252 | 0,330 | 0,205 | ***0,528*** | ***0,645*** | 0,389 | 1 | | | | | |
| **Train frequency** | 0,383 | 0,429 | ***0,792*** | ***0,829*** | ***0,751*** | 0,247 | 0,319 | 0,323 | 0,360 | 1 | | | | |
| **Train directions** | 0,437 | 0,384 | ***0,748*** | ***0,759*** | ***0,680*** | 0,155 | 0,274 | 0,327 | 0,377 | ***0,837*** | 1 | | | |
| **Station within reach** | 0,391 | 0,360 | ***0,889*** | ***0,892*** | ***0,804*** | 0,056 | 0,192 | 0,224 | 0,389 | ***0,833*** | ***0,871*** | 1 | | |
| **Service jobs at highway off-ramps** | 0,451 | ***0,520*** | 0,253 | 0,298 | 0,216 | 0,465 | ***0,596*** | 0,450 | ***0,860*** | 0,271 | 0,418 | 0,401 | 1 | |
| **Office stock** | ***0,738*** | ***0,719*** | 0,272 | 0,414 | 0,322 | ***0,529*** | 0,480 | 0,460 | 0,467 | 0,360 | 0,270 | 0,232 | 0,303 | 1 |

These clusters of correlating variables will be combined due to their high amount of correlation. Combination of those variables is possible because: 1) variables within the mentioned clusters are all strongly correlated with each other and 2) it is, in a qualitative way, logical to assume that those variables are related to each other. Retail jobs/service jobs/population within reach by train are combined into one 'accessibility by train' variable. Jobs/population within reach by car are combined into 'activity within reach by car' and train frequency, train directions and stations within reach are combined into 'station connectivity'.

Combination of variables is done using factor analysis. Factor loadings are determined by performing a multiple regression analysis between the performance indicators and the explanatory variables belonging to accessibility by car, accessibility by train, and station connectivity. Hence, per combined variable, four MLR analyses have been performed (because there are four performance indicators). For these analyses data of the explanatory variables has been standardised (standardization is explained in the next section). The found regression coefficients have been used as the factor loadings in order to combine a new variable.

For example, to determine the new 'activity within reach by car variable' four MLR analyses have been performed: in every MLR one of the performance indicators is used as the explained variable and the jobs and population within reach by car variables are the explanatory variables. Hence, four regression coefficients are found for the jobs within reach by car variable. The mean of these regression coefficients is used as factor loading. Used factor loadings per variable are shown in table 5.4 below.

**TABLE 5.4: FACTOR LOADINGS FOR COMBINATION OF CORRELATING VARIABLES.**

| Combined variable | Factor loadings | | |
|---|---|---|---|
| **Accessibility by train** | 0.472 x<br>Retail jobs within reach by train | 0.318 x<br>Service jobs within reach by train | 0.210 x<br>Population within reach by train |
| **Activity within reach by car** | 0.224 x<br>Jobs within reach by car | 0.776 x<br>Population within reach by car | |
| **Station connectivity** | 0.228 x<br>Train frequency | 0.446 x<br>Train directions | 0.327 x<br>Stations within reach |

In addition to this inspection of the complete dataset, before actual analyses have been performed every used (sub-)dataset has been checked again for correlating variables. For correlating variables with a correlation higher than 0.5 the effect of combination or removal on the results has been investigated. In the case of removal, the explanatory variable with the weakest relation with the performance indicator will be removed.

### Pre- and post-crisis

Inspecting the data (see chapter 7.2) makes clear that the 2008 financial crisis is visible in the data of most economic-related variables. For example the retail and service jobs, and office vacancy performance indicators show a clear change of trend after 2008. Meanwhile, non-economic variables (i.e. station connectivity) do not show this change in trend. Because it is expected that this will influence model results, the dataset used for the actual analyses is split into a pre- and post-crisis part.

### Conceptual models

The previous sections described the data collection. Unfortunately the design variable could not be incorporated due to a lack of data. Other variables have been replaced by proxy variables or are combined because of strong correlation. Figure 5.7 shows the conceptual models as used for analysis. Note that all explanatory variables have a ‘1’ or ‘2’ between brackets. This is the applied lag between explanatory variable and performance indicator. How this lag has been determined is covered in the next section.

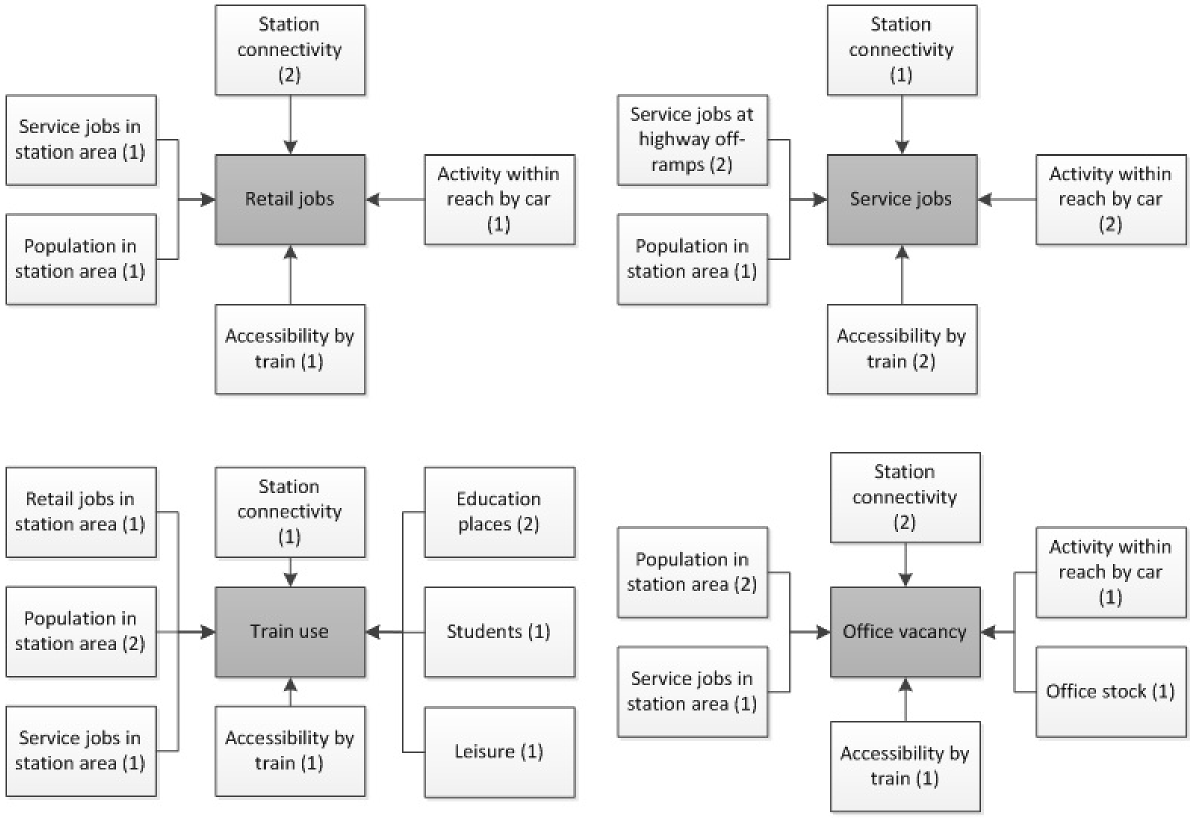



FIGURE 5.5: CONCEPTUAL MODELS EXPLAINING THE PERFORMANCE INDICATORS. BETWEEN BRACKETS THE APPLIED LAG (1 OR 2 YEAR) IS SHOWN.

# 6 Research Methodology

This chapter describes the research methodology. It explains which methods have been used to find an answer to the fourth research question. The first two research questions have already been answered in the previous chapter, describing the performance indicators (explained variables) and explanatory variables of the analyses. The third research question, the actual development of station areas in the analysed time period, is answered in the next chapter. Chapter 7 covers the descriptive statistics per station area and per variable.

This chapter explains the used methodology in the performed analyses is. The conceptual models will be tested with statistical analyses. The twofold goal of this study is to determine which factors, adaptable by local policymakers, influence the changes in the performance of station areas. This is investigated using a longitudinal research method in comparison to the more conventional cross-section approach. A basic difference between a longitudinal and cross-section research method is the surplus of data used for the longitudinal method. This surplus of data gives the researcher the possibility to improve the longitudinal research method even more as opposed to the more conventional cross-section research method. In order to be sure which improvement causes which change in results, the cross-section method is improved stepwise.

## 6.1 Proposed statistical analyses

In total five analyses will be performed. An overview of the performed analysis per step is shown in table 6.1. First analysis is the (conventional) cross-section analysis, using MLR and originally obtained data. After the cross-section analysis, data will be standardised. Analyses in step 1 and 2 are based on absolute data. In step 3 analysis will be performed based on the development (in-/decrease) of variables in the pre- and post-crisis period. Step 4 is based on longitudinal research, meaning that now year-to-year differences are analysed. In step 4 the lag of one or two years has been applied as well. The last step contains the same model as in step 4, but this model has been expanded with a fixed effects model. A more detailed explanation per step is discussed in the sections below.

**TABLE 6.1: FIVE PERFORMED ANALYSES AND THEIR DESCRIPTIONS.**

| Analysis | Description |
|---|---|
| 1.Cross-section | A multiple linear regression analysis using original values. The regression analyses have been performed for the years 2004, 2008, and 2012. |
| 2.Cross-section (standardised) | A MLR analysis using standardised values. Again, regression analyses have been performed for the years 2004, 2008, and 2012. |
| 3.Semi Cross-section | MLR for the pre-crisis (2004-2008) and post-crisis (2008-2012) periods. Model input is the in-/decrease of standardised values for the considered periods. |
| 4.Longitudinal method | MLR analysis pre- and post-crisis using year-to-year differences of standardised values. A 1 or 2 year lag is applied as well. |
| 5.Longitudinal method (fixed effects) | MLR analysis pre- and post-crisis using year-to-year differences of standardised values and a 1 or 2 year lag. In order to make a distinction between the different stations a fixed effects model has been used. |

### Cross-section method

The first step is to perform a cross-section analysis per conceptual model. Per station one observation per variable is used for this analysis. The used data is the unedited absolute data as collected. In order to take the change of trend caused by the financial crisis of 2008 into account, the cross-section analysis has been performed for the years of 2004, 2008, and 2012. Using a MLR model, the relations between performance indicator and explanatory variables are determined.

Standardization

With the aid of a regression analysis the elasticity's (regression coefficient) between the explaining variables and the explained variable can be determined. An elasticity is the ratio of the percentage change of one variable associated with the percentage change of the other variable. In example, an elasticity of 0.1 means that an increase of the explanatory variable of 10%, results in an increase of 1% of the dependent variable. However, the unit of the explaining variable has a direct influence on the found elasticity. This is explained with the aid of equation 1, the basic model behind a multiple linear regression analysis with two explaining variables $x_1$ and $x_2$. If the magnitude of the value for variable $x_1$ is very big (let's say millions) and the magnitude of the value for variable $x_2$ is relatively small (let's say dozens), then this will immediately be reflected in the found elasticity's ($\beta_i$). In this example it is not clear whether a bigger regression coefficient means a more important role in explaining $y_i$.

$$(EQ.1) \quad y_i = \beta_1 x_1 + \beta_2 x_2 + \varepsilon \qquad\qquad (EQ.2) \quad z_i = (x_i - \bar{x})/\sigma_x$$

The process of standardizing is necessary to determine the importance of an explanatory indicator based on the found elasticity. The values are standardised using equation 2. From every data point the mean value of that variable is subtracted and that value is divided by the standard deviation. By standardizing the values, the values of all variables will have the same order of magnitude. Now, the found regression coefficients for $x_1$ and $x_2$ can be compared and a bigger value does mean a greater correlation. If, after standardization, it is found that $\beta_1$ is larger than $\beta_2$, this actually means that $x_1$ has a greater role in explaining $y_i$ than $x_2$. An example of standardised data is shown in figure 6.1 below. In the left figure the absolute data of retail and service jobs at Almere centrum is shown. In the right figures the same data is shown, but now standardised. It is clear that only the scale of the y-axis has changed.

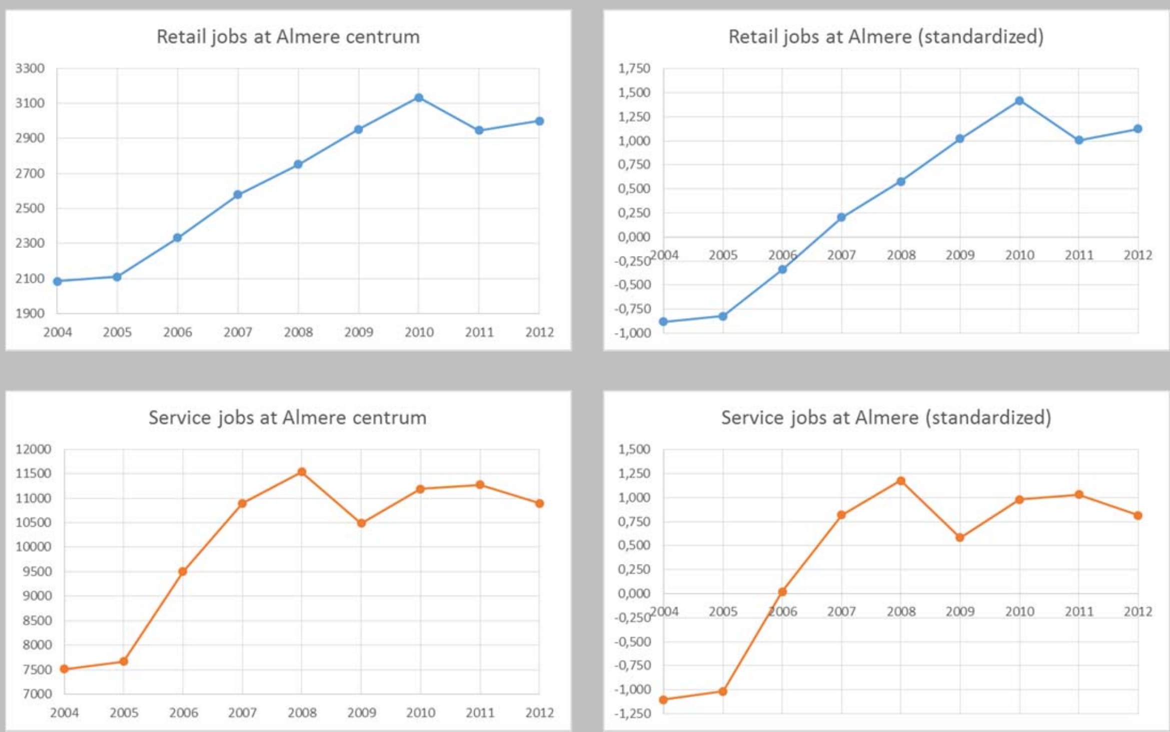



**FIGURE 6.1: RETAIL AND SERVICE JOBS AT ALMERE, ABSOLUTE (LEFT) AND STANDARDISED (RIGHT).**

## Cross-section method (standardised)

The second step entails that the original data is standardised. Standardization 'evens out' the differences between variables in magnitude of order, making the found regression coefficients comparable based on their magnitude. A more detailed explanation of standardization and the used method of standardization can be found in the grey box on the previous page. In this analysis, the standardization is done per variable. Standardizing variables should not affect model results besides the regression coefficients. Without standardization it is only possible to determine whether or not a certain variable is related to another variable. With standardization of data, it is also possible to determine which explanatory variable is the most important variable in explaining the variation of the performance indicator.

## Semi cross-section method

In the first two steps analyses are based on absolute data. In step 3 analysis will be performed based on the development (in-/decrease) of data. This will change the meaning of the found regression coefficients because they now indicate the relation between the change of a variable and the change of another variable. Based on these regression coefficients one can argue, for instance, that there is a relation between the increase of population and the increase of train use. Regression coefficients found in step 1 and 2 only mean, for instance, there is a relation between population and train use.

To take the change of trend caused by the financial crisis into account the dataset is divided into a pre- and post-crisis dataset. For the pre-crisis dataset the development of variables between 2004 and 2008 is analysed. For the post-crisis dataset this was done for the 2008-2012 period. This step is called the semi cross-section method because analyses are still based on one observation per variable. However, this observation is based on (the difference between) two original observations.

## Longitudinal method

In step 4 the longitudinal research method will be applied. Because a longitudinal analysis requires multiple observations per variable per object (station area) data is organized as a panel dataset. An example of a panel dataset is shown in table 6.2. Due to the fact that multiple observations are available per variable, it is possible to analyse year-to-year differences. The multiple observations per variable per station also make it possible to determine a mean and standard deviation per variable per station. In this way data can be standardised per variable per station.

**TABLE 6.2: DATASET USED FOR CROSS-SECTION ANALYSIS (LEFT) VERSUS PANEL DATASET USED FOR LONGITUDINAL ANALYSIS (RIGHT).**

| **Dataset Cross-section** | | | | | | **Panel data (longitudinal research)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Station** | Year | y | $x_1$ | $x_2$ | | Station | Year | y | $x_1$ | $x_2$ |
| **Station A** | 1 | 1 | 1 | 2 | | Station A | 1 | 1 | 3 | 3 |
| **Station B** | 1 | 3 | 3 | 3 | | Station A | 2 | 1 | 3 | 1 |
| **Station C** | 1 | 1 | 3 | 3 | | Station A | 3 | 2 | 1 | 1 |
| **Station D** | 1 | 3 | 1 | 1 | | Station B | 1 | 2 | 3 | 3 |
| **Station E** | 1 | 1 | 1 | 2 | | Station B | 2 | 1 | 3 | 2 |
| **Station F** | 1 | 1 | 3 | 3 | | Station B | 3 | 3 | 3 | 2 |

<u>Implementation of lag</u>

It is expected that the development of explanatory variables will not have an immediate effect on the development of performance indicators. In example, when the population in the station area has increased in a certain year, one cannot expect to see this reflected in the change of train use of that same year. This has to do with the fact that the increase of population probably has not happened overnight, but stretched out over time. The increase in train use will therefore also not happen instantaneously, but stretched out over time.

To cope with this effect in the regression model, relation between explanatory variables and performance indicators are subject to a one or two year lag. This means that, for example, the development of population in

2003 is linked to the development in train use in 2005. The lag between explanatory variables and performance indicators is determined using a simple regression model. Between every explanatory variable and performance indicator two simple regression models are tested: one with a one year lag and one with a two year lag. Whether a one or two year lag is applied is based on the returned $R^2$ value and the regression coefficient. First criterion is whether the direction of the found regression coefficient is in line with the expectations of the conceptual model. If both regression coefficients are in line with the conceptual model, the $R^2$ value will be decisive: the higher $R^2$ value means a higher amount of variation explained. This lag will then be applied. However, if the direction of both regression coefficients is not in line with the conceptual model, then the value of the regression coefficient will be decisive. Tables 6.3 to 6.6 show the analysis of the applied lag per performance indicator. The chosen lag is indicated bold and italic. The lag per explanatory variables is also shown in figure 5.7.

**TABLE 6.3: APPLICATION OF LAG FOR RETAIL JOBS MODEL.**

| Retail jobs | 1 year lag | | 2 year lag | |
|---|---|---|---|---|
| | Regression coeff. | $R^2$ | Regression coeff. | $R^2$ |
| **Service jobs** | ***0.061*** | ***0.003*** | 0.001 | 0.000 |
| **Population** | ***-0.195*** | ***0.014*** | -0.126 | 0.006 |
| **Accessibility by train** | ***0.001*** | ***0.000*** | -0.165 | 0.007 |
| **Activity within reach by car** | ***0.194*** | ***0.011*** | -0.364 | 0.052 |
| **Station connectivity** | 0.006 | 0.000 | ***0.014*** | ***0.000*** |

**TABLE 6.4: APPLICATION OF LAG FOR SERVICE JOBS MODEL.**

| Service jobs | 1 year lag | | 2 year lag | |
|---|---|---|---|---|
| | Regression coeff. | $R^2$ | Regression coeff. | $R^2$ |
| **Population** | ***-0.128*** | ***0.007*** | -0.093 | 0.004 |
| **Accessibility by train** | -0.109 | 0.004 | ***0.054*** | ***0.001*** |
| **Activity within reach by car** | 0.041 | 0.001 | ***0.161*** | ***0.012*** |
| **Station connectivity** | ***0.039*** | ***0.001*** | -0.173 | 0.027 |
| **Service jobs at highway off-ramps** | -0.022 | 0.001 | ***-0.048*** | ***0.003*** |

**TABLE 6.5: APPLICATION OF LAG FOR TRAIN USE MODEL.**

| Train use | 1 year lag | | 2 year lag | |
|---|---|---|---|---|
| | Regression coeff. | $R^2$ | Regression coeff. | $R^2$ |
| **Retail** | ***-0.000*** | ***0.000*** | -0.056 | 0.004 |
| **Service jobs** | ***0.064*** | ***0.004*** | -0.061 | 0.005 |
| **Population** | -0.048 | 0.001 | ***0.077*** | ***0.002*** |
| **Leisure** | ***0.024*** | ***0.001*** | -0.069 | 0.006 |
| **Accessibility by train** | ***0.165*** | ***0.009*** | -0.081 | 0.002 |
| **Education places** | -0.008 | 0.000 | ***0.027*** | ***0.001*** |
| **Students** | ***0.067*** | ***0.000*** | -0.130 | 0.001 |
| **Station connectivity** | ***0.057*** | ***0.003*** | -0.087 | 0.007 |

**TABLE 6.6: APPLICATION OF LAG FOR OFFICE VACANCY MODEL.**

| Office vacancy | 1 year lag | | 2 year lag | |
|---|---|---|---|---|
| | Regression coeff. | $R^2$ | Regression coeff. | $R^2$ |
| **Service jobs** | ***0.030*** | ***0.001*** | 0.042 | 0.003 |
| **Population** | 0.001 | 0.000 | ***0.014*** | ***0.000*** |
| **Accessibility by train** | ***0.138*** | ***0.007*** | 0.248 | 0.021 |
| **Activity within reach by car** | ***-0.087*** | ***0.003*** | 0.132 | 0.009 |
| **Station connectivity** | 0.077 | 0.007 | ***0.065*** | ***0.004*** |
| **Office stock** | ***0.240*** | ***0.038*** | 0.049 | 0.002 |

## Longitudinal method with fixed effects

The last step entails the same longitudinal research method using the same data in the previous step. However, in addition a fixed effects model has been used. Data on multiple station areas cannot simply be pooled in one dataset for analysis. For several reasons the different station areas are not comparable. In example, they differ in function, size, growth potential, position in the network/built-up area, and history. Another important distinction can be the role of local policymakers or unique events that are not included in the dataset. Therefore, for good reliable results, it is not possible to perform a multiple linear regression analysis on the pooled dataset with no distinction between the stations. However, a separate multiple linear regression analysis per station will result in insignificant results due to the small dataset per station and the comprehensive amount of explanatory variables. As a solution the analysis is performed using the method of fixed effects. In this way a distinction is made between different stations, while significant results are achieved due to the greater amount of data. In a multiple linear regression analysis using a fixed effects model, dummy variables are added to correct for the differences between stations that are not present in the dataset. A more detailed explanation of a fixed effects model is discussed in the grey box below. In conclusion, using a fixed effects model will return regression coefficients that respects the differences between the different station areas.

## 6.2 Multimodal stations versus IC-stations

In policy, multimodal accessible stations get extra attention. These locations are places determined for spatial economic development because they ensure accessibility due to their multimodal character. With the development of this unique dataset it might be interesting to analyse whether or not there is a difference between multimodal and IC-stations based on development and which development of explanatory variables has a significant relation with the development of performance indicators. With IC-stations, the station areas with no highway on/off-ramp within 1.500 meters (VROM-council, 2009) are meant. Multimodal stations are defined as stations with a highway on/off-ramp within 1.500 meters. Based on this definition, the selected stations are divided into multimodal and IC-stations. The distribution is shown in table 5.7 below and also shown in figure 5.1.

Chapter seven covers the descriptive statistics of the collected data. Special attention is given to the difference between multimodal and IC-stations. In addition, an extra analysis has been performed for the service jobs performance indicator using a cross-section research method and a longitudinal method with fixed effects. The analysis will be performed once with only IC-stations and once with only multimodal stations.

**TABLE 6.7: LIST OF MULTIMODAL AND IC-STATIONS OF THE SELECTED STATIONS.**

| Multimodal stations | IC-stations |
|---|---|
| Amsterdam Amstel | Almere Centrum |
| Amsterdam Sloterdijk | Amersfoort |
| Amsterdam Zuid | Amsterdam Bijlmer |
| Beverwijk | Amsterdam Centraal |
| Den Haag Centraal | Delft |
| Den Haag HS | Gouda |
| Den Haag Laan van NOI | Haarlem |
| Dordrecht | Hilversum |
| Duivendrecht | Leiden |
| Rotterdam Alexander | Naarden-Bussum |
| Schiedam Centrum | Rotterdam Blaak |
| | Rotterdam Centraal |
| | Utrecht Centraal |
| | Zaandam |

Fixed effects

In this research the dataset consists of multiple observations in time for different objects (station areas). Therefore the dataset is a panel dataset, which has a multidimensional character (time and location). Because of the multidimensional character of the dataset a normal regression model cannot be used: for regression analysis, observations should be independent. Per station, observations over time are dependent because an observation of the population in year *x* will not greatly differ from the population in year *x-1*. However, the complete set of observations for station A can be assumed to be independent from the complete set of observations of station B. The panel dataset with repetitive measurements per station gives a problem and an advantage; the data per station is not independent, but the extra data and the repetition can be used to obtain better parameter estimates. A fixed model can take the repetition into account and controls for fixed differences between stations.

Due to the interdependence of observations per station, normal regression might lead to incorrect results. This is illustrated in figure 6.2. This figure shows the fictional data of three station areas. The x-axis shows the (standardised) development in population and the y-axis the (standardised) development in train use.

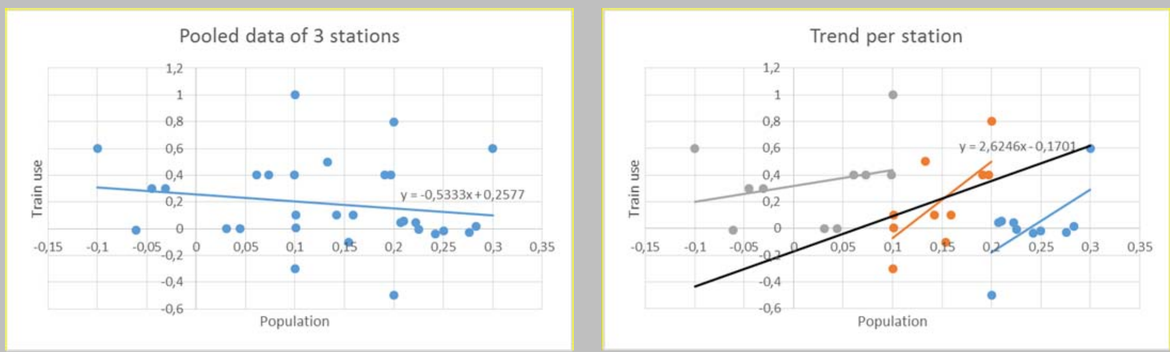



FIGURE 6.2: MISINTERPRETATION OF NORMAL REGRESSION WITH POOLED DATA (LEFT). ACTUAL TREND PER STATION AND TREND FOUND USING A FIXED EFFECTS MODEL (RIGHT).

In the left figure the data is pooled as would be the case using a normal regression analysis. A normal linear regression analysis would return a negative relation between population and train use, which is shown with the blue line. In the right figure, the data has been given a separate colour per station. It becomes clear that every station area shows a positive trend between the development in population and train use. Hence, it can be concluded that the normal linear regression in the left figure misinterprets the data. A fixed effects model will take the distinction per station into account by adding dummy variables for every unique station and variable. The dummy variables will shift the data per station in such a way that they will coincide as much as possible. This is done per variable per station. In the example shown in figure 5.8 this will result in the trend line shown in black. In this way data that cannot be pooled using a normal regression analysis, can be pooled to obtain higher significance levels and better coefficient estimates. (Greene, 1991)

# 7 Descriptive Statistics

This chapter covers a descriptive analysis of the used data. It will provide the reader with the actual development of the station areas, providing an answer to research question three. This chapter consists of two parts. First, a place-node model, as discussed in the theoretical framework, has been developed showing the development of all analysed stations during the considered time period. The place-node model is a visual method to show the development of the analysed train stations over time. Based on the place-node model stations have been grouped and discussed. Second, aggregated data is shown per variable. Discussing the aggregated data will indicate general trends which might be useful to understand the results of the statistical analyses.

Due to the implementation of a lag (a delay in data of 1 or 2 years), the used performance indicator data is from the 2004-2012 period. Therefore only the data from this period has been discussed here.

## 7.1 Place-node model

The place-node model for all station for 2004 and 2012 is shown in figure 6.14. A list explaining the abbreviations is shown below the figure. The model is developed based on the method of Bertolini (1999). However, in this case only the accessibility by train is used as proxy for the node value. The total of retail jobs, service jobs, population, leisure jobs, and education places is used as proxy for place value. The distinction of stations might seem arbitrary, but this distinction is only used for discussion purposes, hence this has no consequences.


●/▲ = IC-station/Multimodal station ▲/▲ = 2004/2012

| | | | |
|---|---|---|---|
| Al = Almere C. | Be = Beverwijk | Go = Gouda | RC = Rotterdam Centraal |
| Am = Amersfoort | De = Delft | Ha = Haarlem | SC = Schiedam Centrum |
| AA = Amsterdam Amstel | DC = Den Haag Centraal | Hi = Hilversum | UC = Utrecht Centraal |
| AB = Amsterdam Bijlmer | DS = Den Haag HS | Le = Leiden | Za = Zaandam |
| AC = Amsterdam Centraal | DL = Den Haag Laan v NOI | NB = Naarden-Bussum | |
| AS = Amsterdam Sloterdijk | Do = Dordrecht | RA = Rotterdam Alexander | |
| AZ = Amsterdam Zuid | Du = Duivendrecht | RB = Rotterdam Blaak | |

**FIGURE 7.1: PLACE-NODE VALUES FOR ALL STATION IN 2004 AND 2012.**

Three general remarks will be made on the development of stations in the 2004-2012 period. The first remark is that for node value only accessibility by train is incorporated. Therefore the node value for multimodal station areas might be underestimated. Second, from figure 7.1 it becomes clear that all stations have developed their node value and the node value has developed much more than the place value. The fourth Balkenende cabinet (2007-2010) had the ambition to increase train use. This should be accomplished with several measures including improving rail infrastructure and by increasing train frequencies. It seems that these efforts are reflected in the place-node model. In addition, it is also apparent that a slight majority of the analysed stations is found at the unsustained node side of the model. Third general remark is that stations that already were situated in the stressed area or at the edges of the model have developed the most. The unsustained nodes of Duivendrecht and Amsterdam Sloterdijk for example have become even more unsustained. The, already, stressed station of Utrecht and Amsterdam Centraal have seen a significant development in both node and place value. Most stations in the centre of figure 7.1 have only experienced a modest development of their values.

Next the development of stations will be discussed per group as indicated in figure 7.1. Actual data per station is shown as well. For all these tables the index is 2004 = 100%. In section 7.2 data is discussed per variable indicating general trends. Discussing the data per station, terms like 'above average' refer to these general trends. Mainly the development of place and node value will be discussed and their reasons.

## Stressed stations

The station areas in the top right of the figure are under stress and it is no surprise to find the central stations of the four biggest cities of the Netherlands in this corner. Den Haag HS and Rotterdam Blaak are also situated in this corner. Amsterdam Centraal is the station servicing the historic centre of Amsterdam. The area has been built up and there is hardly any room for new development, especially because of the protected status of the historic centre. New (high-rise) developments have been realized on the east of the station on an old dock (Piet Heinkade). Station connectivity and train use have hardly increased, probably caused by the fact that this station already is at capacity. Accessibility by train however, increased far above average. For accessibility by train the development of Almere and the high-speed rail connection with Rotterdam play an important role in the increased node value. With Rotterdam Centraal in the north and Blaak in the east, both stations surround the city centre of Rotterdam. Both stations are located in a high urbanized mixed area with offices, retail and residential buildings. Especially around Rotterdam Centraal high-rise offices can be found. For both stations the number of retail and service jobs decreased and office vacancy increased tremendously, explaining the decrease in place value for both stations. Train use for Rotterdam Blaak increased well above average, caused by an increase in train services stopping at Rotterdam Blaak. This also increased the accessibility by train for Rotterdam Blaak. Train use at Rotterdam Centraal on the other hand decreased with 7%. This might be caused by the fact that in the previous years this station has been renovated completely. Construction of the new Rotterdam Centraal has only been completed last year (2014). Accessibility by train increased due to the new high-speed rail connection with Amsterdam.

The stations of Den Haag Centraal and HS both surround the (historic) city centre of Den Haag. The neighbourhood between Den Haag Centraal and city centre has been redeveloped in the past decade, clustering most of the ministries in high-rise office buildings. The number of service jobs however, has decreased. Based on the big increase of office vacancy, this is probably caused by desertion of other office buildings. The increase in place value of Den Haag Centraal and HS is caused by the increase in population and jobs in the leisure sector. Despite the opening of a new train station Ypenburg in 2005 near the equal named new neighbourhood accessibility by train hardly increased. Utrecht Centraal is located between the historic city centre and a typical office location. Retail, leisure, and education places all showed decreases. Service jobs and population both show an increase slightly above average, causing an increase in place value. However, node value has developed much more. Station connectivity and accessibility by train both increased above average. Station connectivity can be attributed to the construction of the 'Utrecht arc' and 'Gooiboog' enabling two new train directions from Utrecht. Accessibility by train is increased with the realization of the new city expansion 'Leidsche Rijn' along the Utrecht – Den Haag corridor with existing stations such as Vleuten and Utrecht Terwijde. Train use increased about average with 26%.

| | AMSTERDAM CENTRAAL (IC-station) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 101 | 102 | 106 | 108 | 106 | 107 | 108 | 108 |
| **Service jobs** | 100 | 101 | 104 | 100 | 104 | 109 | 110 | 109 | 110 |
| **Train use** | 100 | 103 | 108 | 115 | 114 | 116 | 114 | 116 | 110 |
| **Office vacancy** | 100 | 79 | 115 | 77 | 64 | 45 | 82 | 94 | 141 |
| **Leisure** | 100 | 105 | 117 | 121 | 130 | 121 | 133 | 130 | 136 |
| **Population** | 100 | 101 | 101 | 101 | 101 | 101 | 102 | 103 | 104 |
| **Accessibility by train** | 100 | 102 | 102 | 102 | 103 | 106 | 117 | 118 | 119 |
| **Activity within reach by car** | 100 | 101 | 102 | 102 | 103 | 106 | 107 | 108 | 108 |
| **Education places** | 100 | 104 | 104 | 108 | 110 | 109 | 113 | 125 | 134 |
| **Students in municipality** | 100 | 110 | 117 | 125 | 128 | 137 | 146 | 153 | 155 |
| **Station connectivity** | 100 | 102 | 100 | 97 | 96 | 101 | 103 | 104 | 104 |
| **Service jobs at highway off-ramps** | 100 | 114 | 113 | 116 | 111 | 116 | 111 | 111 | 112 |
| **Office stock** | 100 | 102 | 99 | 105 | 105 | 102 | 100 | 108 | 108 |
| | **DEN HAAG CENTRAAL (Multimodal station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 98 | 100 | 102 | 109 | 104 | 102 | 100 | 97 |
| **Service jobs** | 100 | 96 | 94 | 94 | 95 | 95 | 95 | 93 | 93 |
| **Train use** | 100 | 104 | 97 | 102 | 100 | 97 | 95 | 94 | 95 |
| **Office vacancy** | 100 | 156 | 172 | 161 | 146 | 191 | 248 | 296 | 275 |
| **Leisure** | 100 | 100 | 103 | 104 | 114 | 114 | 110 | 110 | 103 |
| **Population** | 100 | 100 | 101 | 100 | 99 | 100 | 101 | 101 | 103 |
| **Accessibility by train** | 100 | 100 | 101 | 101 | 101 | 102 | 103 | 104 | 106 |
| **Activity within reach by car** | 100 | 100 | 100 | 100 | 101 | 101 | 101 | 101 | 101 |
| **Education places** | 100 | 98 | 97 | 106 | 103 | 101 | 102 | 106 | 107 |
| **Students in municipality** | 100 | 104 | 108 | 111 | 112 | 119 | 126 | 131 | 132 |
| **Station connectivity** | 100 | 99 | 101 | 105 | 105 | 104 | 104 | 104 | 111 |
| **Service jobs at highway off-ramps** | 100 | 99 | 105 | 110 | 115 | 119 | 114 | 110 | 110 |
| **Office stock** | 100 | 100 | 101 | 101 | 102 | 108 | 108 | 108 | 108 |
| | **DEN HAAG HS (Multimodal station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 96 | 99 | 100 | 106 | 101 | 99 | 96 | 94 |
| **Service jobs** | 100 | 97 | 97 | 96 | 98 | 100 | 97 | 95 | 93 |
| **Train use** | 100 | 104 | 114 | 114 | 112 | 137 | 140 | 148 | 120 |
| **Office vacancy** | 100 | 132 | 131 | 157 | 155 | 157 | 220 | 250 | 259 |
| **Leisure** | 100 | 100 | 103 | 105 | 118 | 117 | 114 | 114 | 107 |
| **Population** | 100 | 100 | 100 | 100 | 99 | 100 | 101 | 101 | 103 |
| **Accessibility by train** | 100 | 100 | 100 | 99 | 99 | 100 | 101 | 102 | 103 |
| **Activity within reach by car** | 100 | 100 | 100 | 100 | 101 | 101 | 101 | 101 | 101 |
| **Education places** | 100 | 96 | 85 | 95 | 88 | 89 | 89 | 95 | 103 |
| **Students in municipality** | 100 | 104 | 108 | 111 | 112 | 119 | 126 | 131 | 132 |
| **Station connectivity** | 100 | 100 | 100 | 100 | 97 | 97 | 97 | 97 | 102 |
| **Service jobs at highway off-ramps** | 100 | 98 | 104 | 108 | 115 | 116 | 110 | 106 | 105 |
| **Office stock** | 100 | 100 | 100 | 100 | 102 | 110 | 110 | 110 | 109 |
| | **ROTTERDAM BLAAK (IC-station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 94 | 95 | 97 | 95 | 94 | 94 | 95 | 89 |
| **Service jobs** | 100 | 93 | 89 | 91 | 89 | 85 | 89 | 88 | 89 |
| **Train use** | 100 | 102 | 98 | 101 | 106 | 114 | 113 | 135 | 158 |
| **Office vacancy** | 100 | 111 | 158 | 156 | 112 | 143 | 181 | 283 | 311 |
| **Leisure** | 100 | 99 | 104 | 116 | 113 | 111 | 113 | 112 | 100 |
| **Population** | 100 | 99 | 98 | 97 | 96 | 97 | 98 | 99 | 100 |
| **Accessibility by train** | 100 | 100 | 99 | 99 | 99 | 100 | 100 | 101 | 102 |
| **Activity within reach by car** | 100 | 98 | 97 | 98 | 98 | 98 | 99 | 100 | 100 |
| **Education places** | 100 | 95 | 93 | 89 | 83 | 92 | 95 | 94 | 96 |
| **Students in municipality** | 100 | 106 | 108 | 110 | 112 | 119 | 125 | 130 | 132 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Station connectivity** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 112 |
| **Service jobs at highway off-ramps** | 100 | 93 | 96 | 99 | 99 | 98 | 99 | 97 | 94 |
| **Office stock** | 100 | 101 | 100 | 99 | 102 | 102 | 104 | 108 | 108 |

| | ROTTERDAM CENTRAAL (IC-station) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 94 | 93 | 94 | 93 | 92 | 93 | 94 | 91 |
| **Service jobs** | 100 | 92 | 85 | 87 | 86 | 83 | 87 | 85 | 87 |
| **Train use** | 100 | 103 | 105 | 105 | 102 | 101 | 101 | 110 | 93 |
| **Office vacancy** | 100 | 140 | 211 | 204 | 139 | 170 | 186 | 323 | 328 |
| **Leisure** | 100 | 99 | 101 | 104 | 102 | 102 | 103 | 101 | 95 |
| **Population** | 100 | 99 | 98 | 97 | 97 | 98 | 99 | 99 | 100 |
| **Accessibility by train** | 100 | 100 | 100 | 99 | 99 | 100 | 108 | 108 | 109 |
| **Activity within reach by car** | 100 | 98 | 97 | 97 | 97 | 98 | 99 | 99 | 99 |
| **Education places** | 100 | 96 | 95 | 97 | 101 | 108 | 110 | 109 | 110 |
| **Students in municipality** | 100 | 106 | 108 | 110 | 112 | 119 | 125 | 130 | 132 |
| **Station connectivity** | 100 | 100 | 100 | 98 | 96 | 97 | 104 | 110 | 109 |
| **Service jobs at highway off-ramps** | 100 | 93 | 96 | 99 | 99 | 100 | 101 | 99 | 97 |
| **Office stock** | 100 | 100 | 99 | 98 | 99 | 98 | 100 | 100 | 100 |
| | **UTRECHT Centraal (IC-station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 98 | 100 | 102 | 102 | 102 | 99 | 100 | 98 |
| **Service jobs** | 100 | 98 | 99 | 102 | 103 | 104 | 101 | 107 | 111 |
| **Train use** | 100 | 105 | 110 | 115 | 120 | 124 | 119 | 122 | 126 |
| **Office vacancy** | 100 | 112 | 105 | 136 | 100 | 75 | 41 | 34 | 44 |
| **Leisure** | 100 | 81 | 80 | 91 | 92 | 91 | 92 | 96 | 90 |
| **Population** | 100 | 101 | 102 | 102 | 102 | 103 | 104 | 104 | 105 |
| **Accessibility by train** | 100 | 100 | 105 | 106 | 111 | 114 | 114 | 116 | 117 |
| **Activity within reach by car** | 100 | 100 | 101 | 103 | 105 | 106 | 107 | 108 | 108 |
| **Education places** | 100 | 96 | 97 | 91 | 90 | 91 | 90 | 95 | 96 |
| **Students in municipality** | 100 | 110 | 117 | 122 | 126 | 128 | 134 | 135 | 132 |
| **Station connectivity** | 100 | 98 | 101 | 106 | 108 | 112 | 111 | 112 | 111 |
| **Service jobs at highway off-ramps** | 100 | 100 | 99 | 105 | 106 | 110 | 110 | 112 | 112 |
| **Office stock** | 100 | 100 | 100 | 98 | 105 | 105 | 105 | 104 | 111 |

## Unsustained nodes

In the unsustained nodes group the multimodal stations of Duivendrecht and Amsterdam Sloterdijk jump out as they have experienced a big increase in node value becoming even more unsustained. For Duivendrecht this increase in accessibility by train is possibly caused by the opening of new stations. However, the enormous growth of activity at the nearby stations Amsterdam Zuid, Bijlmer and Amstel is probably the biggest reason for this increase. This extra potential of Duivendrecht is not used as actual train usage has dropped with 43%. This is caused by the construction of the 'Gooiboog' and 'Utrecht boog' Duivendrecht. Located on the corridors Amsterdam Centraal – Utrecht and Schiphol – Lelystad Duivendrecht was an importance transferring station. After construction of the connecting arcs the status of transferring station was lost together with the number of trains servicing this station. the station area of Duivendrecht is still not completely built-up while accessibility levels of Duivendrecht are high. This makes this station area a potential location for development. Despite this potential, the place value of Duivendrecht only increased slightly between 2004 and 20012. Amsterdam Sloterdijk Sloterdijk is located in the west of Amsterdam and is located on an important intersection of railways on the corridors of Amsterdam Centraal – Schiphol, Haarlem, and Zaandam. The station has only been started to developed in the past decades reflected in the increase of retail and service jobs, and education places. However, the accessibility by train increased more as reflected by the node value.

The multimodal stations of Dordrecht and Schiedam Centrum did hardly show any development in both place and node value. Dordrecht suffered from a decrease in retail and service jobs, the number of education places decreased the most with 37%. The big growth of leisure jobs (24%) and about average growth of population (2%) made sure the place value did not develop much. The node value also hardly changed. Train infrastructure and service did hardly change and the slight increase in accessibility by train is mostly caused by development at other stations within reach. Developments at Schiedam are comparable to Dordrecht: decreases in retail and service jobs and education places, while leisure increased. However, this increase in leisure jobs was not enough to prevent a decrease in place value. Node value stayed constant (+1%) while station connectivity increased with 15% meaning that this increase is mainly caused by increases in frequency. The increase in frequency therefore is probably the explanation for the big increase in train use (46%).

The station of Leiden has been subject to development which was in balance. The increase in service jobs and education places, pushing the place value, was in line with the increase of the node value. This increase in accessibility by train is caused by the development of other stations within reach (like Amsterdam Zuid).

Leiden is located west from the middle of the Randstad area and has an historic centre within the station area. Both leisure and retail decreased with respectively 7 and 5. Service jobs increased above average with 10 and population hardly increased with 1. Office stock increased well above average with 29 and office vacancy only increased with 25.

The city of Almere is a new town and founded in 1975. Hence it is a relative new city and is still developing. This is reflected in the data. Activities in the station area such as retail, service jobs, office stock, and education places increased more than average and no change of trend due to the financial crisis is recognized in the data. Almere is home to a lot of people that have their jobs in the Amsterdam region. To accommodate this great flow of commuters between Almere and Amsterdam, government has the ambition to improve transit quality of the train corridor between Amsterdam and Almere. Therefore it surprising that station connectivity has decreased. This decrease is caused by a decrease in train frequencies as direct trains connections and the number of stations within reach have increased. The increase of the latter two variables and the ongoing development of Almere accessibility by train has increased significantly with 15%. The station area of Amersfoort has shown a similar trend to the station area of Almere based on the development of place and node value. Place value has been increased due to an increase in service and leisure jobs and the number of education places (68%, caused by the opening of a city college). With hardly any change in station connectivity, the increase in accessibility by train can be allocated to the development at other stations (like Utrecht Centraal).

The station of Gouda is located in the centre of the Randstad on the Utrecht – Den Haag and Utrecht – Rotterdam corridors. The station area has been redeveloped in recent years, resulting in an increase of service and leisure jobs. However, due to the decrease of retail jobs and population the place value hardly changed. On the contrary, the node value did increase significantly mainly due to the increase of station connectivity. The opening of stations (Den Haag Ypenburg, Amsterdam Holendrecht and Utrecht Terwijde) has had the biggest influence on accessibility by train. Hilversum is located in the north-east of the Randstad area. Naarden-Bussum, located south of Hilversum has experienced a similar development as Hilversum. Both station areas experienced that retail, leisure and service jobs all decreased. Due to the increase of population and education places the place value still slightly increased in a positive way for both stations. Being on the corridor Utrecht – Almere, which was realised due to the construction of the 'Gooi boog', the accessibility by train increased a lot due to the new train direction and new stations within reach. Zaandam is located in the north of the Randstad near Amsterdam. Despite an increase of retail, service and leisure jobs and population the place value hardly increased. This is caused by the big decrease (31%) of education places. Accessibility by train increased with 11%, mainly caused by the construction of the 'Hem boog' at the Amsterdam Sloterdijk station. This connecting arc made a direct connection possible to Schiphol.

| ALMERE CENTRUM (IC-station) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 101 | 112 | 124 | 132 | 142 | 150 | 141 | 144 |
| **Service jobs** | 100 | 102 | 126 | 145 | 154 | 140 | 149 | 150 | 145 |
| **Train use** | 100 | 103 | 109 | 105 | 111 | 108 | 110 | 108 | 109 |
| **Office vacancy** | 100 | 86 | 56 | 36 | 39 | 222 | 224 | 247 | 327 |
| **Leisure** | 100 | 88 | 89 | 110 | 108 | 109 | 101 | 100 | 100 |
| **Population** | 100 | 101 | 101 | 102 | 102 | 102 | 102 | 101 | 101 |
| **Accessibility by train** | 100 | 102 | 103 | 103 | 104 | 105 | 112 | 114 | 115 |
| **Activity within reach by car** | 100 | 101 | 105 | 107 | 110 | 110 | 111 | 111 | 112 |
| **Education places** | 100 | 107 | 117 | 118 | 116 | 118 | 125 | 132 | 137 |
| **Students in municipality** | 100 | 108 | 116 | 120 | 126 | 132 | 144 | 147 | 154 |
| **Station connectivity** | 100 | 100 | 102 | 102 | 102 | 102 | 102 | 97 | 97 |
| **Service jobs at highway off-ramps** | 100 | 102 | 113 | 114 | 128 | 132 | 135 | 135 | 134 |
| **Office stock** | 100 | 102 | 102 | 102 | 125 | 125 | 131 | 132 | 132 |

| AMERSFOORT (IC-station) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 98 | 104 | 104 | 103 | 101 | 100 | 101 | 98 |
| **Service jobs** | 100 | 104 | 107 | 106 | 117 | 119 | 113 | 114 | 111 |
| **Train use** | 100 | 109 | 117 | 119 | 124 | 130 | 124 | 130 | 125 |
| **Office vacancy** | 100 | 84 | 103 | 133 | 158 | 114 | 108 | 134 | 121 |
| **Leisure** | 100 | 122 | 137 | 135 | 141 | 139 | 142 | 133 | 127 |
| **Population** | 100 | 100 | 99 | 100 | 100 | 100 | 100 | 101 | 101 |
| **Accessibility by train** | 100 | 100 | 101 | 103 | 103 | 104 | 112 | 113 | 114 |
| **Activity within reach by car** | 100 | 101 | 102 | 104 | 105 | 105 | 105 | 106 | 106 |
| **Education places** | 100 | 126 | 131 | 129 | 127 | 141 | 152 | 165 | 168 |
| **Students in municipality** | 100 | 104 | 110 | 117 | 122 | 126 | 133 | 138 | 138 |
| **Station connectivity** | 100 | 101 | 99 | 108 | 110 | 110 | 110 | 112 | 102 |
| **Service jobs at highway off-ramps** | 100 | 98 | 103 | 110 | 114 | 107 | 104 | 105 | 102 |
| **Office stock** | 100 | 103 | 107 | 110 | 111 | 111 | 113 | 113 | 113 |

| AMSTERDAM SLOTERDIJK (Multimodal station) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 116 | 114 | 117 | 123 | 130 | 136 | 148 | 150 |
| **Service jobs** | 100 | 111 | 115 | 120 | 114 | 118 | 113 | 110 | 113 |
| **Train use** | 100 | 108 | 120 | 122 | 126 | 129 | 120 | 128 | 129 |
| **Office vacancy** | 100 | 132 | 134 | 160 | 153 | 150 | 156 | 172 | 172 |
| **Leisure** | 100 | 124 | 129 | 129 | 138 | 126 | 109 | 88 | 90 |
| **Population** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 102 | 104 |
| **Accessibility by train** | 100 | 100 | 101 | 101 | 103 | 106 | 111 | 112 | 113 |
| **Activity within reach by car** | 100 | 102 | 103 | 103 | 103 | 105 | 106 | 107 | 107 |
| **Education places** | 100 | 115 | 114 | 120 | 150 | 135 | 200 | 240 | 211 |
| **Students in municipality** | 100 | 110 | 117 | 125 | 128 | 137 | 146 | 153 | 155 |
| **Station connectivity** | 100 | 105 | 103 | 108 | 110 | 114 | 126 | 123 | 120 |
| **Service jobs at highway off-ramps** | 100 | 117 | 118 | 118 | 113 | 118 | 113 | 112 | 112 |
| **Office stock** | 100 | 100 | 100 | 99 | 101 | 103 | 103 | 103 | 102 |

| DORDRECHT (Multimodal station) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 98 | 91 | 98 | 96 | 94 | 92 | 99 | 95 |
| **Service jobs** | 100 | 98 | 99 | 98 | 98 | 97 | 94 | 96 | 93 |
| **Train use** | 100 | 107 | 111 | 109 | 108 | 107 | 104 | 107 | 112 |
| **Office vacancy** | 100 | 73 | 70 | 114 | 116 | 157 | 163 | 189 | 222 |
| **Leisure** | 100 | 104 | 124 | 122 | 123 | 121 | 119 | 127 | 124 |
| **Population** | 100 | 100 | 100 | 100 | 100 | 101 | 101 | 102 | 102 |
| **Accessibility by train** | 100 | 100 | 99 | 99 | 99 | 100 | 100 | 101 | 104 |
| **Activity within reach by car** | 100 | 100 | 100 | 100 | 101 | 101 | 102 | 102 | 102 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Education places** | 100 | 88 | 82 | 90 | 63 | 77 | 75 | 67 | 63 |
| **Students in municipality** | 100 | 102 | 102 | 106 | 108 | 108 | 114 | 116 | 115 |
| **Station connectivity** | 100 | 101 | 101 | 101 | 100 | 100 | 100 | 103 | 105 |
| **Service jobs at highway off-ramps** | 100 | 96 | 96 | 98 | 95 | 96 | 100 | 101 | 97 |
| **Office stock** | 100 | 100 | 100 | 102 | 104 | 103 | 103 | 103 | 103 |

| | **DUIVENDRECHT (Multimodal station)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 128 | 135 | 140 | 147 | 148 | 112 | 107 | 111 |
| **Service jobs** | 100 | 106 | 108 | 124 | 116 | 115 | 112 | 111 | 106 |
| **Train use** | 100 | 108 | 102 | 71 | 61 | 61 | 60 | 56 | 57 |
| **Office vacancy** | 100 | 84 | 83 | 89 | 102 | 74 | 70 | 82 | 84 |
| **Leisure** | 100 | 90 | 91 | 92 | 89 | 95 | 96 | 90 | 90 |
| **Population** | 100 | 99 | 99 | 99 | 99 | 101 | 102 | 102 | 103 |
| **Accessibility by train** | 100 | 102 | 102 | 102 | 107 | 110 | 111 | 112 | 113 |
| **Activity within reach by car** | 100 | 102 | 102 | 105 | 106 | 107 | 108 | 109 | 109 |
| **Education places** | 100 | 94 | 89 | 73 | 101 | 101 | 111 | 116 | 79 |
| **Students in municipality** | 100 | 109 | 109 | 126 | 130 | 130 | 128 | 129 | 131 |
| **Station connectivity** | 100 | 101 | 93 | 80 | 81 | 91 | 92 | 90 | 89 |
| **Service jobs at highway off-ramps** | 100 | 109 | 109 | 124 | 128 | 130 | 127 | 128 | 129 |
| **Office stock** | 100 | 100 | 100 | 101 | 101 | 105 | 105 | 107 | 107 |
| | **GOUDA (IC-station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 96 | 93 | 90 | 91 | 91 | 86 | 86 | 86 |
| **Service jobs** | 100 | 114 | 117 | 120 | 125 | 124 | 130 | 130 | 128 |
| **Train use** | 100 | 103 | 105 | 107 | 114 | 113 | 113 | 115 | 112 |
| **Office vacancy** | 100 | 100 | 100 | 100 | 100 | 92 | 104 | 192 | 343 |
| **Leisure** | 100 | 94 | 112 | 98 | 129 | 120 | 113 | 117 | 128 |
| **Population** | 100 | 100 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| **Accessibility by train** | 100 | 100 | 103 | 103 | 104 | 109 | 110 | 110 | 111 |
| **Activity within reach by car** | 100 | 100 | 101 | 101 | 102 | 103 | 103 | 103 | 103 |
| **Education places** | 100 | 105 | 76 | 83 | 81 | 84 | 86 | 100 | 100 |
| **Students in municipality** | 100 | 107 | 106 | 107 | 110 | 110 | 113 | 116 | 117 |
| **Station connectivity** | 100 | 96 | 98 | 130 | 130 | 129 | 134 | 130 | 126 |
| **Service jobs at highway off-ramps** | 100 | 106 | 106 | 106 | 109 | 105 | 105 | 102 | 101 |
| **Office stock** | 100 | 100 | 100 | 100 | 110 | 110 | 110 | 118 | 118 |
| | **HILVERSUM (IC-station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 101 | 98 | 99 | 103 | 103 | 98 | 97 | 94 |
| **Service jobs** | 100 | 101 | 100 | 100 | 104 | 104 | 96 | 92 | 94 |
| **Train use** | 100 | 106 | 111 | 98 | 99 | 97 | 99 | 105 | 105 |
| **Office vacancy** | 100 | 108 | 81 | 178 | 191 | 251 | 458 | 489 | 437 |
| **Leisure** | 100 | 95 | 95 | 99 | 94 | 94 | 96 | 83 | 84 |
| **Population** | 100 | 100 | 100 | 101 | 101 | 101 | 102 | 102 | 103 |
| **Accessibility by train** | 100 | 103 | 103 | 105 | 106 | 107 | 108 | 109 | 109 |
| **Activity within reach by car** | 100 | 100 | 101 | 102 | 103 | 103 | 102 | 102 | 102 |
| **Education places** | 100 | 96 | 94 | 102 | 104 | 112 | 112 | 109 | 108 |
| **Students in municipality** | 100 | 103 | 111 | 110 | 111 | 121 | 127 | 130 | 133 |
| **Station connectivity** | 100 | 103 | 103 | 105 | 131 | 129 | 131 | 120 | 120 |
| **Service jobs at highway off-ramps** | 100 | 102 | 104 | 107 | 106 | 105 | 104 | 103 | 102 |
| **Office stock** | 100 | 100 | 99 | 99 | 99 | 103 | 103 | 103 | 100 |
| | **LEIDEN (IC-station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 97 | 97 | 97 | 99 | 98 | 96 | 95 | 95 |
| **Service jobs** | 100 | 101 | 101 | 109 | 110 | 102 | 103 | 104 | 110 |
| **Train use** | 100 | 105 | 110 | 113 | 112 | 112 | 108 | 117 | 119 |
| **Office vacancy** | 100 | 92 | 26 | 71 | 70 | 116 | 150 | 158 | 125 |
| **Leisure** | 100 | 97 | 96 | 95 | 92 | 94 | 92 | 94 | 93 |
| **Population** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 101 | 101 |
| **Accessibility by train** | 100 | 100 | 100 | 100 | 100 | 101 | 101 | 102 | 104 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Activity within reach by car** | 100 | 100 | 101 | 102 | 103 | 103 | 103 | 104 | 104 |
| **Education places** | 100 | 117 | 114 | 118 | 120 | 116 | 110 | 108 | 113 |
| **Students in municipality** | 100 | 104 | 106 | 106 | 108 | 107 | 112 | 118 | 116 |
| **Station connectivity** | 100 | 100 | 100 | 102 | 102 | 100 | 101 | 101 | 101 |
| **Service jobs at highway off-ramps** | 100 | 100 | 104 | 113 | 116 | 105 | 105 | 104 | 103 |
| **Office stock** | 100 | 104 | 107 | 107 | 124 | 124 | 124 | 129 | 129 |

| | NAARDEN-BUSSUM (IC-station) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 97 | 100 | 103 | 105 | 100 | 94 | 91 | 90 |
| **Service jobs** | 100 | 100 | 99 | 99 | 101 | 101 | 97 | 96 | 97 |
| **Train use** | 100 | 99 | 103 | 104 | 105 | 106 | 107 | 108 | 90 |
| **Office vacancy** | 100 | 100 | 129 | 129 | 129 | 29 | 29 | 78 | 164 |
| **Leisure** | 100 | 107 | 138 | 136 | 131 | 114 | 122 | 107 | 99 |
| **Population** | 100 | 100 | 100 | 100 | 101 | 101 | 101 | 102 | 102 |
| **Accessibility by train** | 100 | 103 | 104 | 107 | 107 | 108 | 109 | 110 | 111 |
| **Activity within reach by car** | 100 | 100 | 101 | 102 | 103 | 103 | 103 | 103 | 103 |
| **Education places** | 100 | 113 | 118 | 123 | 134 | 137 | 140 | 138 | 138 |
| **Students in municipality** | 100 | 100 | 99 | 94 | 99 | 99 | 109 | 113 | 118 |
| **Station connectivity** | 100 | 103 | 103 | 105 | 105 | 105 | 105 | 105 | 105 |
| **Service jobs at highway off-ramps** | 100 | 102 | 103 | 107 | 109 | 113 | 109 | 107 | 110 |
| **Office stock** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | **SCHIEDAM CENTRUM (Multimodal station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 98 | 92 | 91 | 88 | 88 | 86 | 85 | 84 |
| **Service jobs** | 100 | 95 | 96 | 91 | 90 | 92 | 88 | 90 | 88 |
| **Train use** | 100 | 105 | 104 | 109 | 114 | 116 | 113 | 122 | 146 |
| **Office vacancy** | 100 | 90 | 91 | 65 | 82 | 79 | 75 | 73 | 75 |
| **Leisure** | 100 | 99 | 102 | 111 | 110 | 113 | 118 | 118 | 112 |
| **Population** | 100 | 99 | 98 | 97 | 97 | 98 | 99 | 99 | 100 |
| **Accessibility by train** | 100 | 100 | 99 | 99 | 99 | 99 | 100 | 101 | 101 |
| **Activity within reach by car** | 100 | 98 | 97 | 98 | 98 | 98 | 98 | 99 | 99 |
| **Education places** | 100 | 104 | 108 | 82 | 78 | 80 | 77 | 77 | 80 |
| **Students in municipality** | 100 | 103 | 103 | 107 | 106 | 113 | 118 | 121 | 125 |
| **Station connectivity** | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 107 | 115 |
| **Service jobs at highway off-ramps** | 100 | 88 | 90 | 90 | 91 | 91 | 91 | 87 | 88 |
| **Office stock** | 100 | 100 | 105 | 105 | 105 | 115 | 115 | 115 | 115 |
| | **ZAANDAM (IC-station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 104 | 99 | 100 | 97 | 97 | 99 | 100 | 115 |
| **Service jobs** | 100 | 96 | 95 | 97 | 104 | 111 | 111 | 110 | 101 |
| **Train use** | 100 | 104 | 107 | 107 | 110 | 109 | 102 | 109 | 132 |
| **Office vacancy** | 100 | 194 | 268 | 288 | 309 | 289 | 264 | 215 | 205 |
| **Leisure** | 100 | 141 | 206 | 194 | 256 | 263 | 234 | 205 | 180 |
| **Population** | 100 | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 101 |
| **Accessibility by train** | 100 | 100 | 101 | 101 | 104 | 109 | 109 | 110 | 111 |
| **Activity within reach by car** | 100 | 102 | 102 | 102 | 103 | 104 | 105 | 106 | 105 |
| **Education places** | 100 | 68 | 65 | 63 | 62 | 64 | 60 | 69 | 69 |
| **Students in municipality** | 100 | 104 | 107 | 108 | 114 | 115 | 124 | 129 | 132 |
| **Station connectivity** | 100 | 100 | 98 | 113 | 115 | 115 | 117 | 117 | 117 |
| **Service jobs at highway off-ramps** | 100 | 108 | 110 | 115 | 111 | 117 | 119 | 119 | 118 |
| **Office stock** | 100 | 100 | 100 | 100 | 112 | 112 | 110 | 110 | 110 |

## Unsustained places

All four stations grouped as unsustained places can be categorised as secondary big city stations. Their location near big cities can explain why they have a high place value. It has to be noted however that all four stations are multimodal and accessibility by car is not incorporated in the node value. This might explain why these stations are grouped as unsustained places. Within this group, only the station near Amsterdam (Zuid and Amstel) have experienced a big growth in place value. For Amsterdam Zuid this is mainly caused by the big increase in service jobs and education (respectively 43 and 50%). Amsterdam Amstel has experienced an enormous increase in education places with 467%. The reason for this increase is the development of the campus of the 'Hogeschool of Amsterdam' (Amsterdam City University) near the station. Both stations also have experienced a significant increase in accessibility by train. For Amsterdam Zuid this is mainly caused by the construction of the 'Utrecht boog'. The development of place and node value has had a tremendous effect on train use of these stations. Train use at Amsterdam Amstel increased 65%, while train use at Amsterdam Zuid increased 199%. It is also noteworthy that Amsterdam Zuid is one of the few stations where office vacancy has decreased. In the analysed period office vacancy has decreased 45%.

Den Haag Laan v. NOI has experienced a small increase in both place and node value. This station area has suffered from a decrease in retail and service jobs, also reflected in the increased office vacancy of 332%. The increase in leisure jobs and population has affected a small increase for the place value. The node value also increased a little bit. Despite the small increase of both values, train use increased 146%. This increase can probably be allocated to the increase in station connectivity. The number of train servicing Den Haag Laan v. NOI has increased significantly during the analysed period, increasing train frequency and the number of direct train connections. For Rotterdam Alexander the node value hardly change. The place value, on the other hand, even decreased. Rotterdam Alexander suffered from a decrease in retail and service jobs and population. On top of the decrease in service jobs, office stock was increased with 25%, resulting in an office vacancy increase of 273%.

| | **AMSTERDAM AMSTEL (Multimodal station)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 99 | 103 | 107 | 109 | 114 | 113 | 114 | 116 |
| **Service jobs** | 100 | 119 | 109 | 112 | 120 | 129 | 107 | 106 | 110 |
| **Train use** | 100 | 107 | 112 | 123 | 135 | 144 | 141 | 148 | 165 |
| **Office vacancy** | 100 | 220 | 265 | 219 | 100 | 93 | 98 | 131 | 113 |
| **Leisure** | 100 | 92 | 95 | 96 | 40 | 42 | 43 | 44 | 45 |
| **Population** | 100 | 100 | 100 | 100 | 100 | 101 | 101 | 102 | 103 |
| **Accessibility by train** | 100 | 100 | 101 | 101 | 102 | 108 | 109 | 110 | 110 |
| **Activity within reach by car** | 100 | 102 | 102 | 103 | 105 | 106 | 108 | 109 | 109 |
| **Education places** | 100 | 101 | 315 | 313 | 528 | 550 | 555 | 558 | 567 |
| **Students in municipality** | 100 | 110 | 117 | 125 | 128 | 137 | 146 | 153 | 155 |
| **Station connectivity** | 100 | 100 | 99 | 92 | 92 | 97 | 108 | 108 | 108 |
| **Service jobs at highway off-ramps** | 100 | 114 | 112 | 119 | 125 | 132 | 126 | 128 | 129 |
| **Office stock** | 100 | 100 | 100 | 100 | 100 | 100 | 101 | 101 | 102 |
| | **AMSTERDAM ZUID W.T.C. (Multimodal station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 90 | 90 | 93 | 94 | 95 | 95 | 99 | 98 |
| **Service jobs** | 100 | 117 | 111 | 113 | 122 | 138 | 141 | 144 | 143 |
| **Train use** | 100 | 139 | 155 | 199 | 212 | 215 | 218 | 272 | 299 |
| **Office vacancy** | 100 | 103 | 112 | 85 | 97 | 100 | 75 | 66 | 55 |
| **Leisure** | 100 | 108 | 110 | 113 | 119 | 42 | 51 | 45 | 47 |
| **Population** | 100 | 100 | 100 | 100 | 100 | 101 | 102 | 105 | 106 |
| **Accessibility by train** | 100 | 103 | 116 | 117 | 117 | 118 | 119 | 119 | 120 |
| **Activity within reach by car** | 100 | 102 | 103 | 103 | 104 | 106 | 107 | 109 | 109 |
| **Education places** | 100 | 99 | 103 | 86 | 97 | 136 | 138 | 152 | 150 |
| **Students in municipality** | 100 | 110 | 117 | 125 | 128 | 137 | 146 | 153 | 155 |
| **Station connectivity** | 100 | 104 | 121 | 130 | 132 | 135 | 143 | 138 | 134 |
| **Service jobs at highway off-ramps** | 100 | 117 | 116 | 120 | 118 | 122 | 114 | 112 | 112 |
| **Office stock** | 100 | 100 | 104 | 111 | 116 | 116 | 116 | 116 | 116 |
| | **DEN HAAG LAAN VAN NOI (Multimodal station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 101 | 93 | 98 | 102 | 98 | 96 | 93 | 89 |
| **Service jobs** | 100 | 94 | 91 | 92 | 94 | 94 | 93 | 90 | 92 |
| **Train use** | 100 | 94 | 101 | 95 | 104 | 194 | 192 | 217 | 246 |
| **Office vacancy** | 100 | 191 | 221 | 165 | 182 | 205 | 330 | 405 | 432 |
| **Leisure** | 100 | 109 | 105 | 105 | 111 | 113 | 110 | 107 | 101 |
| **Population** | 100 | 100 | 100 | 100 | 99 | 100 | 100 | 100 | 102 |
| **Accessibility by train** | 100 | 100 | 100 | 100 | 99 | 100 | 101 | 102 | 104 |
| **Activity within reach by car** | 100 | 100 | 100 | 100 | 101 | 101 | 101 | 101 | 101 |
| **Education places** | 100 | 100 | 107 | 107 | 104 | 91 | 90 | 99 | 84 |
| **Students in municipality** | 100 | 104 | 108 | 111 | 112 | 119 | 126 | 131 | 132 |
| **Station connectivity** | 100 | 100 | 101 | 104 | 112 | 110 | 110 | 110 | 113 |
| **Service jobs at highway off-ramps** | 100 | 101 | 107 | 113 | 119 | 129 | 125 | 122 | 122 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Office stock** | 100 | 100 | 100 | 101 | 102 | 109 | 109 | 109 | 109 |
| | **ROTTERDAM ALEXANDER (Multimodal station)** | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 98 | 96 | 92 | 88 | 85 | 97 | 98 | 96 |
| **Service jobs** | 100 | 96 | 87 | 81 | 83 | 98 | 105 | 100 | 95 |
| **Train use** | 100 | 104 | 108 | 117 | 120 | 129 | 129 | 134 | 147 |
| **Office vacancy** | 100 | 405 | 450 | 278 | 244 | 131 | 147 | 191 | 373 |
| **Leisure** | 100 | 96 | 83 | 79 | 83 | 94 | 101 | 96 | 105 |
| **Population** | 100 | 100 | 99 | 98 | 98 | 98 | 98 | 97 | 98 |
| **Accessibility by train** | 100 | 100 | 99 | 99 | 99 | 100 | 100 | 101 | 102 |
| **Activity within reach by car** | 100 | 99 | 99 | 100 | 100 | 101 | 102 | 102 | 102 |
| **Education places** | 100 | 108 | 108 | 103 | 91 | 89 | 91 | 90 | 94 |
| **Students in municipality** | 100 | 106 | 108 | 110 | 112 | 119 | 125 | 130 | 132 |
| **Station connectivity** | 100 | 104 | 104 | 102 | 99 | 99 | 102 | 102 | 97 |
| **Service jobs at highway off-ramps** | 100 | 100 | 105 | 110 | 109 | 111 | 113 | 116 | 115 |
| **Office stock** | 100 | 100 | 102 | 109 | 117 | 117 | 125 | 125 | 125 |

## Balanced stations

Analysing figure 7.1 it becomes clear that the group of station called balanced stations where balanced in both 2004 and 2012. This means that the development of both their node and place value were in balance as well. It has to be noted however that the station areas of Beverwijk, Delft and Haarlem, relatively, hardly experienced any development. Although local development at those station might have been significant, due to the small character of those station areas that development is hardly noticeable in figure 7.1. This holds especially for Beverwijk. Despite the increase in service (20%) and leisure jobs (29%), population (7%) and education places (9%), the place value in figure 7.1 only shifted a little bit meaning that starting levels in 2004 were small. In Delft the station area experienced a drain of activities reflected in the decrease of retail, service and leisure jobs and education places. Only population increased slightly above average with 5. The drain is also shown in the enormous growth in office vacancy with 359. However, part of this ‘drain’ might be attributable to the construction of railway tunnel in 2010 which turned the centre of Delft into an excavation. The big decrease of education places is due to a reorganization of locations at the TU Delft they decided to bundle all their activities at their south-campus, this led to the disappearances of their education activities in the north of the campus which was within range of the station of Delft. Despite the decrease of those activities, the increase of population with 5% has made sure the place value of Delft increased a little bit. At Haarlem the increase of the place value was also small. Retail and leisure jobs and population increased, but a decrease in service jobs and education places suppressed a big increase in place value. The node value of Beverwijk, Delft and Haarlem hardly increased as well. This can be explained by the fact that hardly any train service or infrastructural changes were made. Only for Haarlem station connectivity decreased significantly due to the removal of a train service. This might explain the small increase for train use at Haarlem, which is far below average.

Amsterdam Bijlmer on the other hand did experienced a lot of development during the past two decades. This reflected in the increase of retail, service and leisure jobs, education places and population. Node value increased as well, mainly due to an increase in station connectivity. Due to construction of the ‘Utrecht boog’ a direct connection with Schiphol became available. This increased the number of direct train connections and developed stations like Amsterdam Zuid became directly available. The extra train connections also increased train frequency. Together with the big increase in activities, train use increased 137%.

| AMSTERDAM BIJLMER (IC-station) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 127 | 270 | 273 | 256 | 274 | 256 | 258 | 255 |
| **Service jobs** | 100 | 103 | 109 | 136 | 141 | 126 | 130 | 131 | 131 |
| **Train use** | 100 | 105 | 142 | 146 | 231 | 236 | 239 | 235 | 237 |
| **Office vacancy** | 100 | 93 | 84 | 112 | 120 | 97 | 89 | 95 | 95 |
| **Leisure** | 100 | 99 | 130 | 145 | 166 | 181 | 169 | 160 | 162 |
| **Population** | 100 | 98 | 96 | 97 | 97 | 99 | 100 | 101 | 102 |
| **Accessibility by train** | 100 | 100 | 101 | 101 | 101 | 107 | 107 | 108 | 109 |
| **Activity within reach by car** | 100 | 101 | 102 | 106 | 106 | 107 | 108 | 109 | 110 |
| **Education places** | 100 | 103 | 95 | 81 | 111 | 117 | 123 | 123 | 129 |
| **Students in municipality** | 100 | 110 | 117 | 125 | 128 | 137 | 146 | 153 | 155 |
| **Station connectivity** | 100 | 100 | 102 | 111 | 114 | 133 | 139 | 139 | 139 |
| **Service jobs at highway off-ramps** | 100 | 112 | 110 | 123 | 127 | 129 | 123 | 124 | 126 |
| **Office stock** | 100 | 101 | 102 | 102 | 103 | 105 | 107 | 108 | 108 |
| **BEVERWIJK (Multimodal station)** | | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 102 | 103 | 107 | 111 | 110 | 98 | 92 | 91 |
| **Service jobs** | 100 | 103 | 101 | 105 | 104 | 106 | 103 | 106 | 120 |
| **Train use** | 100 | 102 | 116 | 118 | 119 | 113 | 115 | 117 | 122 |
| **Office vacancy** | 100 | 74 | 74 | 72 | 72 | 72 | 29 | 28 | 36 |
| **Leisure** | 100 | 107 | 102 | 107 | 125 | 126 | 125 | 115 | 129 |
| **Population** | 100 | 100 | 100 | 101 | 103 | 105 | 107 | 108 | 109 |
| **Accessibility by train** | 100 | 100 | 101 | 101 | 101 | 102 | 102 | 103 | 104 |
| **Activity within reach by car** | 100 | 101 | 101 | 102 | 104 | 104 | 104 | 104 | 104 |
| **Education places** | 100 | 104 | 133 | 117 | 122 | 118 | 120 | 110 | 107 |
| **Students in municipality** | 100 | 101 | 106 | 111 | 118 | 127 | 136 | 138 | 144 |
| **Station connectivity** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Service jobs at highway off-ramps** | 100 | 103 | 107 | 105 | 110 | 101 | 103 | 103 | 92 |
| **Office stock** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 113 | 113 |
| **DELFT (IC-station)** | | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 101 | 100 | 102 | 109 | 106 | 102 | 96 | 99 |
| **Service jobs** | 100 | 124 | 130 | 131 | 88 | 85 | 85 | 85 | 83 |
| **Train use** | 100 | 106 | 111 | 117 | 119 | 112 | 104 | 112 | 126 |
| **Office vacancy** | 100 | 0 | 76 | 116 | 94 | 25 | 19 | 431 | 459 |
| **Leisure** | 100 | 113 | 112 | 123 | 131 | 118 | 115 | 107 | 98 |
| **Population** | 100 | 100 | 101 | 101 | 102 | 103 | 103 | 104 | 105 |
| **Accessibility by train** | 100 | 100 | 99 | 99 | 98 | 99 | 100 | 101 | 102 |
| **Activity within reach by car** | 100 | 100 | 101 | 102 | 104 | 105 | 105 | 106 | 106 |
| **Education places** | 100 | 171 | 181 | 183 | 32 | 31 | 37 | 37 | 35 |
| **Students in municipality** | 100 | 99 | 101 | 103 | 105 | 112 | 116 | 125 | 125 |
| **Station connectivity** | 100 | 102 | 102 | 103 | 102 | 102 | 100 | 102 | 114 |
| **Service jobs at highway off-ramps** | 100 | 103 | 107 | 111 | 118 | 116 | 113 | 110 | 109 |
| **Office stock** | 100 | 100 | 105 | 105 | 105 | 105 | 105 | 105 | 105 |
| **HAARLEM (IC-station)** | | | | | | | | | |
| **Variable** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Retail jobs** | 100 | 106 | 106 | 111 | 110 | 112 | 108 | 103 | 106 |
| **Service jobs** | 100 | 102 | 101 | 103 | 106 | 108 | 109 | 107 | 94 |
| **Train use** | 100 | 105 | 109 | 109 | 116 | 118 | 112 | 117 | 104 |
| **Office vacancy** | 100 | 93 | 98 | 311 | 193 | 120 | 95 | 202 | 210 |
| **Leisure** | 100 | 103 | 107 | 115 | 124 | 128 | 131 | 123 | 121 |
| **Population** | 100 | 100 | 100 | 100 | 100 | 101 | 102 | 103 | 104 |
| **Accessibility by train** | 100 | 100 | 100 | 100 | 100 | 101 | 101 | 102 | 103 |
| **Activity within reach by car** | 100 | 101 | 101 | 102 | 103 | 104 | 103 | 103 | 104 |
| **Education places** | 100 | 94 | 97 | 100 | 101 | 103 | 89 | 88 | 87 |
| **Students in municipality** | 100 | 105 | 106 | 110 | 111 | 114 | 125 | 129 | 128 |
| **Station connectivity** | 100 | 95 | 98 | 94 | 100 | 95 | 95 | 94 | 65 |
| **Service jobs at highway off-ramps** | 100 | 95 | 98 | 94 | 101 | 96 | 95 | 94 | 98 |
| **Office stock** | 100 | 100 | 100 | 100 | 105 | 105 | 105 | 110 | 111 |

## 7.2 Data per variable

This section discusses the aggregated data per variable. The aggregated data is shown in total, for all multimodal stations and for all IC-stations. The data is shown relatively where 2004 = 100. Appendix A shows the data per station per variable in graphical form.

<u>Retail jobs (in station area)</u>

The overall data shows a clear trend pre- and post-crisis. After a decline of 1% in the first year retail increases with almost 7% until 2008. After 2008 retail decreases with almost 4%. The multimodal stations show a similar trend: A decline of 1% in the first year and after that an increase of almost 6% until 2008. After 2008 retail decreases hard with over 7%. The IC-stations show a similar trend. A small decrease followed by an increase until 2008. However, after 2008 IC-stations only show a small decrease in retail with less than 3%. Analysing the data per station the enormous expansion in retail of Amsterdam Bijlmer Arena is remarkable. Between 2005 and 2006 this station area experienced a growth of over 150% in retail. The majority of the increase of almost 5% in the aggregated IC-station data can therefore be allocated to Amsterdam Bijlmer Arena.

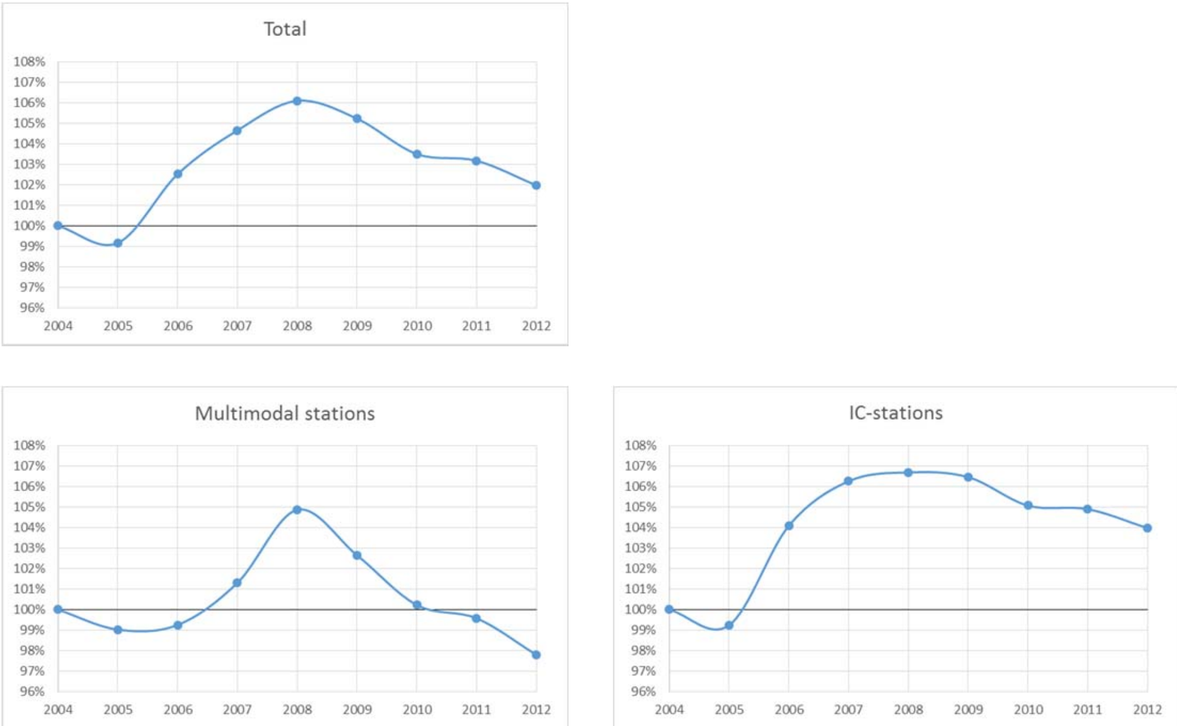



**FIGURE 7.2: AGGREGATED DATA OF RETAIL JOBS.**

Multimodal stations clearly show a more decreasing trend than IC-stations after 2008. This might be explained by the fact that most multimodal stations, as opposed to IC-stations, are not situated near the city centre. This can be seen in figure 5.1. The city centres are, originally, the locations where most of the retail is situated in the Netherlands. In addition, these city centres normally are more attractive for visitors than the new centres due to their historic character, higher population densities, and other amenities. This might help explain why in times of economic decline retail at new centres has declined the most.

## Service jobs (in station area)

The aggregated data of all service jobs shows a small increase, followed by a small decrease in 2006. After 2006 the number of service jobs increased with 4% until 2009. After 2009 the growth stagnated and even showed a small decrease in the post-crisis period. The aggregated data for multimodal and IC-stations show different trends. The number of service jobs at multimodal stations increased with almost 8% until 2009. After 2009 a clear change of trend is visible and the number of service jobs decreased with almost 4%. IC-stations show a complete different trend. They had a decrease of 1% in the first two years, than a big increase between 2006 and 2007 of 4%, followed by again a decrease of 3% until 2009. Remarkably IC-stations had a steady increase in service jobs after 2009 of almost 2%.

Inspecting the data per station, the IC-stations of Almere, Amsterdam Bijlmer, Gouda, and Delft have had a big increase in service jobs in the pre-crisis period. Almere, Amsterdam Bijlmer, and Gouda all three had a small dip between 2008 and 2009, but then grew again a little bit between 2009 and 2010 before stagnating. It is also remarkable that in the pre-crisis period the number of service jobs grew with almost 20% at Amsterdam Zuid.

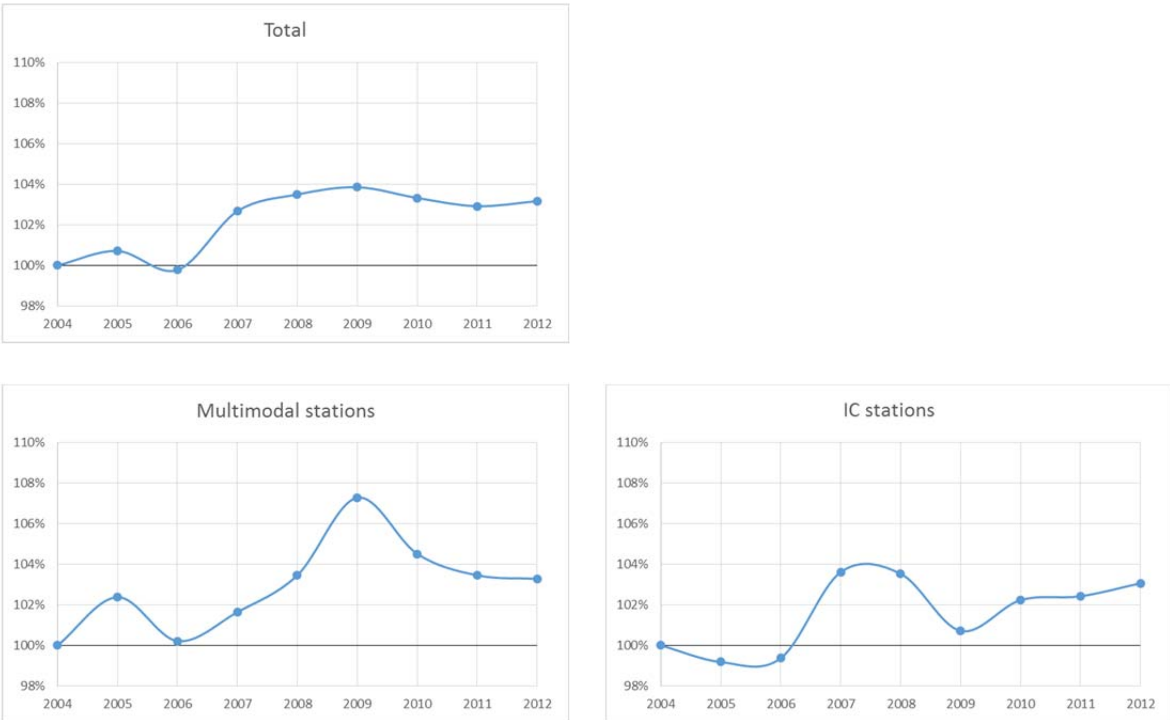
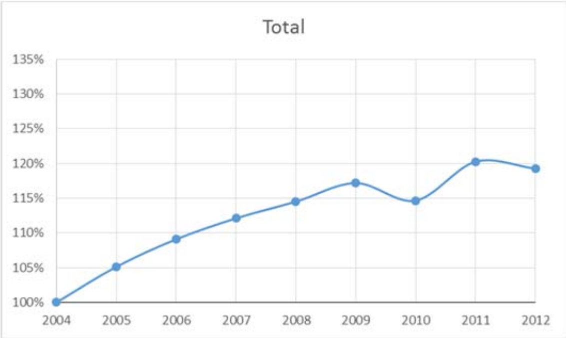


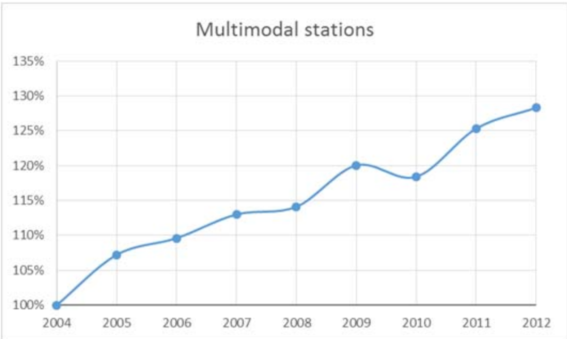

**FIGURE 7.3: AGGREGATED DATA OF SERVICE JOBS.**

## Train Use

Train use data shows a steady increasing trend with a small dip in 2010 and 2012. After inquiry with NS, the dips of 2010 and 2012 are not explainable by real world events. Therefore it is assumed that these dips are caused by random variation in the data collection method of the NS. This collection method is explained in section 5.3. Over the considered time period train use increased with almost 20%. The aggregated data for only multimodal and IC-stations show similar trends. Train use at multimodal stations almost increased with 30%. The fourth Balkenende cabinet (2007-2010) had the ambition to increase train use annually with 5% until 2012. This should be accomplished with several measures including improving rail infrastructure and by increasing train frequencies. Although an annual growth of 5% was not accomplished, the increase is in line with efforts made by government.

Inspecting the data per station, it becomes clear that Amsterdam Zuid, Amsterdam Bijlmer, and Den Haag Laan van NOI have had a big increase in train users. Amsterdam Zuid even grew 200% between 2004 and 2012. A reason for this might be found in the construction of the 'Utrecht arc' in 2006. Since the construction of this connection arc there is a direct connection between Schiphol and Utrecht, also increasing train frequency at Amsterdam Zuid (and Amsterdam Bijlmer). On the other side, Duivendrecht has had a decrease of over 40% in train users. The construction of the 'Gooiboog' in 2003 and the 'Utrecht boog' in 2006 is probably the reason for this. Both arcs created new direct connections and decreased the importance of station Duivendrecht, which until then had been an important transfer station. People transferring are not included in the data, but due to losing the important transfer status, Duivendrecht also has had a decrease in trains servicing the station.



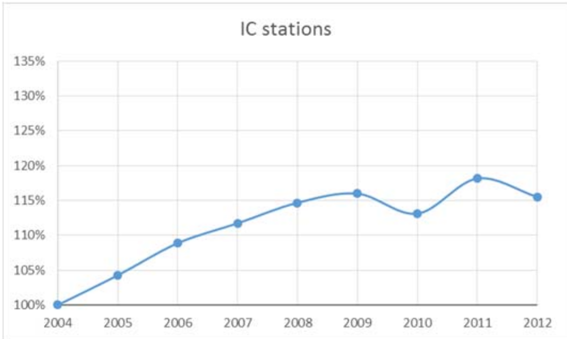




**FIGURE 7.4: AGGREGATED DATA OF TRAIN USE.**

## Office vacancy (in station area)

Overall, office vacancy shows an increase of 70% in the considered time period. It is remarkable that all aggregated data show a small decrease of vacancy before the financial crisis, a stagnation in 2008, and a big increase after that. Multimodal stations have suffered less from office vacancy with only a 60% increase, while office vacancy at IC-stations was worse with an 80% increase.

Data per station shows a lot of fluctuation. In the pre-crisis period Rotterdam Alexander had a tremendous increase in vacancy, a big decrease between 2006 and 2009, and ended with a big increase again. The most spectacular increase in office vacancy was in Delft with an increase of 412% between 2010 and 2011. However, it needs to be said that office vacancy in Delft in 2004 was very low with only 2% (about 3,000m$^2$) vacant office space in the station area. Hence, the relative development is big, while the absolute development is not that big. Other station areas with a big increase in vacancy levels in the post-crisis period are Den Haag Laan van NOI and Hilversum. In 2012 there were only six station areas with a decrease in vacancy levels: Amsterdam Bijlmer, Amsterdam Zuid, Schiedam, Duivendrecht, Utrecht, and Beverwijk.

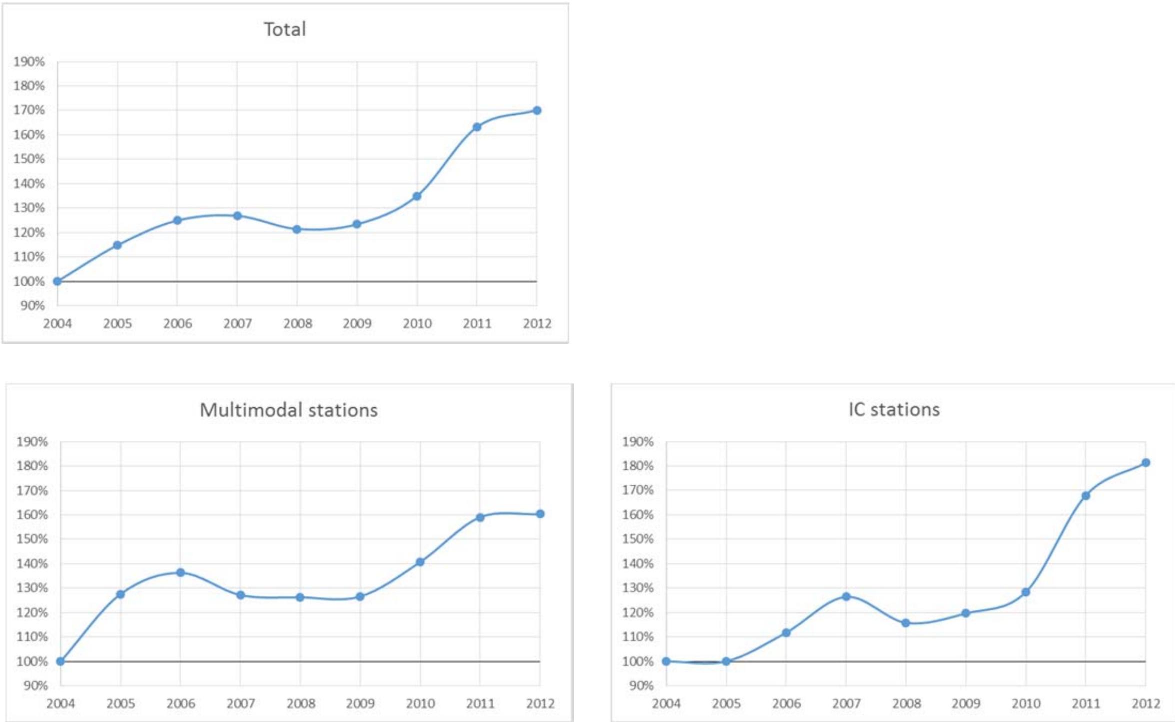



**FIGURE 7.5: AGGREGATED DATA OF OFFICE VACANCY.**

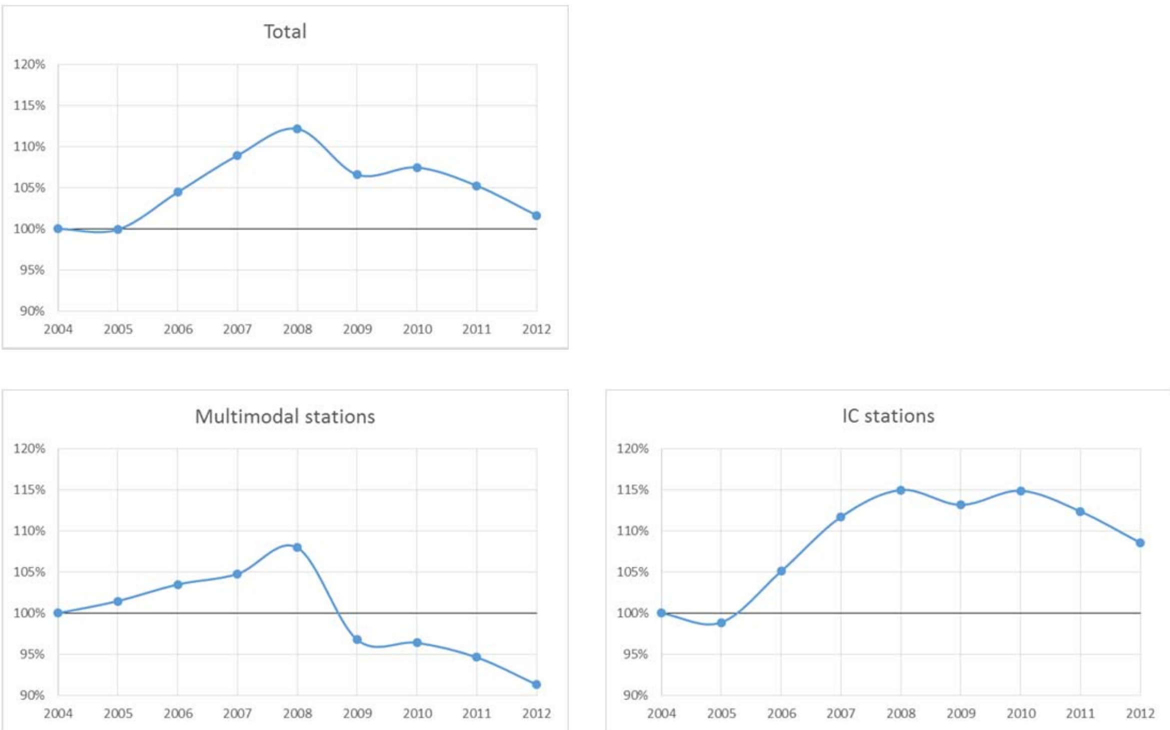



**FIGURE 7.6: AGGREGATED DATA OF LEISURE.**

## Leisure (in station area)

The total aggregated data of leisure also shows a clear change of trend pre- and post-crisis. Until 2008 leisure increased with 12% and in the post-crisis period in decrease again with 10%. This decrease can mostly be allocated to multimodal stations. Both multimodal and IC-stations had an increase in leisure until 2008. Between 2008 and 2009 multimodal station had a big decrease from +8% to -3% compared with 2004. After that it decreased even more. IC-stations show a stagnating trend between 2008 and 2010 and a steady decrease since 2010. Analysing the data per station it becomes clear that there are two station areas with a big increase in leisure and that there are two station areas with a big decrease in leisure. Both Amsterdam Bijlmer and Zaandam have had a big increase. Both stations are also IC-stations. The two station areas with a big decrease are both multimodal stations. Both Amsterdam Amstel and Amsterdam Zuid have had a big decrease in leisure.

## Population (in station area)

The development of population at both multimodal and IC-stations show a similar trend. In the pre-crisis period there is a small decrease of less than 1%. In the post-crisis period population increases again in station areas with almost 3%. It is remarkable that almost all stations show a similar trend as well. Eventually, in 2012, there are only three station areas with a decrease in population: Rotterdam Blaak, Rotterdam Alexander, and Gouda. Beverwijk and Amsterdam Zuid have had the biggest increase with respectively 9% and 6%.

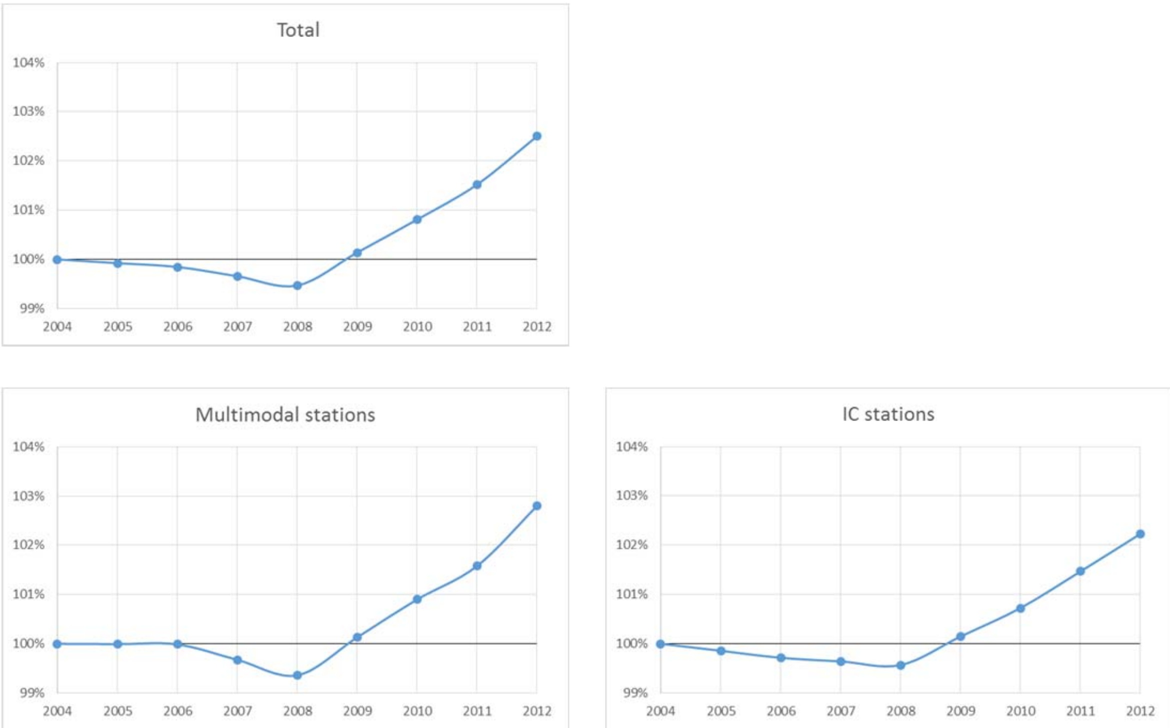



**FIGURE 7.7: AGGREGATED DATA OF POPULATION**

## Accessibility by train

Comparable to train use, accessibility by train has steadily been increasing during the entire analysed time period. Trend of both multimodal and IC-stations is similar as well and for both accessibility by train increased with around 10%. Analysing the data per stations it becomes clear that in 2012, all stations have had an increase in accessibility by train. Stations with the biggest increase are Amsterdam Zuid, Amsterdam Centraal, and Utrecht Centraal. The overall increase of the accessibility by train is in line with the ambitions of government. The increase of accessibility by train is a result of the increase of retail and service jobs, and population within reach by train.

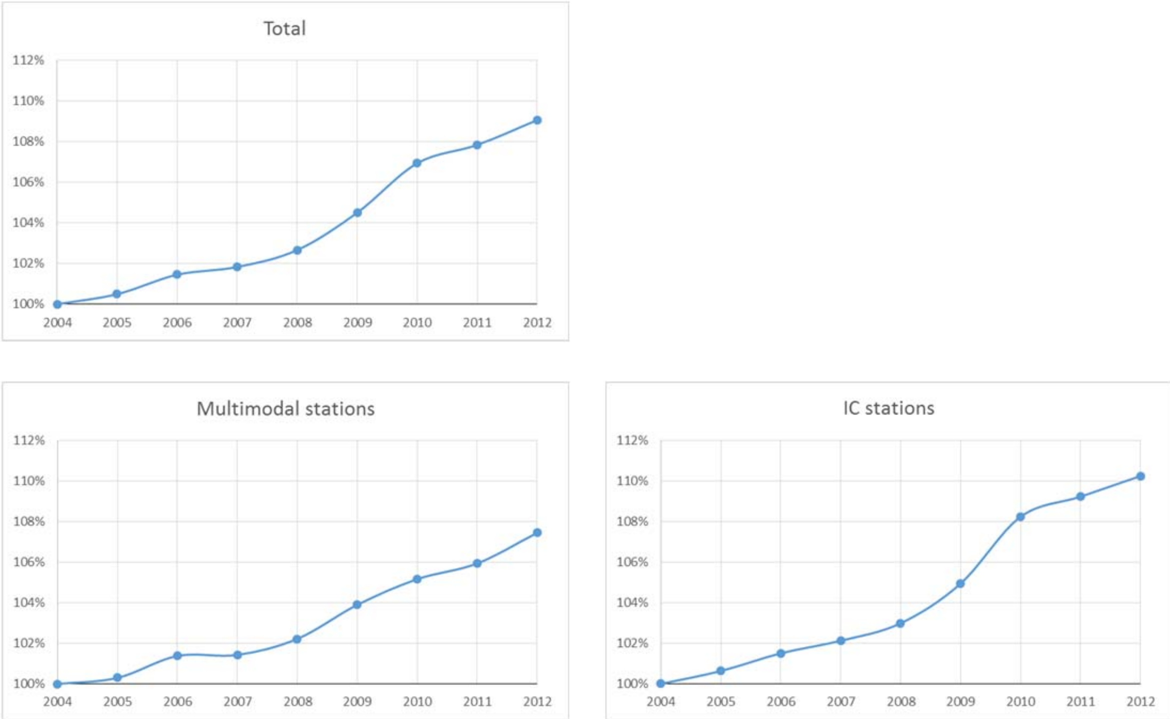



**FIGURE 7.8: AGGREGATED DATA OF ACCESSIBILITY BY TRAIN.**

## Activity within reach by car

After a slow first two years, activity within reach by car steadily increased until 2012. Multimodal and IC-stations show a similar trend and had an overall increase of around 4%. Based on the method of measurement, this increase of activity within reach by car is to be allocated to the increase of activity intensity. Only three stations have experienced a decrease in activity within reach by car and are all located in the Rotterdam region; Rotterdam Centraal, Rotterdam Blaak, and Schiedam Centrum. On the other side, activity within reach by car at Almere Centrum increased the most with almost 12%. This is probably caused by the fact that Almere is still developing due to its young age.

## Education places (in station area)

The overall number of education places increases until 2007 with 8%. Between 2007 and 2008 the variable decreased 10% to be below 2004 levels. After 2008 the number of education places steadily increases again to be 9% above 2004 levels. Here multimodal and IC-stations show a different trend. At multimodal stations the number of education places grew rapidly, after a small dip in 2005, to increase with over 25%. This growth can be allocated to the growth at the Amsterdam Amstel station for the main part. Amsterdam Amstel has experienced an enormous growth in education places which increased with over 560%. This growth is caused by realization of a new campus of the 'Hogeschool of Amsterdam' which is just within 1.500 meters of the Amstel station. IC-stations have experienced a big growth of over 10% between 2004 and 2005, followed by a stagnation until 2007. In 2008, the number of education places decreased with 21%. After this enormous dip, the number of education places started to increase again in a steady fashion, but in 2012 levels are still just below 2004 level. The big decrease between 2007 and 2008 can, for the majority of the part, be allocated to Delft. TU Delft decided to reorganise and to bundle all their activities at their south-campus, this led to the disappearances of their education activities in the north of the campus which was within range of the station of Delft.

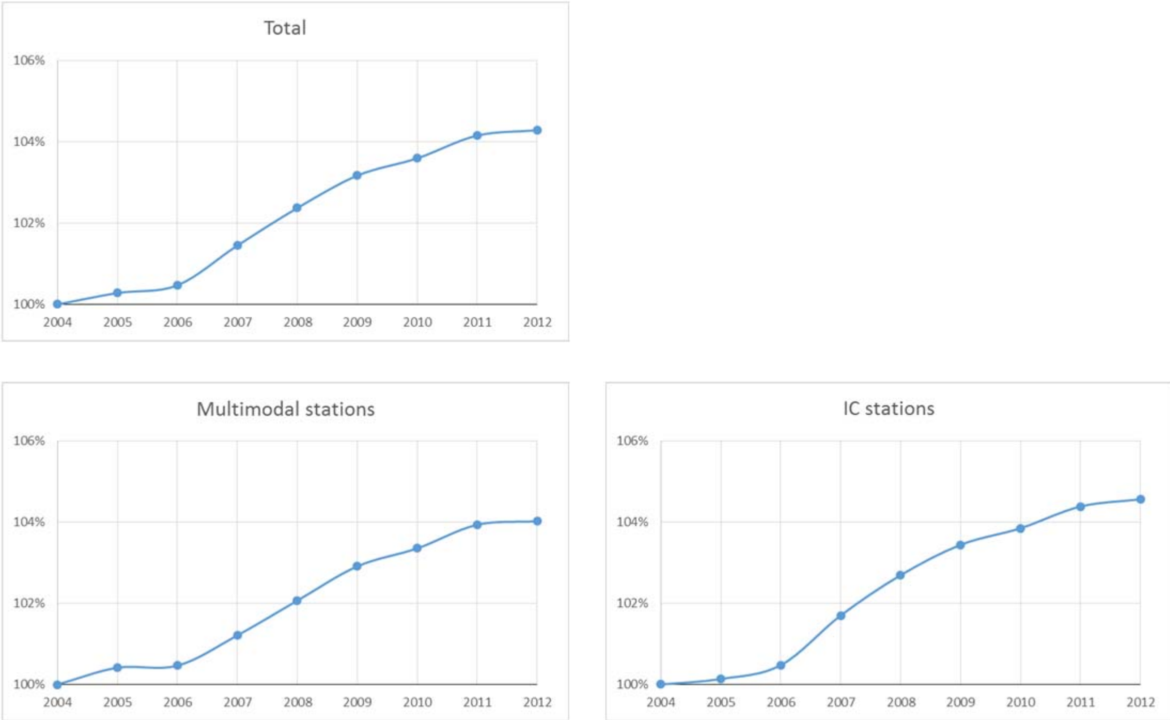



**FIGURE 7.9: AGGREGATED DATA OF ACTIVITY WITHIN REACH BY CAR.**

FIGURE 7.10: AGGREGATED DATA OF EDUCATION PLACES.

## Students in municipality

The number of students show a steady and relative big increase for the entire analysed period. This is the same for both Multimodal and IC-stations. The overall number of students increased with over 43%. For some stations the number of students is the same as those stations are located in the same municipality. It is remarkable that in all analysed municipalities the number of students has increased with at least 15%.

## Station connectivity

After a two year period of small increase/stagnation a steady growth incurred until 2010. After that, station connectivity stagnated again. For multimodal stations this first period took three years and after 2007 it grew to an increase of over 8%. IC-stations started increasing stations connectivity after 2006 until 2010. After 2010 station connectivity decreased a little bit. Overall an increase of almost 9% was realized. The steady period of growth after 2006 was in line with government programs increasing quality of the train network in order to increase train use.

Stations with the biggest increase in station connectivity are Amsterdam Zuid and Amsterdam Bijlmer. Duivendrecht has experienced a decrease of station connectivity. Reason for the increase and decrease of station connectivity of these stations has been explained before and is probably related to the construction of the 'Utrecht arc' in 2006. This arc made a direct connection between Schiphol and Utrecht (via Amsterdam Zuid and Amsterdam Bijlmer) and increased train frequencies due to the addition of an extra train service. Duivendrecht lost its importance as a transfer station and thereby train services.

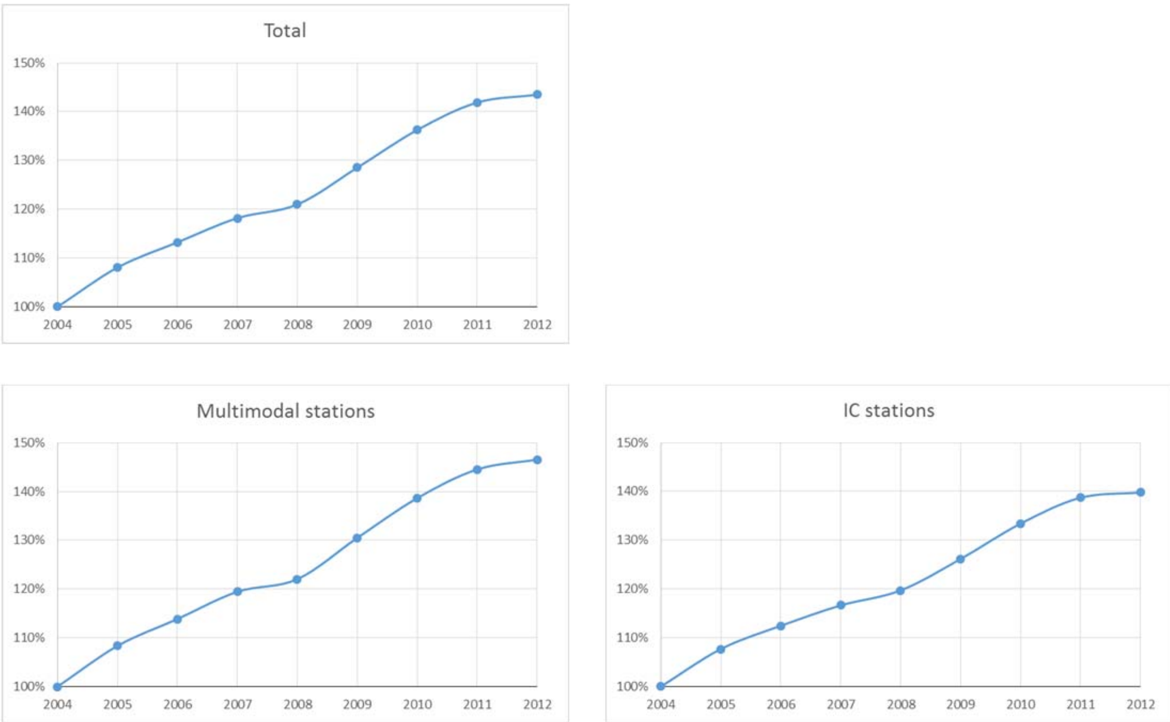



FIGURE 7.11: AGGREGATED DATA OF STUDENTS IN MUNICIPALITY.

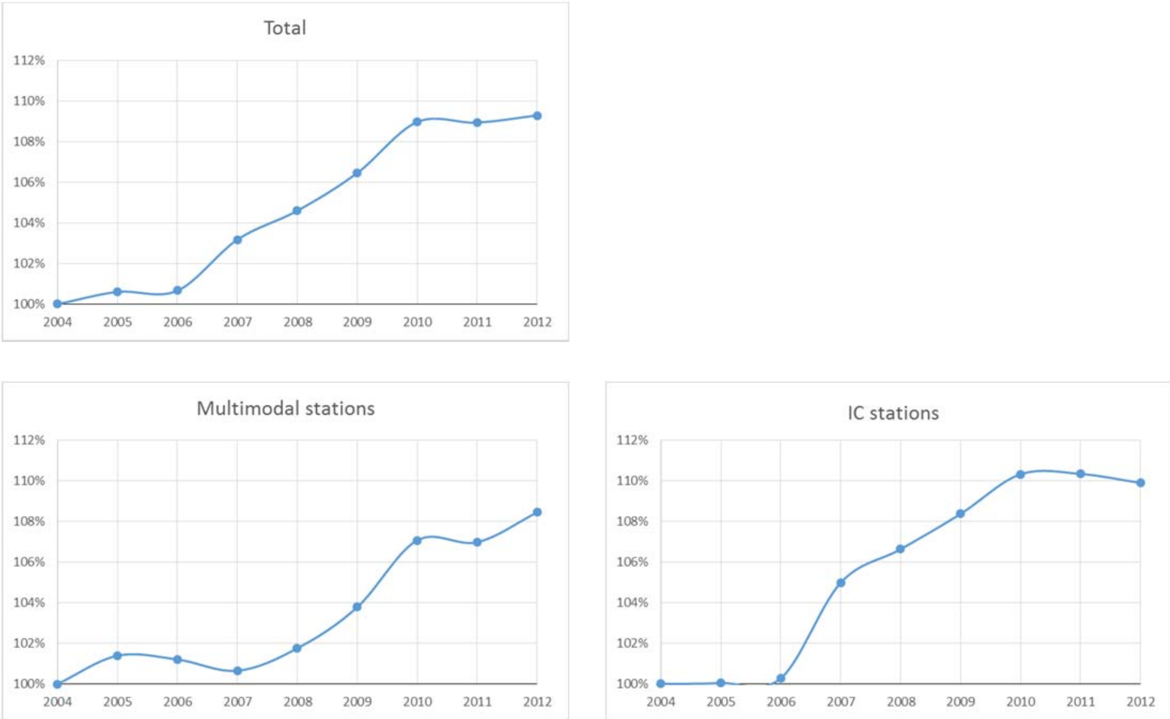



**FIGURE 7.12: AGGREGATED DATA OF STATION CONNECTIVITY.**

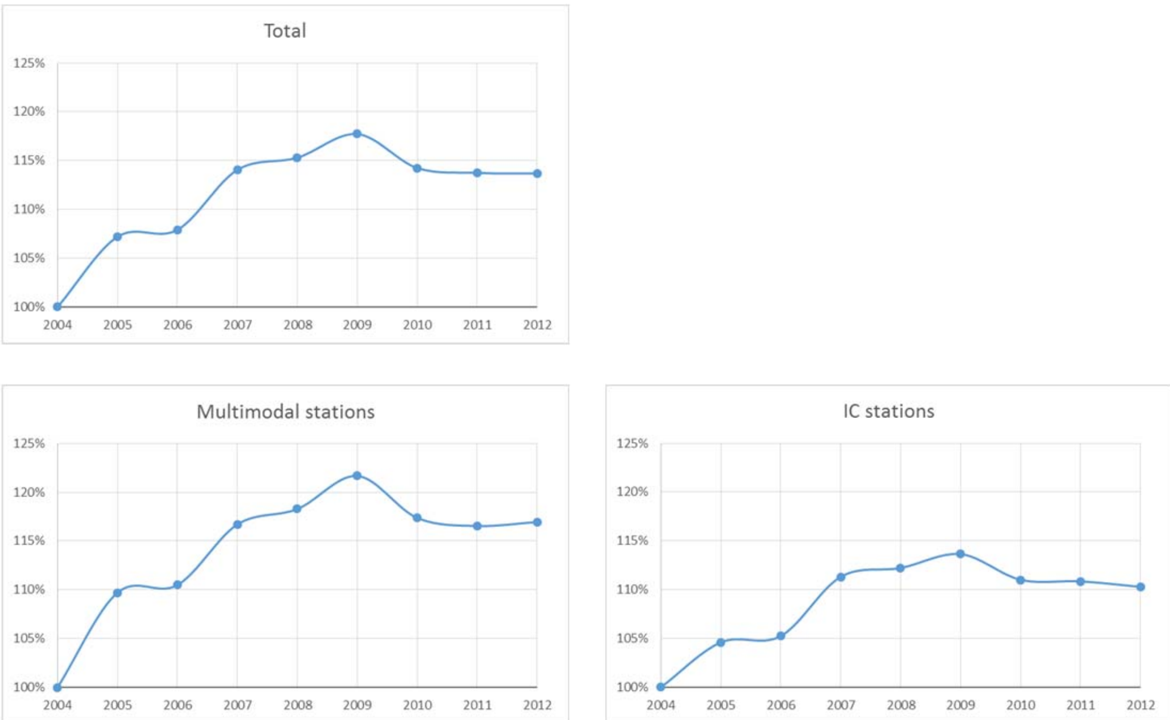



**FIGURE 7.13: AGGREGATED DATA OF SERVICE JOBS AT HIGHWAY OFF-RAMPS.**

## Service jobs at highway off-ramps (within region)

The number of service jobs at highway off-ramps show a change of trend after 2009. Until 2009 the number of service jobs at highway off-ramps overall increased with 18%. After 2009 it decreased again with 4% before stagnating until 2012. Multimodal and IC-stations show similar trends, although the number of service jobs at highway off-ramps around multimodal stations increased with even 22% until 2009. At IC-stations this was only 14%.

Analysing the data per station it becomes clear that the number of service jobs at highway off-ramps mostly increased in the Amsterdam metropolitan area. Stations with the biggest increase are Amsterdam Amstel, Amsterdam Bijlmer, Duivendrecht, and Almere. Around Haarlem however, the number of service jobs at highway off-ramps decreased with over 35%.

## Office stock (in station area)

The total supply of office stock within the station areas of the analysed stations has increased steadily until 2007, hard between 2007 and 2009, before growing steadily again. Multimodal and IC-stations show a similar trend with the exception that the supply of office stock stagnated after 2009 at multimodal stations. For the analysed period office stocks increased within the station area of most analysed stations. Especially the station areas of Almere, Leiden, and Rotterdam Alexander have experienced a big growth. No station areas have experienced a decrease in office stock in 2012.

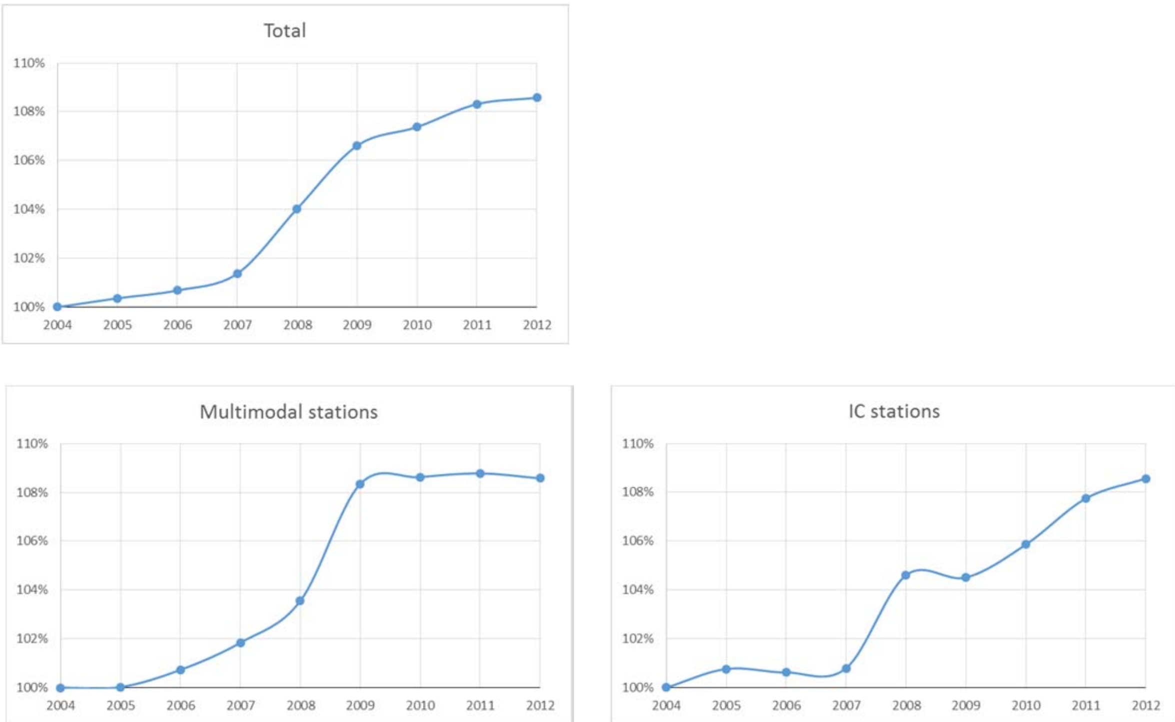



**FIGURE 7.14: AGGREGATED DATA OF OFFICE STOCK.**

# 8 Regression Analysis

This chapter covers the results of the several analyses. The five analyses and their descriptions are summarized in table 8.1 and are discussed in that order. Before an analysis has been performed, the dataset is checked for correlating variables. Correlating variables with a correlation greater than 0.5 are discussed. All found regression coefficients are subject to a significance level of α=0.1, meaning that coefficients with a P-value (probability of exceedance) of 0.1 or lower are considered to be significant.

**TABLE 8.1: FIVE PERFORMED ANALYSES AND THEIR DESCRIPTIONS.**

| Analysis | Description |
|---|---|
| 1.Cross-section | A multiple linear regression analysis using original values. The regression analyses have been performed for the years 2004, 2008, and 2012. |
| 2.Cross-section (standardised) | A MLR analysis using standardised values. Regression analyses have been performed for the years 2004, 2008, and 2012. |
| 3.Semi Cross-section | MLR for the pre-crisis (2004-2008) and post-crisis (2008-2012) periods. Model input is the in-/decrease of standardised values for the considered periods. |
| 4.Longitudinal method | MLR analysis pre- and post-crisis using year-to-year differences of standardised values. A 1 or 2 year lag is applied as well. |
| 5.Longitudinal method (fixed effects) | MLR analysis pre- and post-crisis using year-to-year differences of standardised values and a 1 or 2 year lag. In order to make a distinction between the different stations a fixed effects model has been used. |

## 8.1 Cross-section

The first performed analysis is a cross-section method, using the original, absolute, values of the performance indicators and explanatory variables. Per performance indicator three analyses have been performed using the data from 2004, 2008, and 2012. The results are discussed for each performance indicator.

### Retail jobs

The correlation matrix of the explanatory variables used for the 2004 model are shown in table 8.2. With slightly different values, the 2008 and 2012 data returns the same correlating variables. For both correlating cases there is also a qualitative reason to assume that both variables are too related. Service jobs and population are combined into a single variable. This variable is created by summing both variables. The similarity in their measuring unit makes this possible. For the other two correlating variables this is not possible. Hence, the removal of one of the variables is analysed. Based on the regression results of the analysis with no variables removed, station connectivity shows a more important role in explaining retail than accessibility by train (based on the P-value). Therefore the latter variable will be removed.

The 2004, 2008, and 2012 analyses all show the most explained variation in retail with the combined variable and without the variable accessibility by train. Model results are shown in table 8.3. Variables that are found to be significant are indicated with a bold font. All three models return similar results. Only the regression coefficient found for population+service jobs is significant. It is found that the population+service jobs variable is positively correlated with retail jobs. This is in line with expectations as mentioned in the conceptual model.

**TABLE 8.2: CORRELATION MATRIX 2004 RETAIL JOBS DATA.**

| | Service jobs | Population | Accessibility by train | Activity within reach by car | Station connectivity |
|---|---|---|---|---|---|
| **Service jobs** | 1 | | | | |
| **Population** | ***0.809*** | 1 | | | |
| **Accessibility by train** | 0.464 | 0.446 | 1 | | |
| **Activity within reach by car** | 0.477 | 0.484 | 0.135 | 1 | |
| **Station connectivity** | 0.329 | 0.367 | ***0.884*** | 0.040 | 1 |

**TABLE 8.3: MODEL RESULTS, PERFORMANCE INDICATOR: RETAIL JOBS (CROSS-SECTION METHOD).**

| Retail jobs | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.649 | | | $R^2$=0.556 | | | $R^2$=0.553 | |
| Variables | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| population + service jobs | **0.041** | **0.000** | | **0.041** | **0.000** | | **0.037** | **0.000** |
| Activity within reach by car | -0.002 | 0.138 | | -0.002 | 0.330 | | -0.002 | 0.270 |
| Station connectivity | 72.184 | 0.169 | | 52.342 | 0.370 | | 61.212 | 0.260 |
| Constant | -1492.2 | 0.380 | | -1237.42 | 0.545 | | -1111.62 | 0.553 |

## Service jobs

The correlation matrix for service jobs also shows two cases of correlating variables. The correlation matrix for the 2004 data is shown in table 8.4 below. The 2008 and 2012 data have the same correlating variables. There is no qualitative reason to assume that Activity within reach by car and the number of service jobs at highway off-ramps are related too much. Therefore none of these variables has been removed. Station connectivity and accessibility by train are the other two correlating variables. This time, station connectivity shows a less explaining role in explaining service jobs. Hence, the removal of this explanatory variable has been investigated.

Based on the $R^2$ value, the models without the station connectivity variable return the most explained variation. The results are shown in table 8.5. The cross-section models explaining service jobs also return only one significant variable; population. The found correlation is positive, which is in line with expectations. Furthermore the three models show similar results. Peculiar is the service jobs at highway off-ramps variable which shows a negative correlation in 2004 and a positive correlation in 2008 and 2012. Although the found regression coefficients are not significant, a positive correlation between service jobs and service jobs at highway off-ramps is not in line with the conceptual model.

**TABLE 8.4: CORRELATION MATRIX 2004 SERVICE JOBS DATA.**

| | Population | Accessibility by train | Activity within reach by car | Station connectivity | Service jobs at highway off-ramps |
|---|---|---|---|---|---|
| Population | 1 | | | | |
| Accessibility by train | 0.446 | 1 | | | |
| Activity within reach by car | 0.484 | 0.135 | 1 | | |
| Station connectivity | 0.367 | ***0.884*** | 0.040 | 1 | |
| Service jobs at highway off-ramps | 0.400 | 0.175 | ***0.522*** | 0.275 | 1 |

**TABLE 8.5: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS (CROSS-SECTION METHOD).**

| Service Jobs | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.685 | | | $R^2$=0.649 | | | $R^2$=0.653 | |
| Variables | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| Population | **0.160** | **0.000** | | **0.141** | **0.001** | | **0.145** | **0.001** |
| Accessibility by train | 0.006 | 0.314 | | 0.005 | 0.369 | | 0.003 | 0.470 |
| Activity within reach by car | 0.006 | 0.312 | | 0.008 | 0.516 | | 0.002 | 0.708 |
| Service jobs at highway off-ramps | -0.022 | 0.576 | | 0.016 | 0.619 | | 0.02 | 0.536 |
| Constant | -13667.2 | 0.049 | | -10034.8 | 0.144 | | -8953.16 | 0.193 |

## Train use

The correlation matrix for the train use data shows multiple cases of correlation. The matrix of the 2004 data is shown in table 8.6. Most cases of correlation are similar to the 2008 and 2012 data. Besides station connectivity and accessibility by train, all correlating cases are related to retail, service and leisure jobs and population. Therefore it is decided to combine these variables into a variable called urban intensity. This is possible due to the similar unit of measure and the fact that all those variables are correlated. The new combined variable is developed by summing the four correlating variables. The new correlation matrix for the 2004 data with the new combined variable is shown in table 8.7. Now the 2008 and 2012 data returns the same cases of correlation. However, the 2008 and 2012 data show an even bigger correlation between urban intensity and education places (0.703 and 0.701 respectively). Hence, education places is combined with the urban intensity variable as well. There is no qualitative reason to assume a relation between the number of students in a municipality and the urban intensity in the station area. Lastly the effect of removal of accessibility by train is investigated due to the correlation between accessibility by train and station connectivity.

The models with the accessibility by train variable included show the most explained variation based on the $R^2$ value. Model results are shown in table 8.8. All three models consistently show two significant variables; urban intensity and station connectivity. Both are, as expected, positively correlated with train use. The 2004 model however, also shows a significant and negative correlation between accessibility by train and train use. This is not in line with expectations. The other models shows a negative regression coefficient as well, although not significant. This negative relation, however, might be a result of the correlation between station connectivity and accessibility by train. Note that the three models also show relatively high $R^2$ values.

**TABLE 8.6: CORRELATION MATRIX 2004 TRAIN USE DATA.**

| | Retail jobs | Service jobs | Leisure | Population | Accessibility by train | Education places | Students in municipality | Station connectivity |
|---|---|---|---|---|---|---|---|---|
| **Retail jobs** | 1 | | | | | | | |
| **Service jobs** | ***0.639*** | 1 | | | | | | |
| **Leisure** | ***0.878*** | ***0.873*** | 1 | | | | | |
| **Population** | ***0.746*** | ***0.808*** | ***0.863*** | 1 | | | | |
| **Accessibility by train** | 0.490 | 0.464 | ***0.513*** | 0.446 | 1 | | | |
| **Education places** | ***0.504*** | ***0.629*** | ***0.669*** | ***0.572*** | 0.383 | 1 | | |
| **Students in municipality** | 0.299 | 0.486 | 0.443 | ***0.554*** | 0.230 | 0.269 | 1 | |
| **Station connectivity** | 0.485 | 0.329 | 0.417 | 0.367 | ***0.884*** | 0.257 | 0.328 | 1 |

**TABLE 8.7: CORRELATION MATRIX 2004 TRAIN USE DATA, COMBINED VARIABLE.**

| | Urban intensity | Accessibility by train | Education places | Students in municipality | Station connectivity |
|---|---|---|---|---|---|
| **Urban intensity** | 1 | | | | |
| **Accessibility by train** | 0.470 | 1 | | | |
| **Education places** | ***0.603*** | 0.383 | 1 | | |
| **Students in municipality** | ***0.551*** | 0.230 | 0.269 | 1 | |
| **Station connectivity** | 0.381 | 0.884 | 0.257 | 0.328 | 1 |

**TABLE 8.8: MODEL RESULTS, PERFORMANCE INDICATOR: TRAIN USE (CROSS-SECTION METHOD).**

| Train use | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.806 | | | $R^2$=0.761 | | | $R^2$=0.783 | |
| **Variables** | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| **Urban intensity** | **0.232** | **0.002** | | **0.241** | **0.008** | | **0.233** | **0.004** |
| **Students in municipality** | -0.579 | 0.126 | | -0.136 | 0.687 | | -0.242 | 0.367 |
| **Accessibility by train** | **-0.044** | **0.086** | | -0.026 | 0.333 | | -0.035 | 0.193 |
| **Station connectivity** | **3900.786** | **0.000** | | **3453.908** | **0.001** | | **3686.163** | **0.001** |
| **Constant** | -40680.00 | 0.003 | | -55385.00 | 0.001 | | -47859.3 | 0.002 |

## Office vacancy

The 2004 office vacancy models also show multiple cases of correlating variables. The correlation matrix for the 2004 data is shown in table 8.9. De 2008 and 2012 data return the same correlating variables. There is only a qualitative reason to believe that service jobs and population, service jobs and office stock, and station connectivity and accessibility by train are too much related. Combining service jobs and population again to urban intensity will still not resolve the correlation with office stock. Hence, the removal of service jobs is investigated. The same is done for the accessibility by train variable. Those two variables show the least explaining power in explaining the variation of office vacancy.

The models without the removed variables return the most explained variation. The results are shown in table 8.10. 2004 and 2008 models return activity within reach by car as a significant variable. The 2008 returns office stock as a significant variable as well, such as the 2012 model. Activity within reach by car is found to be positively correlated with office vacancy, this was not expected. The positive relation means that a location with higher activity within reach by car levels has higher office vacancy levels. This is not in line with the conceptual model. The positive correlation between office stock and office vacancy on the other hand is in line with the conceptual model. It is also noteworthy that the $R^2$ value of the models increases significantly in time.

**TABLE 8.9: CORRELATION MATRIX 2004 OFFICE VACANCY DATA.**

| | Service Jobs | Population | Accessibility by train | Activity within reach by car | Station connectivity | Office stock |
|---|---|---|---|---|---|---|
| **Service Jobs** | 1 | | | | | |
| **Population** | ***0.809*** | 1 | | | | |
| **Accessibility by train** | 0.464 | 0.446 | 1 | | | |
| **Activity within reach by car** | 0.477 | 0.484 | 0.135 | 1 | | |
| **Station connectivity** | 0.329 | 0.367 | ***0.884*** | 0.097 | 1 | |
| **Office stock** | ***0.920*** | ***0.704*** | 0.389 | ***0.537*** | 0.229 | 1 |

**TABLE 8.10: MODEL RESULTS, PERFORMANCE INDICATOR: OFFICE VACANCY (CROSS-SECTION METHOD).**

| Office vacancy | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.340 | | | $R^2$=0.536 | | | $R^2$=0.729 | |
| **Variables** | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| **Population** | -0.284 | 0.233 | | -0.520 | 0.227 | | -0.269 | 0.201 |
| **Activity within reach by car** | **0.055** | **0.080** | | **0.074** | **0.018** | | 0.027 | 0.296 |
| **Station connectivity** | 207.868 | 0.830 | | 501.654 | 0.597 | | -401.981 | 0.628 |
| **Office stock** | 0.037 | 0.108 | | **0.061** | **0.010** | | **0.101** | **0.000** |
| **Constant** | 3581.106 | 0.917 | | -472.266 | 0.989 | | 25119.71 | 0.419 |

## 8.2 Cross-section (standardised)

This section discusses the results of the cross-section analyses with standardised values. In this way it is possible to compare the importance of explanatory variables based on the found regression coefficients. Per model, only one observation per variable per station is used. Hence, it is not possible to standardize data per station as this would lead to wrong results. This is illustrated in figure 8.1. The figure shows the standardised retail jobs and accessibility by train data of Almere. In absolute form, both variables are positive and increasing between 2004 and 2010. The standardised data per variable show a positive trend as well during this period. However, due to the greater standard deviation of retail, this standardised variable starts off with a negative value. If one only uses the data of 2004, one will find a negative relation, while the relation in absolute form is positive.


**FIGURE 8.1: STANDARDISED DATA OF RETAIL AND ACCESSIBILITY BY TRAIN OF ALMERE CENTRUM.**

Therefore, the data for this type of analysis has been standardised per variable. Thus the 25 observations of the 25 stations have been standardised per variable. For all the analyses the same dataset has been used as in the previous section. Standardizing data does not influence the correlation matrix, therefore the correlation of the explanatory variables is not discussed again. Model output returns the same $R^2$ values and significance levels as the non-standardised model output, only regression coefficients have changed. The analyses have, again, been performed for the 2004, 2008, and 2012 data and are discussed per performance indicator.

### Retail jobs

The results are shown in table 8.11. Population+service jobs is still the only, positively, significant correlated variable. However, based on the regression coefficient it can be concluded that this variable is related with retail jobs in a relatively strong fashion. An elasticity (regression coefficient) of 0.789 means that an increase of 10 in the population+service jobs variable results in a 7.89 increase of the retail jobs variable.

**TABLE 8.11: MODEL RESULTS, PERFORMANCE INDICATOR: RETAIL JOBS (CROSS-SECTION METHOD (STANDARDISED)).**

| Retail jobs | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.649 | | | $R^2$=0.556 | | | $R^2$=0.553 | |
| **Variables** | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| **Population + Service jobs** | **0.789** | **0.000** | | **0.741** | **0.000** | | **0.716** | **0.000** |
| **Activity within reach by car** | -0.233 | 0.138 | | -0.169 | 0.330 | | -0.190 | 0.270 |
| **Station connectivity** | 0.202 | 0.169 | | 0.145 | 0.370 | | 0.186 | 0.260 |
| **Constant** | 0 | 0.380 | | 0 | 0.545 | | 0 | 0.553 |

## Service jobs

Model results are shown in table 8.12. Still only the population variable is significant, but now it can be concluded that this variable is relatively strong related to service jobs.

**TABLE 8.12: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS (CROSS-SECTION METHOD (STANDARDISED)).**

| Service Jobs | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.685 | | | $R^2$=0.649 | | | $R^2$=0.653 | |
| Variables | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| Population | **0.699** | **0.000** | | **0.645** | **0.001** | | **0.676** | **0.001** |
| Accessibility by train | 0.146 | 0.314 | | 0.137 | 0.369 | | 0.110 | 0.470 |
| Activity within reach by car | 0.164 | 0.312 | | 0.112 | 0.516 | | 0.066 | 0.708 |
| Service jobs at highway off-ramps | -0.085 | 0.576 | | 0.081 | 0.619 | | 0.102 | 0.536 |
| Constant | 0 | 0.049 | | 0 | 0.144 | | 0 | 0.193 |

## Train use

Table 8.13 shows the model results. Based on the standardised data, it can be seen that station connectivity is the most important variable in explaining the variation in train use. The relation between station connectivity and train use is found to be very strong (almost 1 on 1). The found regression coefficients for urban intensity show relatively strong relations as well. The same holds for the negative relation found between accessibility by train and train use for the 2004 model.

**TABLE 8.13: MODEL RESULTS, PERFORMANCE INDICATOR: TRAIN USE (CROSS-SECTION METHOD (STANDARDISED)).**

| Train use | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.806 | | | $R^2$=0.761 | | | $R^2$=0.783 | |
| Variables | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| Urban intensity | **0.471** | **0.002** | | **0.422** | **0.008** | | **0.431** | **0.004** |
| Students in municipality | -0.203 | 0.126 | | -0.054 | 0.687 | | -0.117 | 0.367 |
| Accessibility by train | **-0.427** | **0.086** | | -0.234 | 0.333 | | -0.355 | 0.193 |
| Station connectivity | **1.093** | **0.000** | | **0.869** | **0.001** | | **0.999** | **0.001** |
| Constant | 0 | 0.003 | | 0 | 0.001 | | 0 | 0.002 |

## Office vacancy

Model results are shown in table 8.14. The 2008 and 2012 models found office stock as the most important variable in explaining office vacancy. The found correlations are relatively strong as well. The 2004 and 2008 models also found activity within reach by car as significant variable. This relation was found to be relatively strong as well.

**TABLE 8.14: MODEL RESULTS, PERFORMANCE INDICATOR: OFFICE VACANCY (CROSS-SECTION METHOD (STANDARDISED)).**

| Office vacancy | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=25 | | | N=25 | | | N=25 | |
| | $R^2$=0.340 | | | $R^2$=0.536 | | | $R^2$=0.729 | |
| Variables | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| Population | -0.338 | 0.233 | | -0.513 | 0.227 | | -0.230 | 0.201 |
| Activity within reach by car | **0.409** | **0.080** | | **0.475** | **0.018** | | 0.148 | 0.296 |
| Station connectivity | 0.043 | 0.830 | | 0.089 | 0.597 | | -0.062 | 0.628 |
| Office stock | 0.455 | 0.108 | | **0.639** | **0.010** | | **0.928** | **0.000** |
| Constant | 0 | 0.917 | | 0 | 0.989 | | 0 | 0.419 |

## 8.3 Semi Cross-section

*Note that until now absolute data was used for analysis. From this step on the development of variables is used for analysis.*

The semi cross-section analyses describe the pre- and post-crisis period. The pre-crisis data describes the in/decrease between 2004 and 2008, the post-crisis data does the same for the 2008-2012 period. By using the differences of the standardised data, the relation between the development in explanatory variables and performance indicators is analysed. The results are discussed per performance indicators.

### Retail jobs

The pre-crisis data has four cases of correlation bigger than 0.5 shown in table 8.15 below. Only two cases also have a qualitative reason to assume that they are related too much; the correlation between activity within reach by car and population and service jobs. The post-crisis data only returned correlation between activity within reach by car and service jobs. The removal of population and service jobs has been investigated and the models including all variables turned out to explain the most variation.

Model results are shown in table 8.16. Both models return similar results. Similar $R^2$ values and a strong positive relation between activity within reach by car and retail jobs. In both models activity within reach by car turned out to be the most important variable in explaining the variation in the development of retail jobs. The pre-crisis model found a relative strong and negative relation between station connectivity and retail jobs as well. This negative relation is not in line with the conceptual model.

**TABLE 8.15: CORRELATION MATRIX PRE-CRISIS RETAIL JOBS DATA (STANDARDISED DIFFERENCES).**

| | Service jobs | Population | Accessibility by train | Activity within reach by car | Station connectivity |
|---|---|---|---|---|---|
| **Service jobs** | 1 | | | | |
| **Population** | 0.482 | 1 | | | |
| **Accessibility by train** | ***0.590*** | 0.388 | 1 | | |
| **Activity within reach by car** | ***0.627*** | ***0.697*** | ***0.554*** | 1 | |
| **Station connectivity** | 0.119 | 0.039 | 0.171 | 0.242 | 1 |

**TABLE 8.16: MODEL RESULTS, PERFORMANCE INDICATOR: RETAIL JOBS (SEMI CROSS-SECTION METHOD (STANDARDISED)).**

| Retail jobs | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=25 | | | N=25 | |
| | $R^2$=0.560 | | | $R^2$=0.578 | |
| **Variables** | Coefficient | P-value | | Coefficient | P-value |
| **Service jobs** | -0,056 | 0,794 | | -0,311 | 0,279 |
| **Population** | 0,386 | 0,128 | | 0,012 | 0,965 |
| **Accessibility by train** | -0,190 | 0,554 | | -0,192 | 0,461 |
| **Activity within reach by car** | **0,617** | **0,055** | | **2,345** | **0,000** |
| **Station connectivity** | **-0,393** | **0,040** | | -0,226 | 0,355 |
| **Constant** | 0,420 | 0,335 | | -2,085 | 0,018 |

### Service jobs

The pre-crisis data has three cases of correlation, which can be seen in table 8.17. Only for the correlation between population and Activity within reach by car there is a qualitative reason to assume that they are related. The removal of population has been investigated. The post-crisis data did not show any cases of correlation. Model results are shown table 8.18. The pre-crisis model was found to explain the most variation in service jobs development without the population variable. Furthermore, model results are comparable. Both found a strong and positive relation between Activity within reach by car and service jobs. In the post-crisis model this was even the strongest explainer of the variation in development of service jobs. The pre-crisis model found accessibility by train as the most important variable in explaining the variation in development of service jobs. This relation was found to be positive as well.

**TABLE 8.17: CORRELATION MATRIX PRE-CRISIS SERVICE JOBS DATA (STANDARDISED DIFFERENCES).**

| | Population | Accessibility by train | Activity within reach by car | Station connectivity | Service jobs at highway off-ramps |
|---|---|---|---|---|---|
| **Population** | 1 | | | | |
| **Accessibility by train** | 0.388 | 1 | | | |
| **Activity within reach by car** | ***0.697*** | ***0.554*** | 1 | | |
| **Station connectivity** | 0.039 | 0.171 | 0.242 | 1 | |
| **Service jobs at highway off-ramps** | 0.316 | 0.396 | ***0.639*** | 0.221 | 1 |

**TABLE 8.18: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS (SEMI CROSS-SECTION METHOD (STANDARDISED)).**

| **Service Jobs** | **Pre-crisis** | | | **Post-crisis** | |
|---|---|---|---|---|---|
| | N=25 | | | N=25 | |
| | $R^2$=0.483 | | | $R^2$=0.348 | |
| **Variables** | Coefficient | P-value | | Coefficient | P-value |
| **Population** | / | / | | -0.206 | 0.370 |
| **Accessibility by train** | **0.561** | **0.087** | | 0.035 | 0.876 |
| **Activity within reach by car** | **0.474** | **0.099** | | **0.909** | **0.021** |
| **Station connectivity** | -0.060 | 0.751 | | -0.151 | 0.456 |
| **Service jobs at highway off-ramps** | 0.084 | 0.737 | | 0.095 | 0.632 |
| **Constant** | -0.257 | 0.484 | | -0.307 | 0.651 |

## Train use

**TABLE 8.19: CORRELATION MATRIX PRE-CRISIS TRAIN USE DATA (STANDARDISED DIFFERENCES).**

| | Retail jobs | Service Jobs | Leisure | Population | Accessibility by train | Education places | Students in municipality | Station connectivity |
|---|---|---|---|---|---|---|---|---|
| **Retail jobs** | 1 | | | | | | | |
| **Service Jobs** | 0.327 | 1 | | | | | | |
| **Leisure** | 0.155 | -0.142 | 1 | | | | | |
| **Population** | ***0.623*** | 0.482 | -0.006 | 1 | | | | |
| **Accessibility by train** | 0.212 | ***0.590*** | -0.234 | 0.388 | 1 | | | |
| **Education places** | 0.317 | 0.427 | -0.298 | 0.323 | 0.343 | 1 | | |
| **Students in municipality** | 0.053 | ***0.501*** | -0.171 | 0.083 | ***0.513*** | -0.129 | 1 | |
| **Station connectivity** | -0.239 | 0.119 | 0.147 | 0.039 | 0.171 | 0.131 | 0.056 | 1 |

The post-crisis data did not return any cases of correlation. The correlation matrix of the pre-crisis data is shown in table 8.19 below. From the four cases of correlation there is only one case with a qualitative reason to believe that they are too related; retail jobs and population. The model with all variables however returned better results than the model with one variable removed. These model results are shown in table 8.20. It is remarkable that the pre-crisis model returns four significant variables against only significant variable in the post-crisis model. The pre-crisis model finds the number of students to be the most important variable. The relation between train use and retail and leisure jobs and population is relatively high as well. The relation between train use and retail however is found to be negative. This is not in line with expectations. The post-crisis model only finds accessibility by train to be positively correlated with train use. The $R^2$ value of the pre-crisis model is somewhat higher than the $R^2$ value of the post-crisis model.

**TABLE 8.20: MODEL RESULTS, PERFORMANCE INDICATOR: TRAIN USE (SEMI CROSS-SECTION METHOD (STANDARDISED)).**

| Train use | Pre-crisis | | Post-crisis | |
|---|---|---|---|---|
| | N=25 | | N=25 | |
| | $R^2$=0.533 | | $R^2$=0.339 | |
| **Variables** | Coefficient | P-value | Coefficient | P-value |
| **Retail jobs** | **-0.385** | **0.046** | 0.238 | 0.185 |
| **Service Jobs** | 0.119 | 0.524 | 0.168 | 0.552 |
| **Leisure** | **0.393** | **0.011** | -0.127 | 0.694 |
| **Population** | **0.411** | **0.049** | 0.169 | 0.616 |
| **Accessibility by train** | -0.405 | 0.145 | **0.532** | **0.097** |
| **Education places** | 0.219 | 0.155 | -0.010 | 0.975 |
| **Students in municipality** | **1.437** | **0.094** | -0.695 | 0.428 |
| **Station connectivity** | -0.055 | 0.722 | -0.294 | 0.278 |
| **Constant** | 0.109 | 0.876 | 0.173 | 0.905 |

## Office vacancy

The pre-crisis data of the office vacancy model returned four cases of correlation of which only two cases have a qualitative reason to assume that they are too related as well; activity within reach by car with both service jobs and population. The post-crisis model only found correlation between activity within reach by car and service jobs. After investigating the removal of variables it turned out that models explain the most variation with all variables included. Model results are shown in table 8.21. The pre-crisis model found activity within reach by car as the most important variable, while the post-crisis model finds accessibility by train as the only and most important significant variable. Both variables however, show a positive correlation with office vacancy meaning that they are assumed to contribute to office vacancy. This is not in line with the conceptual model. The pre-crisis model also found a strong and negative relation between population and office vacancy. This is in line with expectations. Both models found similar $R^2$ values, but the one of the pre-crisis model is slightly higher.

**TABLE 8.21: CORRELATION MATRIX PRE-CRISIS OFFICE VACANCY DATA (STANDARDISED DIFFERENCES).**

| | **Service Jobs** | **Population** | **Accessibility by train** | **Activity within reach by car** | **Station connectivity** | **Office stock** |
|---|---|---|---|---|---|---|
| **Service Jobs** | 1 | | | | | |
| **Population** | 0.482 | 1 | | | | |
| **Accessibility by train** | ***0.590*** | 0.388 | 1 | | | |
| **Activity within reach by car** | ***0.627*** | ***0.697*** | ***0.554*** | 1 | | |
| **Station connectivity** | 0.119 | 0.039 | 0.171 | 0.242 | 1 | |
| **Office stock** | 0.216 | 0.237 | -0.118 | 0.242 | 0.280 | 1 |

**TABLE 8.22: MODEL RESULTS, PERFORMANCE INDICATOR: OFFICE VACANCY (SEMI CROSS-SECTION METHOD (STANDARDISED)).**

| Office vacancy | Pre-crisis | | Post-crisis | |
|---|---|---|---|---|
| | N=25 | | N=25 | |
| | $R^2$=0.241 | | $R^2$=0.220 | |
| **Variables** | Coefficient | P-value | Coefficient | P-value |
| **Service jobs** | -0.153 | 0.307 | -0.148 | 0.652 |
| **Population** | **-0.288** | **0.097** | -0.150 | 0.605 |
| **Accessibility by train** | 0.087 | 0.712 | **0.454** | **0.090** |
| **Activity within reach by car** | **0.397** | **0.065** | -0.166 | 0.761 |
| **Station connectivity** | 0.009 | 0.946 | 0.070 | 0.777 |
| **Office stock** | 0.012 | 0.958 | -0.021 | 0.965 |
| **Constant** | -0.188 | 0.565 | 0.112 | 0.894 |

## 8.4 Longitudinal method

Using the longitudinal method multiple observations per analysed station area have been included. The year-to-year differences of the (standardised) data are used for this method. The data is, again, split into two models; pre- and post-crisis. Because of the use of small time steps a lag has been implemented as well: it cannot be expected that an increase in, for example, population in year x will immediately have increased train use in year x. Therefore a lag of 1 or 2 years has been implemented. The implementation of the lag is explained in more detail in section 6.1. The analyses are discussed per performance indicator. Note that the number of observations differs between the pre- and post-crisis models. This is because the pre-crisis model contains 5 years of data (2004-2008) and the post-crisis model contains 4 years of data (2009-2012).

### Retail jobs

The correlation matrix of the pre-crisis data is shown in table 8.23. It was found that the correlation between service jobs and activity within reach by car is bigger than 0.5. Because there is a qualitative reason to assume a too big relation between service jobs and activity within reach by car the analysis has been performed twice; once with service jobs and once without that variable. The post-crisis model did not return any cases of correlation. The results are shown table 8.24. Models with all variables included returned best results. Model output shows activity within reach by car as the most important variable in explaining the variation in retail jobs. The second important variable is population. The correlation found between population and retail jobs is negative, this is not in line with the conceptual model. All significant variables are found in the pre-crisis model, the post-crisis model did not return any significant variables. It is also noteworthy that the $R^2$ values of both models are relatively low. The $R^2$ value of the pre-crisis model is however much higher than the post-crisis model.

**TABLE 8.23: CORRELATION MATRIX PRE-CRISIS RETAIL JOBS PANEL DATA (STANDARDISED YEAR-TO-YEAR DIFFERENCES).**

| | Service jobs | Population | Accessibility by train | Activity within reach by car | Station connectivity |
|---|---|---|---|---|---|
| **Service jobs** | 1 | | | | |
| **Population** | 0.036 | 1 | | | |
| **Accessibility by train** | 0.079 | 0.259 | 1 | | |
| **Activity within reach by car** | ***0.550*** | 0.169 | 0.125 | 1 | |
| **Station connectivity** | 0.199 | -0.120 | -0.037 | 0.070 | 1 |

**TABLE 8.24: MODEL RESULTS, PERFORMANCE INDICATOR: RETAIL JOBS (LONGITUDINAL METHOD).**

| **Retail jobs** | **Pre-crisis** | | | **Post-crisis** | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | $R^2$= 0.075 | | | $R^2$= 0.013 | |
| **Variable** | Coefficient | P-value | | Coefficient | P-value |
| **Service jobs** | -0,127 | 0,273 | | 0,043 | 0,724 |
| **Population** | **-0,351** | **0,052** | | 0,025 | 0,889 |
| **Accessibility by train** | 0,168 | 0,438 | | 0,122 | 0,530 |
| **Activity within reach by car** | **0,452** | **0,014** | | 0,145 | 0,572 |
| **Station connectivity** | 0,063 | 0,607 | | -0,013 | 0,894 |
| **Constant** | -0,060 | 0,451 | | -0,332 | 0,018 |

### Service jobs

Both the pre- and post-crisis data did not contain any cases of correlating variables. Model results are shown in table 8.25 below. Both models have a relative low $R^2$ value, the value of the pre-crisis model is however much higher than that of the post-crisis value. The post-crisis model did also not return any significant variables. The pre-crisis model did return three significant variables. Activity within reach by car was found to be the most important variable explaining the variation in development in service jobs. The correlation between service jobs and station connectivity was found to be relatively modest. The third relation was found between service jobs and service jobs at highway off-ramps and is relatively modest as well. This relation was found to be negative, which is in line with expectations. The sign of the other two significant variables is in line with expectations as well.

**TABLE 8.25: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS (LONGITUDINAL METHOD).**

| Service jobs | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | $R^2$= 0.139 | | | $R^2$= 0.045 | |
| **Variable** | Coefficient | P-value | | Coefficient | P-value |
| **Population** | -0,204 | 0,199 | | -0,127 | 0,428 |
| **Accessibility by train** | 0,029 | 0,878 | | 0,091 | 0,629 |
| **Activity within reach by car** | **0,482** | **0,001** | | -0,167 | 0,463 |
| **Station connectivity** | **0,169** | **0,055** | | -0,163 | 0,140 |
| **Service jobs at highway off-ramps** | **-0,170** | **0,031** | | -0,059 | 0,601 |
| **Constant** | 0,055 | 0,460 | | 0,051 | 0,685 |

## Train use

The pre- and post-crisis dataset used for the longitudinal train use model do not contain any cases of correlation. The model output is shown in table 8.26. Both models show again a relatively low $R^2$ value and the value of the pre-crisis model is slightly higher than the value of the post-crisis model. The post-crisis model did not return any significant variables and the pre-crisis model did only return one significant variable: population. A positive relation was found between train use and population.

**TABLE 8.26: MODEL RESULTS, PERFORMANCE INDICATOR: TRAIN USE (LONGITUDINAL METHOD).**

| Train use | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | $R^2$= 0.071 | | | $R^2$= 0.062 | |
| **Variable** | Coefficient | P-value | | Coefficient | P-value |
| **Retail jobs** | 0,006 | 0,922 | | -0,083 | 0,553 |
| **Service jobs** | 0,020 | 0,764 | | 0,095 | 0,482 |
| **Leisure** | -0,076 | 0,268 | | 0,108 | 0,420 |
| **Population** | **0,243** | **0,035** | | -0,102 | 0,588 |
| **Accessibility by train** | 0,177 | 0,244 | | 0,307 | 0,175 |
| **Education places** | -0,032 | 0,555 | | 0,139 | 0,270 |
| **Students in municipality** | -0,136 | 0,566 | | 0,019 | 0,969 |
| **Station connectivity** | -0,024 | 0,729 | | 0,081 | 0,562 |
| **Constant** | 0,302 | 0,000 | | -0,030 | 0,870 |

## Office vacancy

The correlation matrix of the pre-crisis dataset is shown in table 8.27 and shows one case of correlation. The post-crisis data did not return any cases of correlation. The pre-crisis correlation matrix indicates correlation between activity within reach by car and service jobs. After investigating removal of variables models returned best results with all variables included. Model output is shown in table 8.28. Both models show relatively low $R^2$ values, but this time the post-crisis model has the higher value and returned the most significant variables. The post-crisis model found accessibility by train to be the most important variable. The relation between office vacancy and accessibility by train however is positive. This is not in line with the conceptual model meaning that it assumes that accessibility by train contributes to office vacancy. Both models found a relatively strong correlation between office vacancy and office stock. This relation was found to be positive as well, which is in line with the conceptual model.

**TABLE 8.27: CORRELATION MATRIX PRE-CRISIS OFFICE VACANCY PANEL DATA (STANDARDISED YEAR-TO-YEAR DIFFERENCES).**

| | Service jobs | Population | Accessibility by train | Activity within reach by car | Station connectivity | Office stock |
|---|---|---|---|---|---|---|
| **Service jobs** | 1 | | | | | |
| **Population** | 0.006 | 1 | | | | |
| **Accessibility by train** | 0.079 | 0.151 | 1 | | | |
| **Activity within reach by car** | ***0.549*** | 0.007 | 0.125 | 1 | | |
| **Station connectivity** | 0.199 | 0.049 | -0.037 | 0.070 | 1 | |
| **Office stock** | -0.014 | 0.160 | -0.068 | -0.063 | -0.057 | 1 |

**TABLE 8.28: MODEL RESULTS, PERFORMANCE INDICATOR: OFFICE VACANCY (LONGITUDINAL METHOD).**

| **Office vacancy** | **Pre-crisis** | | | **Post-crisis** | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | $R^2$= 0.054 | | | $R^2$= 0.120 | |
| **Variable** | Coefficient | P-value | | Coefficient | P-value |
| **Service jobs** | 0,153 | 0,133 | | -0,075 | 0,470 |
| **Population** | 0,031 | 0,834 | | -0,116 | 0,386 |
| **Accessibility by train** | 0,031 | 0,870 | | **0,306** | **0,054** |
| **Activity within reach by car** | -0,138 | 0,385 | | -0,256 | 0,239 |
| **Station connectivity** | 0,031 | 0,771 | | 0,071 | 0,404 |
| **Office stock** | **0,249** | **0,059** | | **0,211** | **0,052** |
| **Constant** | 0,147 | 0,049 | | 0,077 | 0,513 |

## 8.5 Longitudinal method (fixed effects)

The last analyses expand the longitudinal method with fixed effects. A fixed effects model is explained in detail in section 6.1. The used datasets are similar to the datasets used for the longitudinal method without fixed effects. The correlation matrices of these datasets are already discussed in the previous section and will not be discussed again. The model results are discussed per performance indicator.

### Retail jobs

The post-crisis model returns a very low $R^2$ value and the value of the pre-crisis model is relatively low as well. Only the pre-crisis model returns significant variables. Population was found to be the most important variable in explaining retail. However, the found relation between retail jobs and population is negative which is not in line with what was expected. The same holds for the service jobs variable which was found to be relatively strong and negatively correlated with retail jobs. These negative relations can probably be explained by the fact that the development of one activity happened at the expense of another. This caused by the fact that most station areas of the analysed station are already built-up. The last significant variable found was activity within reach by car. This variable is positively correlated with retail jobs and also relatively important.

**TABLE 8.29: MODEL RESULTS, PERFORMANCE INDICATOR: RETAIL JOBS (LONGITUDINAL METHOD (FIXED EFFECTS)).**

| **Retail jobs** | **Pre-crisis** | | | **Post-crisis** | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | R2= 0.124 | | | R2= 0.013 | |
| **Variable** | Coefficient | P-value | | Coefficient | P-value |
| **Service jobs** | **-0.212** | **0.100** | | -0.061 | 0.634 |
| **Population** | **-0.680** | **0.003** | | 0.057 | 0.752 |
| **Accessibility by train** | 0.183 | 0.493 | | 0.074 | 0.711 |
| **Activity within reach by car** | **0.416** | **0.039** | | 0.004 | 0.989 |
| **Station connectivity** | 0.056 | 0.675 | | -0.052 | 0.599 |
| **Constant** | -0.067 | 0.422 | | -0.276 | 0.052 |

## Service jobs

The $R^2$ value of both models are relatively low and the pre-crisis model returns a higher value than the post-crisis model. The post-crisis model, again, does not return any significant variables. The pre-crisis model returns four significant variables. Population and activity within reach by car are found to be relatively strong correlated with service jobs. Population, however, was found to be negatively correlated with service jobs. This is not in line with the conceptual model. Station connectivity and service jobs at highway off-ramps are found to be relatively modest correlated with service jobs. The signs of both those variables are in line with expectations.

**TABLE 8.30: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS (LONGITUDINAL METHOD (FIXED EFFECTS)).**

| Service jobs | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | $R^2$= 0.136 | | | $R^2$= 0.046 | |
| **Variable** | Coefficient | P-value | | Coefficient | P-value |
| **Population** | **-0.415** | **0.046** | | -0.047 | 0.799 |
| **Accessibility by train** | -0.080 | 0.706 | | 0.030 | 0.886 |
| **Activity within reach by car** | **0.438** | **0.005** | | -0.164 | 0.504 |
| **Station connectivity** | **0.181** | **0.059** | | -0.180 | 0.162 |
| **Service jobs at highway off-ramps** | **-0.141** | **0.092** | | -0.048 | 0.699 |
| **Constant** | 0.058 | 0.456 | | 0.042 | 0.758 |

## Train use

It is noteworthy that for the train use model the post-crisis model returned the higher $R^2$ value. Both values however are relatively low. The pre-crisis model returns two significant variables positively correlated with train use: population and accessibility by train. The post-crisis model has found education places to be positively correlated with train use. All three significant variables are found to be relatively important in explaining the variation in development in train use. The found signs of all significant variables are in line with the conceptual model.

**TABLE 8.31: MODEL RESULTS, PERFORMANCE INDICATOR: TRAIN USE (LONGITUDINAL METHOD (FIXED EFFECTS)).**

| Train use | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | $R^2$= 0.081 | | | $R^2$= 0.122 | |
| **Variable** | Coefficient | P-value | | Coefficient | P-value |
| **Retail jobs** | 0.003 | 0.962 | | -0.176 | 0.252 |
| **Service jobs** | 0.002 | 0.981 | | 0.114 | 0.460 |
| **Leisure** | -0.083 | 0.281 | | 0.108 | 0.502 |
| **Population** | **0.262** | **0.076** | | -0.085 | 0.694 |
| **Accessibility by train** | **0.359** | **0.082** | | 0.219 | 0.398 |
| **Education places** | -0.035 | 0.561 | | **0.281** | **0.062** |
| **Students in municipality** | -0.345 | 0.251 | | 0.177 | 0.758 |
| **Station connectivity** | -0.067 | 0.386 | | 0.160 | 0.323 |
| **Constant** | 0.347 | 0.000 | | -0.081 | 0.685 |

## Office vacancy

The pre-crisis model returns two significant variables while the post-crisis model returns one significant variable. Both models return office stock as an important variable in explaining office vacancy. The found relation is positive which is in line with expectations. The pre-crisis model also found a negative correlation between service jobs and office vacancy. This found correlation is also relatively strong, but not in line with expectations. Both models also return a relatively low $R^2$ value.

TABLE 8.32: MODEL RESULTS, PERFORMANCE INDICATOR: OFFICE VACANCY (LONGITUDINAL METHOD (FIXED EFFECTS)).

| Office vacancy | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=125 | | | N=100 | |
| | $R^2$= 0.083 | | | $R^2$= 0.144 | |
| Variable | Coefficient | P-value | | Coefficient | P-value |
| Service jobs | **0.203** | **0.092** | | 0.036 | 0.762 |
| Population | 0.217 | 0.269 | | 0.043 | 0.775 |
| Accessibility by train | 0.025 | 0.918 | | 0.229 | 0.193 |
| Activity within reach by car | -0.106 | 0.569 | | -0.388 | 0.112 |
| Station connectivity | 0.017 | 0.892 | | 0.122 | 0.194 |
| Office stock | **0.254** | **0.090** | | **0.200** | **0.082** |
| Constant | 0.134 | 0.109 | | 0.109 | 0.391 |

## 8.6 IC-stations vs Multimodal stations

In order to investigate whether or not there is a difference between which variables influence IC-stations and multimodal stations the cross-section and longitudinal (with fixed effects) analyses have been performed again with a distinction between IC-stations and multimodal stations. This has only been done for the service jobs performance indicator. Model results are shown tables 8.33 to 8.36 below.

For the cross-section model no differences between IC and multimodal station are found. $R^2$ values are comparable and all models return one variable to be significantly correlated with service jobs; population. All models return that population is positively correlated with service jobs. The longitudinal method with fixed effects do return different results. The model containing the IC-stations explains far less variation in service jobs than the model containing multimodal stations. This is reflected in both the $R^2$ values and the number of significant variables found. It is remarkable however, that some significant variables returned by the model containing multimodal stations are not in line with the conceptual model.

TABLE 8.33: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS, IC-STATIONS ONLY (CROSS-SECTION METHOD).

| Service Jobs (IC-stations) | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=14 | | | N=14 | | | N=14 | |
| | $R^2$=0.745 | | | $R^2$=0.670 | | | $R^2$=0.698 | |
| Variables | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| Population | **0,178** | **0,031** | | **0,128** | **0,086** | | **0,139** | **0,064** |
| Accessibility by train | -0,002 | 0,854 | | -0.000 | 0,999 | | -0,001 | 0,959 |
| Activity within reach by car | 0,005 | 0,556 | | 0,001 | 0,938 | | -0,001 | 0,914 |
| Service jobs at highway off-ramps | -0,010 | 0,878 | | 0,044 | 0,425 | | 0,044 | 0,428 |
| Constant | -6544,775 | 0,559 | | -1667,610 | 0,880 | | -1535,743 | 0,890 |

TABLE 8.34: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS, MULTIMODAL STATION ONLY (CROSS-SECTION METHOD).

| Service Jobs (Multimodal stations) | 2004 | | | 2008 | | | 2012 | |
|---|---|---|---|---|---|---|---|---|
| | N=11 | | | N=11 | | | N=11 | |
| | $R^2$=0.659 | | | $R^2$=0.698 | | | $R^2$=0.656 | |
| Variables | Coefficient | P-value | | Coefficient | P-value | | Coefficient | P-value |
| Population | **0,184** | **0,041** | | **0,186** | **0,030** | | **0,177** | **0,039** |
| Accessibility by train | 0,009 | 0,373 | | 0,008 | 0,351 | | 0,006 | 0,505 |
| Activity within reach by car | 0,004 | 0,788 | | 0,003 | 0,835 | | 0,003 | 0,835 |
| Service jobs at highway off-ramps | -0,020 | 0,769 | | 0,011 | 0,824 | | 0,017 | 0,768 |
| Constant | -19182,665 | 0,214 | | -19755,193 | 0,174 | | -17668,184 | 0,246 |

TABLE 8.35: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS, IC-STATIONS ONLY (LONGITUDINAL METHOD (FIXED EFFECTS)).

| Service jobs (IC-stations) | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=70 | | | N=56 | |
| | $R^2$= 0.062 | | | $R^2$= 0.139 | |
| Variable | Coefficient | P-value | | Coefficient | P-value |
| Population | 0.117 | 0.648 | | **0.638** | **0.036** |
| Accessibility by train | -0.007 | 0.975 | | -0.215 | 0.427 |
| Activity within reach by car | 0.013 | 0.952 | | 0.108 | 0.781 |
| Station connectivity | 0.036 | 0.743 | | -0.111 | 0.541 |
| Service jobs at highway off-ramps | -0.164 | 0.121 | | -0.147 | 0.425 |
| Constant | 0.194 | 0.053 | | -0.220 | 0.247 |

TABLE 8.36: MODEL RESULTS, PERFORMANCE INDICATOR: SERVICE JOBS, MULTIMODAL STATIONS ONLY (LONGITUDINAL METHOD (FIXED EFFECTS)).

| Service jobs (Multimodal stations) | Pre-crisis | | | Post-crisis | |
|---|---|---|---|---|---|
| | N=55 | | | N=44 | |
| | $R^2$= 0.399 | | | $R^2$= 0.351 | |
| Variable | Coefficient | P-value | | Coefficient | P-value |
| Population | **-0.846** | **0.011** | | **-0.572** | **0.010** |
| Accessibility by train | **-0.758** | **0.070** | | 0.475 | 0.166 |
| Activity within reach by car | **0.779** | **0.001** | | -0.135 | 0.651 |
| Station connectivity | **0.342** | **0.039** | | **-0.488** | **0.009** |
| Service jobs at highway off-ramps | -0.060 | 0.632 | | 0.120 | 0.443 |
| Constant | -0.037 | 0.751 | | 0.146 | 0.414 |

# 9 Conclusion and Discussion

## 9.1 Conclusion

This research has a twofold research goal which are repeated below. The conclusion is organized based on the twofold goal. First the cross-section method, longitudinal method and all intermediate steps are discussed that have been used to find land-use transport interactions in station areas. This part focusses on the methodology used. The second part discusses the found results using the different methods. This part focusses on implications for future policy. The goal of this study is to:

I. ***Investigate land-use transport interactions for station areas using a longitudinal research method in comparison to the more conventional cross-section approach.***
II. ***Determine which factors, adaptable by local policymakers, influence the changes in the performance of station areas.***

### Methodology

With several intermediate steps, a cross-section research method has been turned into a longitudinal research method with fixed effects. In this way the change in results can be allocated to a certain theoretical improvement of the model. Finally, the results of both methods can compared. Tables 9.1 to 9.5 show a summary of all model results. Only significant variables are shown. Significant variables that did return an unexpected relation are shown in italic. Note that results in table 9.2 to 9.5 (with standardised data) can reflect the importance of an explanatory variable based on its regression coefficient (a higher coefficient means a stronger relation found).

Analysing the model results it becomes clear that the longitudinal methods return different results than the cross-section methods. This is expressed in both the $R^2$ values as the significant variables found. The longitudinal method consistently returns lower $R^2$ values than the cross-section method. This means that these models explained less variation than the cross-section models. The found $R^2$ values of the longitudinal method are considered to be very low. This means that the year-to-year differences of explanatory variables in the domain of spatial planning and transport are not very suitable to explain the year-to-year differences of the performance indicators. This implies that changing the explanatory variables, through policy, one should not expect changes in the performance indicators on the short term. This implication is founded by the findings of the semi cross-section model where development over four and five years in explanatory variables and performance indicators was analysed. These models found, in comparison to the longitudinal models, relative high $R^2$ values comparable to the cross-section methods. This also supports that the found differences between cross-section and longitudinal research methods are not caused by the difference in data input (absolute data vs. variation of data). In other words: there are relationships between the performance indicators and the explanatory variables, but they take time to surface.

TABLE 9.1: MODEL RESULTS CROSS-SECTION RESEARCH METHOD.

| Cross-section | | Model results | | |
|---|---|---|---|---|
| **Performance indicator** | Significant variables | 2004 | 2008 | 2012 |
| **Retail jobs** | **$R^2$** | **0.649** | **0.556** | **0.553** |
| | Population+service jobs | 0.041 | 0.041 | 0.037 |
| **Service jobs** | **$R^2$** | **0.685** | **0.649** | **0.653** |
| | Population | 0.160 | 0.141 | 0.145 |
| **Train use** | **$R^2$** | **0.806** | **0.761** | **0.783** |
| | Urban intensity | 0.232 | 0.241 | 0.233 |
| | Accessibility by train | *-0.044* | / | / |
| | Station connectivity | 3900.786 | 3453.908 | 3686.163 |
| **Office vacancy** | **$R^2$** | **0.340** | **0.536** | **0.729** |
| | *Activity within reach by car* | *0.055* | *0.074* | / |
| | Office stock | / | 0.061 | 0.101 |

Another distinction is found in the different models per research methodology. The 2004, 2008, and 2012 cross-section models all consistently return the same variables to be significant. In addition, the $R^2$ values are comparable as well. Only the office vacancy performance indicator is an exception with a different $R^2$ value for the 2004 model and different significant variables. The longitudinal method with fixed effects clearly shows a distinction between the pre- and post-crisis models. Pre-crisis models return several significant variables, while post-crisis model return almost none significant variables. In addition, the retail and service jobs performance indicators differ again from the train use and office vacancy performance indicators. For retail and service jobs, the post-crisis models return much lower $R^2$ values and no significant variables. The train use and office vacancy indicators show higher $R^2$ values for the post-crisis models. It is remarkable that the longitudinal results show a clear distinction in pre-crisis and post-crisis results, while the cross-section model consistently returns similar results. Based on the used data (see chapter 7) it is clear that the financial crisis of 2008 has had an effect on several economic-related spatial developments such as retail and service jobs and office vacancy within the station area. This is reflected in the clear change of trend of those variables. The cross-section method does not reflect the influence of the 2008 financial crisis because it shows the relation between, for example, the presence of retail and the presence of population. Even after the crisis locations with a higher number of inhabitants will have a higher amount of retail (jobs) than locations with a lower number of inhabitants. Hence, cross-section research might lead to overestimation of effects by readers due to the found relations between explanatory variables and performance indicators in times of economic decline. Longitudinal research using year-to-year differences make clear that during economic recession accessibility measures cannot explain variation in the performance indicators. This is clearly reflected by the lack of significant variables found in the post-crisis models. During economic recession, other factors (some of them are discussed in section 4.4) are more important.

**TABLE 9.2: MODEL RESULTS CROSS-SECTION (STANDARDISED) RESEARCH METHOD.**

| Cross-section (standardised) | | Model results | | |
|---|---|---|---|---|
| **Performance indicator** | Significant variables | 2004 | 2008 | 2012 |
| **Retail jobs** | **$R^2$** | **0.649** | **0.556** | **0.553** |
| | Population+service jobs | 0.789 | 0.741 | 0.716 |
| **Service jobs** | **$R^2$** | **0.685** | **0.649** | **0.653** |
| | Population | 0.699 | 0.645 | 0.676 |
| **Train use** | **$R^2$** | **0.806** | **0.761** | **0.783** |
| | Urban intensity | 0.471 | 0.422 | 0.431 |
| | Accessibility by train | *-0.427* | / | / |
| | Station connectivity | 1.093 | 0.869 | 0.999 |
| **Office vacancy** | **$R^2$** | **0.340** | **0.536** | **0.729** |
| | Activity within reach by car | *0.409* | *0.475* | / |
| | Office stock | / | 0.639 | 0.928 |

**TABLE 9.3: MODEL RESULTS SEMI CROSS-SECTION RESEARCH METHOD.**

| Semi Cross-section | | Model results | |
|---|---|---|---|
| **Performance indicator** | Significant variables | Pre-crisis | Post-crisis |
| **Retail jobs** | **$R^2$** | **0.560** | **0.578** |
| | Activity within reach by car | 0.617 | 2.345 |
| | Station connectivity | *-0.393* | / |
| **Service jobs** | **$R^2$** | **0.483** | **0.348** |
| | Accessibility by train | 0.561 | / |
| | Activity within reach by car | 0.474 | 0.909 |
| **Train use** | **$R^2$** | **0.533** | **0.339** |
| | Retail jobs | *-0.385* | |
| | Leisure | 0.393 | |
| | Population | 0.411 | |
| | Accessibility by train | / | 0.532 |
| | Students in municipality | 1.437 | |
| **Office vacancy** | **$R^2$** | **0.241** | **0.220** |
| | Population | -0.288 | / |
| | Accessibility by train | / | 0.*454* |

| | | | |
|---|---|---|---|
| | Activity within reach by car | *0.397* | / |

The intermediate steps make clear that standardization of data does not have an influence on model results, except for regression coefficients. Model output of step 1 (cross-section) and step 2 (standardised cross-section) is, with the exception of the regression coefficients, the same. Between step 3 (semi cross-section) and step 2 a clear difference can be seen. Although $R^2$ values are similar, step 3 returns different significant variables than step 1 and 2. This can be allocated to the fact that in step 3 the development in variables is analysed instead of absolute values. $R^2$ values in model output of step are still relatively high, but consistently lower than in step 1 and 2. $R^2$ values significantly drop after step 3. In step 4 (longitudinal method) year-to-year differences are used for the first time. This extra portion of variation could not be explained with the explanatory variables. The significant variables found in model output of step 4 are comparable to model output of step 3. Model output of step 4 is also very comparable to model output of step 5 (longitudinal method with fixed effects). It seems that the fixed effects model hardly had an influence on model output of step 4. Hence the added value of a fixed effects model seems not to be present based on results of this study. However, this does not mean fixed effects should not be used in this type of research. The added value of a fixed effect model is explained in section 6.1. The fact the models with and without fixed effects return similar results simply mean that in this case the pooled data was not misinterpret in the first place. This research study investigated land-use transport interactions (Luti) in station areas with different research methodologies, but the same dataset. The study makes clear that choice of research methodology has a direct effect on found results. It underpins the assumption in chapter 2 that the differences in Luti results are caused by the different research methods used in the different studies. Assuming that, due to its characteristics, longitudinal research is more appropriate to investigate how the performance indicators can be influenced, it can be concluded that relations in Luti are not as strong as often thought.

**TABLE 9.4: MODEL RESULTS LONGITUDINAL RESEARCH METHOD.**

| **Longitudinal** | | **Model results** | |
|---|---|---|---|
| **Performance indicator** | Significant variables | Pre-crisis | Post-crisis |
| **Retail jobs** | **$R^2$** | **0.075** | **0.013** |
| | Population | *-0.351* | / |
| | Activity within reach by car | 0.452 | / |
| **Service jobs** | **$R^2$** | **0.139** | **0.045** |
| | Activity within reach by car | 0.482 | / |
| | Station connectivity | 0.169 | / |
| | Service jobs at highway off-ramps | -0.170 | / |
| **Train use** | **$R^2$** | **0.071** | **0.062** |
| | Population | 0.243 | / |
| **Office vacancy** | **$R^2$** | **0.054** | **0.120** |
| | Accessibility by train | / | 0.306 |
| | Office stock | 0.249 | 0.211 |

**TABLE 9.5: MODEL RESULTS LONGITUDINAL (FIXED EFFECTS) RESEARCH METHOD.**

| **Longitudinal (fixed effects)** | | **Model results** | |
|---|---|---|---|
| **Performance indicator** | Significant variables | Pre-crisis | Post-crisis |
| **Retail jobs** | $R^2$ | 0.124 | 0.013 |
| | Service jobs | *-0.212* | / |
| | Population | *-0.680* | / |
| | Activity within reach by car | 0.416 | / |
| **Service jobs** | $R^2$ | 0.136 | 0.046 |
| | Population | *-0.415* | / |
| | Activity within reach by car | 0.438 | / |
| | Station connectivity | 0.181 | / |
| | Service jobs at highway off-ramps | -0.141 | / |
| **Train use** | $R^2$ | 0.081 | 0.122 |
| | Population | 0.262 | / |
| | Accessibility by train | 0.359 | / |
| | Education places | / | 0.281 |
| **Office vacancy** | $R^2$ | 0.083 | 0.144 |

| | | | |
|---|---|---|---|
| | Service jobs | 0.*203* | / |
| | Office stock | 0.254 | 0.200 |

## Significant variables

This second part of the conclusion focusses on the found results running the different models. The results will be discussed per performance indicator starting with retail and service jobs. A clear distinction can be found between the significant variables in model output of step 1 and 2 (cross-section) and the model output of step 3, 4, and 5 (semi cross-section and longitudinal). The cross-section methods found a strong and positive relation between different forms of land-use. The cross-section methods returned population to be positively related to both retail and service jobs. Service jobs was also found to be positively related to retail jobs. The longitudinal methods found the same relations, but negative. The reason for this distinction can be found in the data used. The cross-section method uses absolute data and found a relation between the presence of population, retail and service jobs. Using the longitudinal method, the development of those variables was analysed. Most analysed station areas do not have a lot of space left for development. Hence, development of one activity (population, retail or service jobs) will probably happen at the expense of another activity. The longitudinal methods (and the semi cross-section) found a positive relation between transport and retail and service jobs (in the pre-crisis models, the post-crisis models found no significant relations). Examples are the positive relations found of accessibility by train, activity within reach by car and station connectivity on retail and service jobs. Especially activity within reach by car was consistently found as significant. However, based on the $R^2$ values of the longitudinal models, it should be pointed out that these relations are not very strong. This is also reflected in the place-node model of Bertolini (1999) discussed in section 7.1. From the place-node model it becomes clear that, over the years, node value of stations has increased significantly. However, the place value of the analysed stations have increased much less. Some station areas even experienced a decline in place value. Implications for policy are that policymakers should not have too high expectations of boosting (economic) development by increasing accessibility levels. Although the model results underpin that there is a relation between increased accessibility and (economic) development, these relations are only modest. The difference in development of node and place value can be explained by the fact that node value is mainly influenced by (local) government. In line with their ambitions, accessibility levels of station areas have been increased (Atelier Zuidvleugel, 2006; Deltametropool, 2013; Ministerie I&M, 2012). Developing those station areas is mainly done by private companies and investors. The development of (retail and service) jobs in the past decade has occurred at other locations than station areas (PBL, 2014). This is supported by model outcome: a negative relation was found between the development of service jobs in station areas and the development of service jobs at highway off-ramps. Due to the fact that demand for offices and service jobs is limited, the development of service jobs at highway off-ramps has had a negative effect on the development of service jobs in station areas. Hence, another implication for policy is that if one has the ambition to develop its station area, scarcity should be created by limiting offices to locate at other locations.

For the train use performance indicator cross-section research consistently found a positive relation with urban intensity and station connectivity. Here, urban intensity was a combined variable consisting of retail, leisure and service jobs, population and education places. These variables were combined due to high mutual correlation. These results mean that train use is higher at station located in high dens neighbourhoods and a high station connectivity (train frequency, direct connections and stations within reach) than at locations with low dens neighbourhoods and station connectivity. Analysing the relation between the variation in train use and the explanatory variables, only population of the station area was found to be consistently correlated with train use in a positive way. Other variables that were found to have a positive relation with the variation in trains use are accessibility by train, education places and the number of students in de municipality. These results imply that train use can be influenced by increasing demand at the origin side of train trips (population of station area and students). That accessibility by train has a positive relation is perfectly in line with the principles of TOD and Cervero & Ewing's two D's: distance to transit and destination accessibility.

For the office vacancy models it is remarkable that both the cross-section methods as the longitudinal methods consistently returned office stock to be positively correlated with office vacancy. However, that this variable is found to be an important factor in explaining office vacancy is not a surprise. The importance of this factor was already recognized by Geurs, Koster & de Visser (2013). It makes clear that the number of $m^2$ of office space constructed was not in line with the demand for office space. That the models also consistently return a positive relation between both activity within reach by car and accessibility by train and office vacancy seems illogical, but is perfectly explainable. The increase of activity within reach by car and accessibility by train imply an increase in general accessibility levels and therefore agglomeration effects. The theoretical framework suggests that this will have a positive effect on demand for (economic) spatial developments. However, the increased accessibility levels also increase competition between locations. In combination with the oversupply of office space this has led to high levels of office vacancy.

The oversupply of office space implies that in future policy the construction of new office space should be restricted. Focus should be on (re)developing existing, vacant, office space in order to cope with the high vacancy levels. The found relation between improved accessibility and increasing vacancy supports the aforementioned implication that scarcity should be created. Demand for development is too low to development all currently available locations (hence the high vacancy levels), therefore clear choices have to be made to decide which locations to develop and which not.

### IC-stations vs Multimodal stations

To assess whether or not there is a difference between IC and multimodal stations the service jobs performance indicator was analysed again using the cross-section and longitudinal method with fixed effects. For this assessment the used dataset was split into one containing all IC-stations and one containing all multimodal stations. The cross-section models do not show any differences between IC and multimodal stations. Both the $R^2$ values as the returned significant variables are similar. All cross-section models returned a positive relation between service jobs and population, this relation was also found in the models containing all stations. The longitudinal method did return a clear distinction between IC and multimodal stations. The model containing only IC-stations did hardly explain any variation and returned only one significant variable. The model containing only multimodal stations returned much higher $R^2$ values and multiple significant variables. However, most significant variables returned by the model containing only multimodal stations are not in line with expectations. A negative correlation between service jobs and population at multimodal stations might be explained by the fact that at those locations development of service jobs has occurred at the expense of housing. The negative relation with accessibility by train seems to imply that public transport is less important at those locations. However, it can also be explained that an increased accessibility by train means more competition with other station areas. In the post-crisis model the negative relation between station connectivity and service jobs can probably be explained by the fact that station connectivity, generally, kept increasing due to government efforts while the number of service jobs decreased due to the financial crisis. Based on the longitudinal models, the variation in service jobs is better explained at multimodal locations than at IC locations. This seems to imply that (spatial development at) multimodal locations is more sensitive to accessibility measures than IC-locations.

## 9.2 Discussion

This section reflects on this research and discusses the used methodology.

First point of reflection is the used model. The used model was linear. This choice was a result of the fact that there was a great variety in explanatory variables. Therefore the type of relation between all variables was unknown and a linear model is the most common model to use in such a situation. More research is needed to get a better insight in the relation between the different explanatory variables. The use of models with the correct relation between variables will make model outcomes more accurate and veracious. Especially for the longitudinal method a better model might increase the amount of variation explained.

It was found that the (semi) cross-section methods consistently led to higher $R^2$ values and this is probably also the result of the used time steps in this research. The longitudinal method, using year-to-year differences, contains a significant extra amount of variation due to the big increase of observations per analysed station. It is assumable that the year-to-year variation of the performance indicators is a result of numerous other factors (see chapter 4.2) as well that this variation cannot be explained by the proposed set of explanatory variables. For future research it might be interesting to increase the time steps to two or three years. This was unfortunately not possible with the dataset used in this research as it would lead to an unbalanced situation between the number of observations and variables to be explained. However, the size of the dataset used was not a result of choice, but a result of available data. Hence, it will not be possible to imply this research improvement within the next few years.

One should also note that there are many factors in real life that will influence the performance indicators researched in this study. From this broad context of factors only the factors from the spatial planning and transport domain that can be influenced by local policy makers are used to explain the variation of the four performance indicators over time. An overview of this context is visualized in chapter 4.2. The reader should have it clear that there are many more variables than the variables discussed in this research that will influence the performance of station areas as defined in this research.

Although data collection has high priority in the Netherlands, collecting good year-to-year data for all variables in this research was not possible without some assumptions. For example, Activity within reach by car data actually consists of proximity data of jobs and population subject to a distance-decay curve to incorporate travel times. This assumes that car travel times have not changed within the considered time period, while this might be an important factor in explaining certain variation. However, year-to-year traffic models are not available, thus this data could not be collected more precisely. Another example is the available data for train use. The collection method of the NS, as explained before, results in the train use data to have random variation that cannot be explained by real world events. This makes this data less usable for year-to-year analysis. With the implementation of the OV-chipkaart better train use data will become available, as all train trips will be digitally registered.

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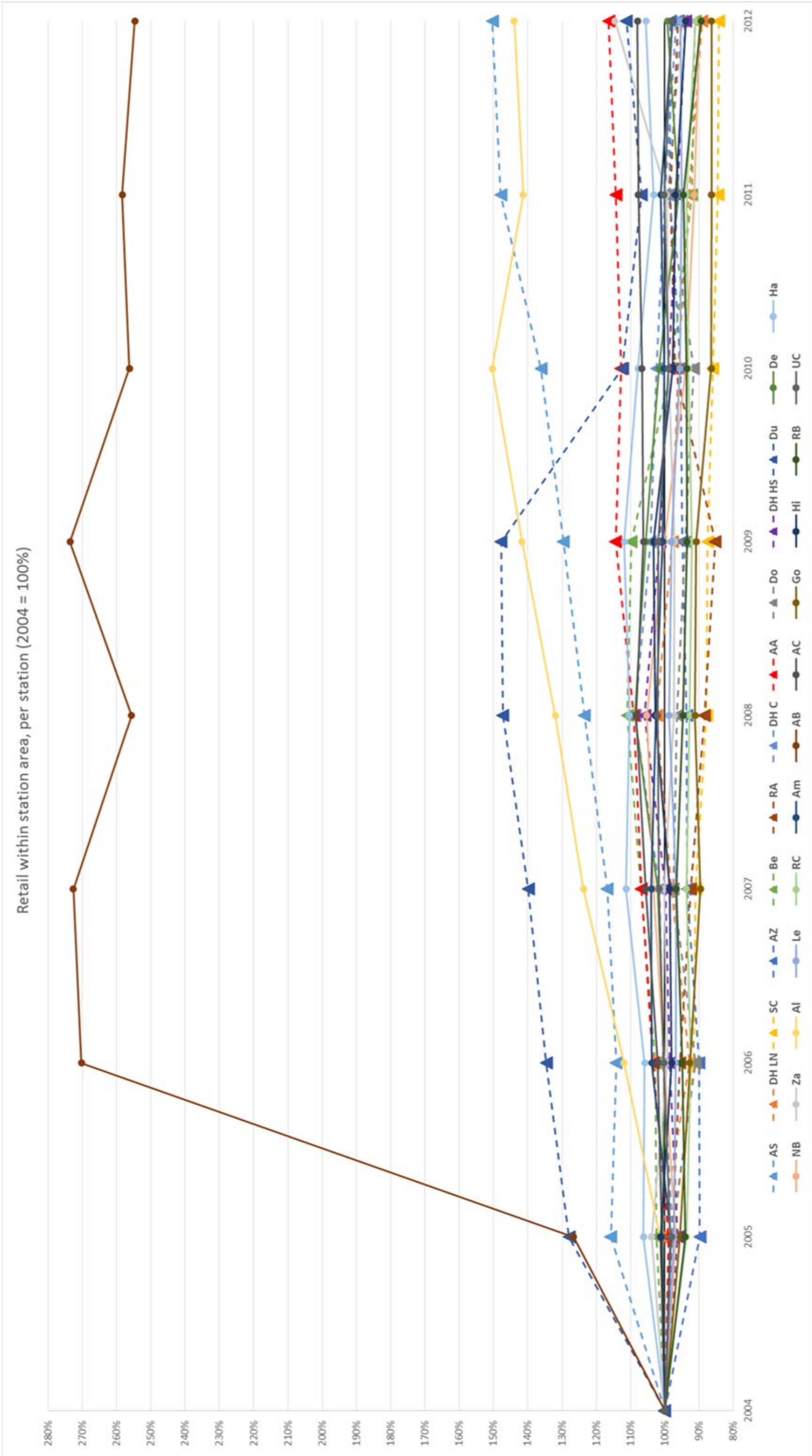
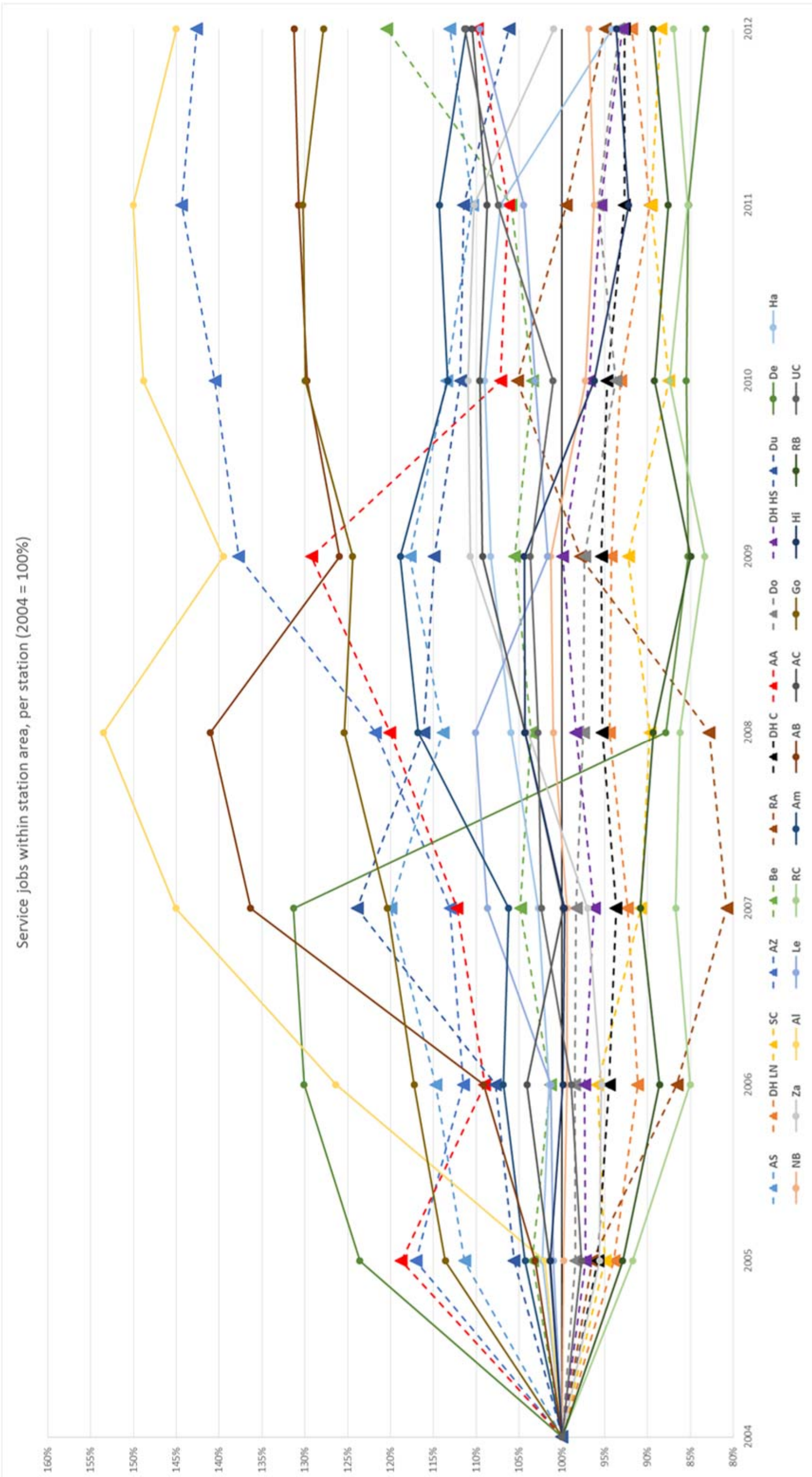
# Appendix A: Descriptive Analysis –data per station per variable

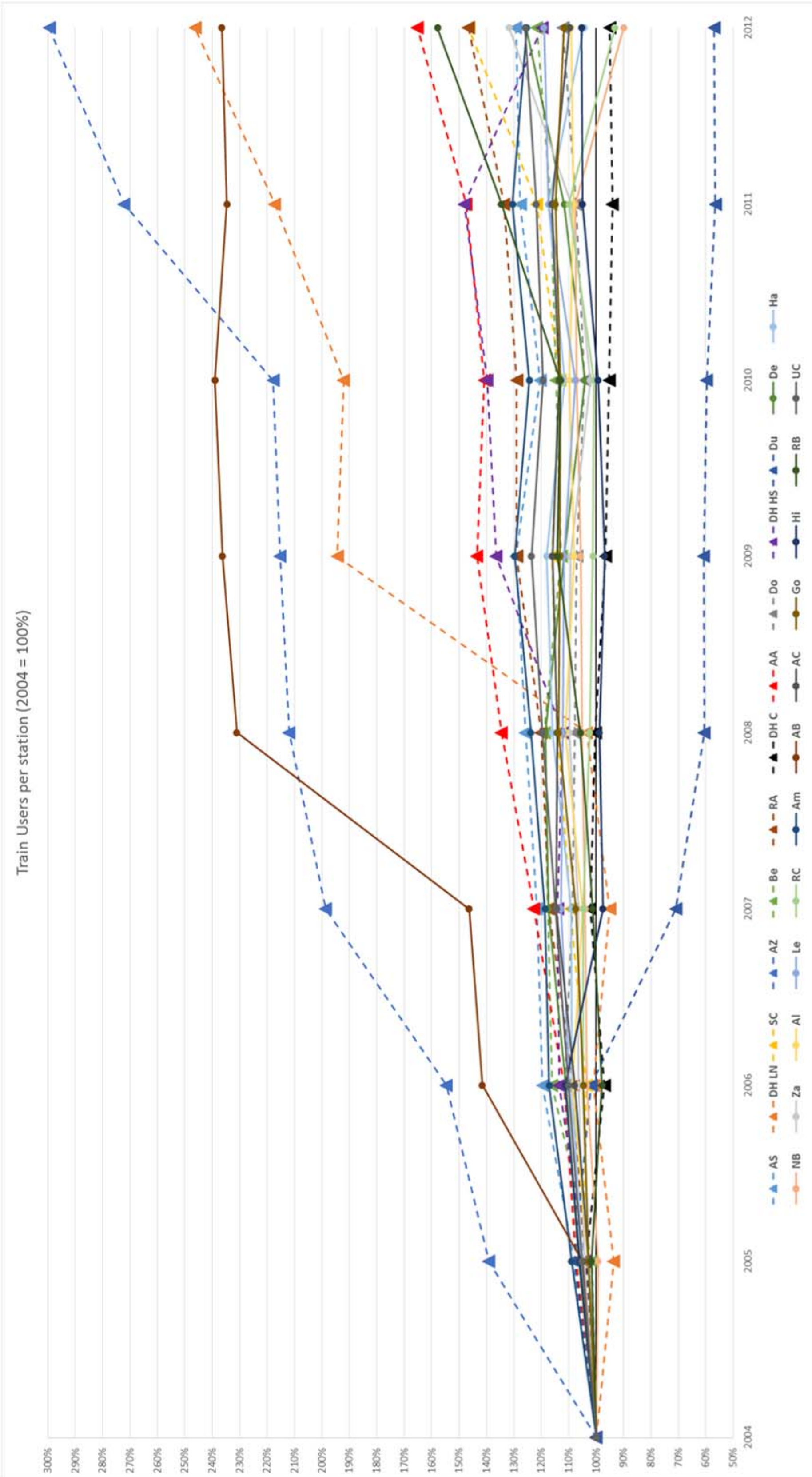
This appendix shows the data per station per variable. The legend considering the graphs is shown below. Multimodal stations are indicated with a dashed line and triangles while IC-stations are indicated with a solid line and dots.

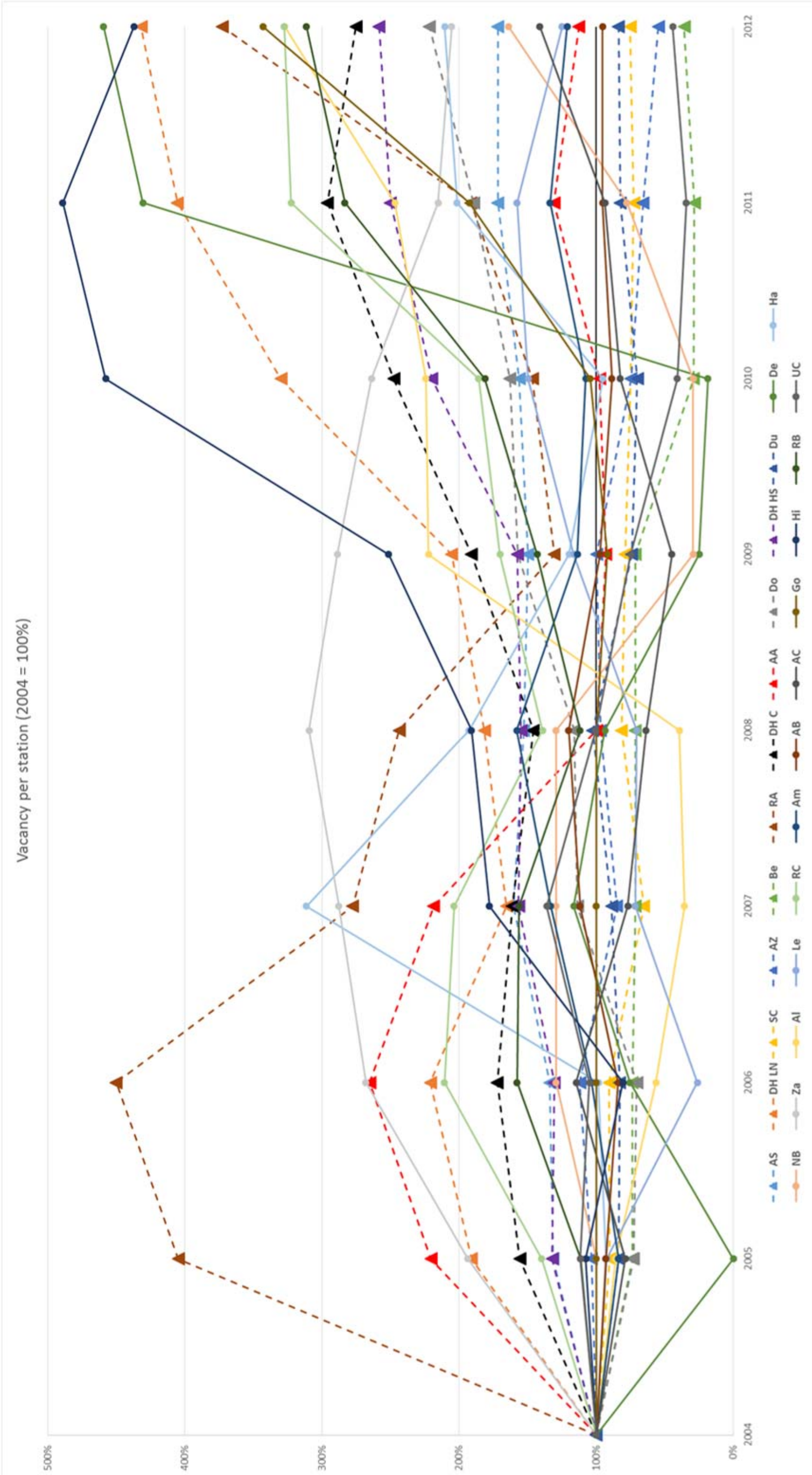
●/▲ = IC-station/Multimodal station

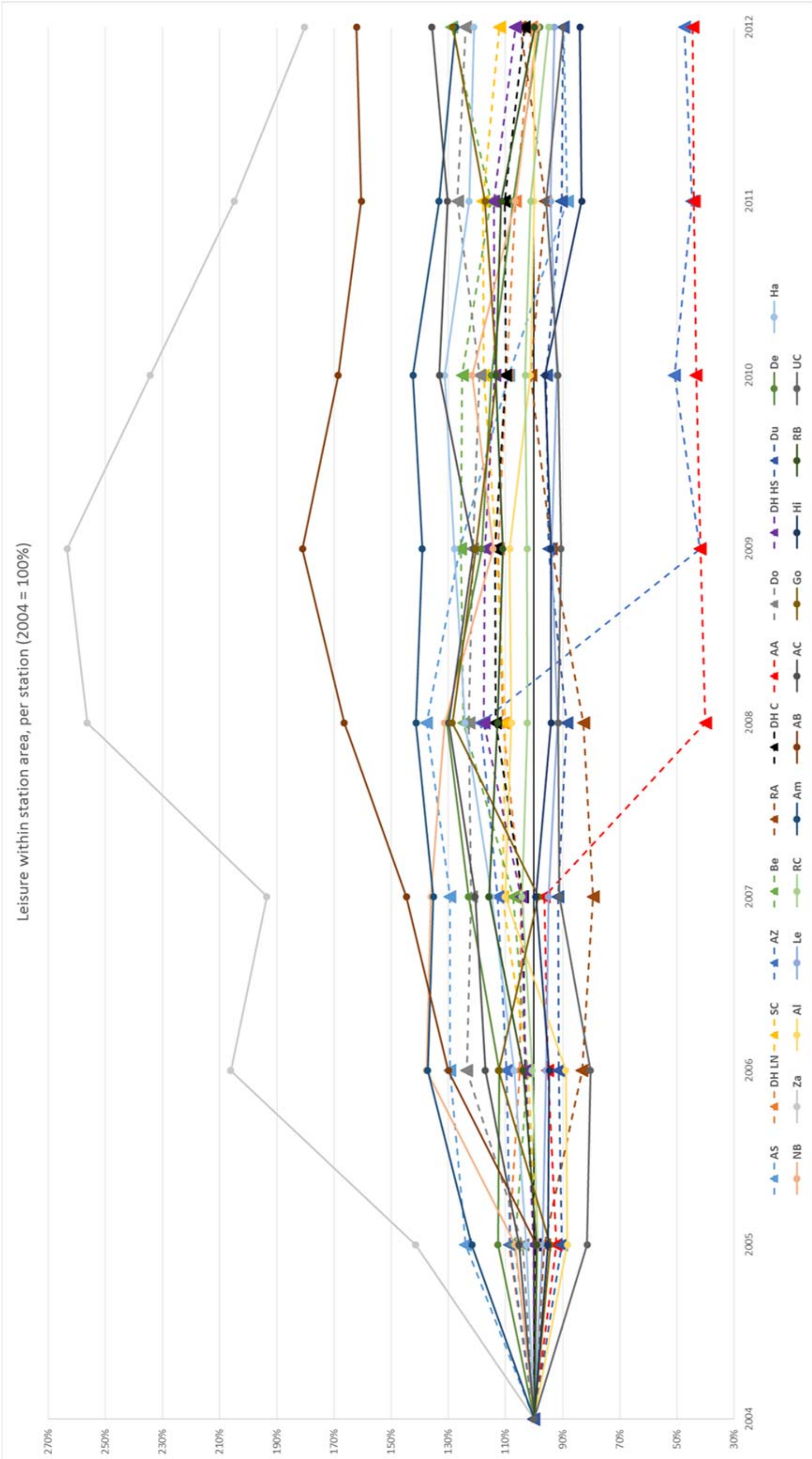
| | | | |
|---|---|---|---|
| Al = Almere C. | Be = Beverwijk | Go = Gouda | RC = Rotterdam Centraal |
| Am = Amersfoort | De = Delft | Ha = Haarlem | SC = Schiedam Centrum |
| AA = Amsterdam Amstel | DH C = Den Haag Centraal | Hi = Hilversum | UC = Utrecht Centraal |
| AB = Amsterdam Bijlmer | DH HS = Den Haag HS | Le = Leiden | Za = Zaandam |
| AC = Amsterdam Centraal | DH LN = Den Haag Laan v NOI | NB = Naarden-Bussum | |
| AS = Amsterdam Sloterdijk | Do = Dordrecht | RA = Rotterdam Alexander | |
| AZ = Amsterdam Zuid | Du = Duivendrecht | RB = Rotterdam Blaak | |

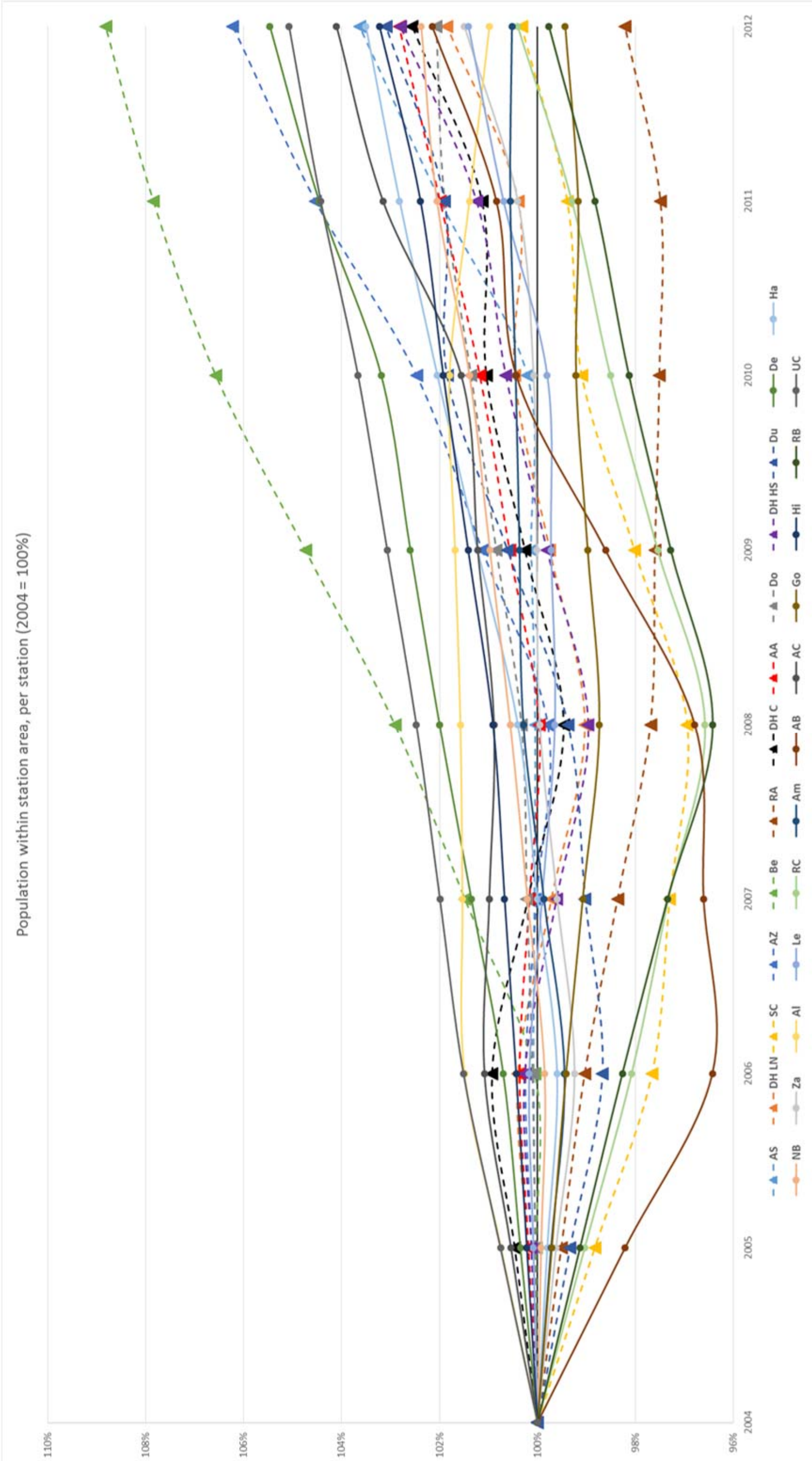

Retail within station area, per station (2004 = 100%)
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC

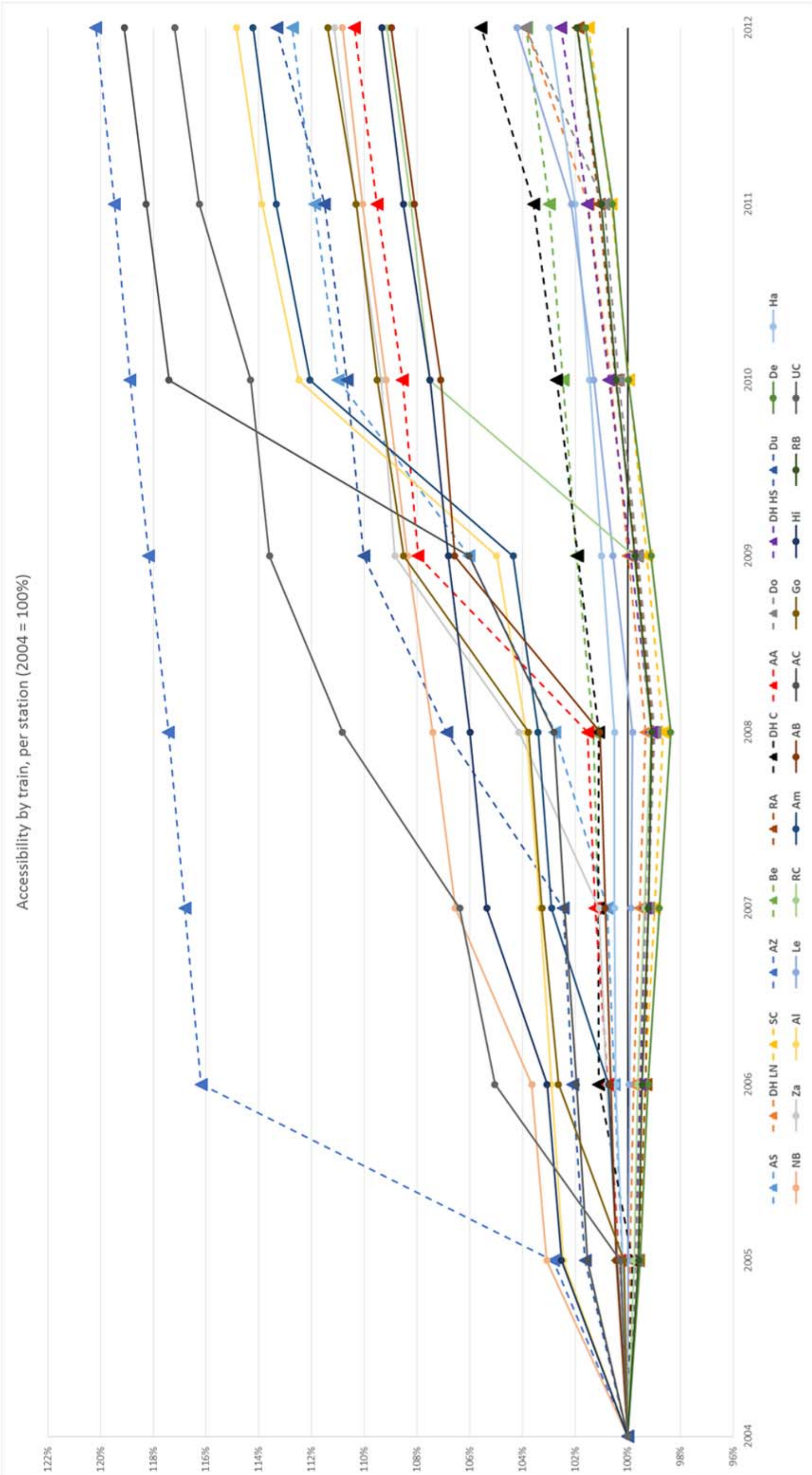

Service jobs within station area, per station (2004 = 100%)
160%
155%
150%
145%
140%
135%
130%
125%
120%
115%
110%
105%
100%
95%
90%
85%
80%
2004
2005
2006
2007
2008
2009
2010
2011
2012
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC

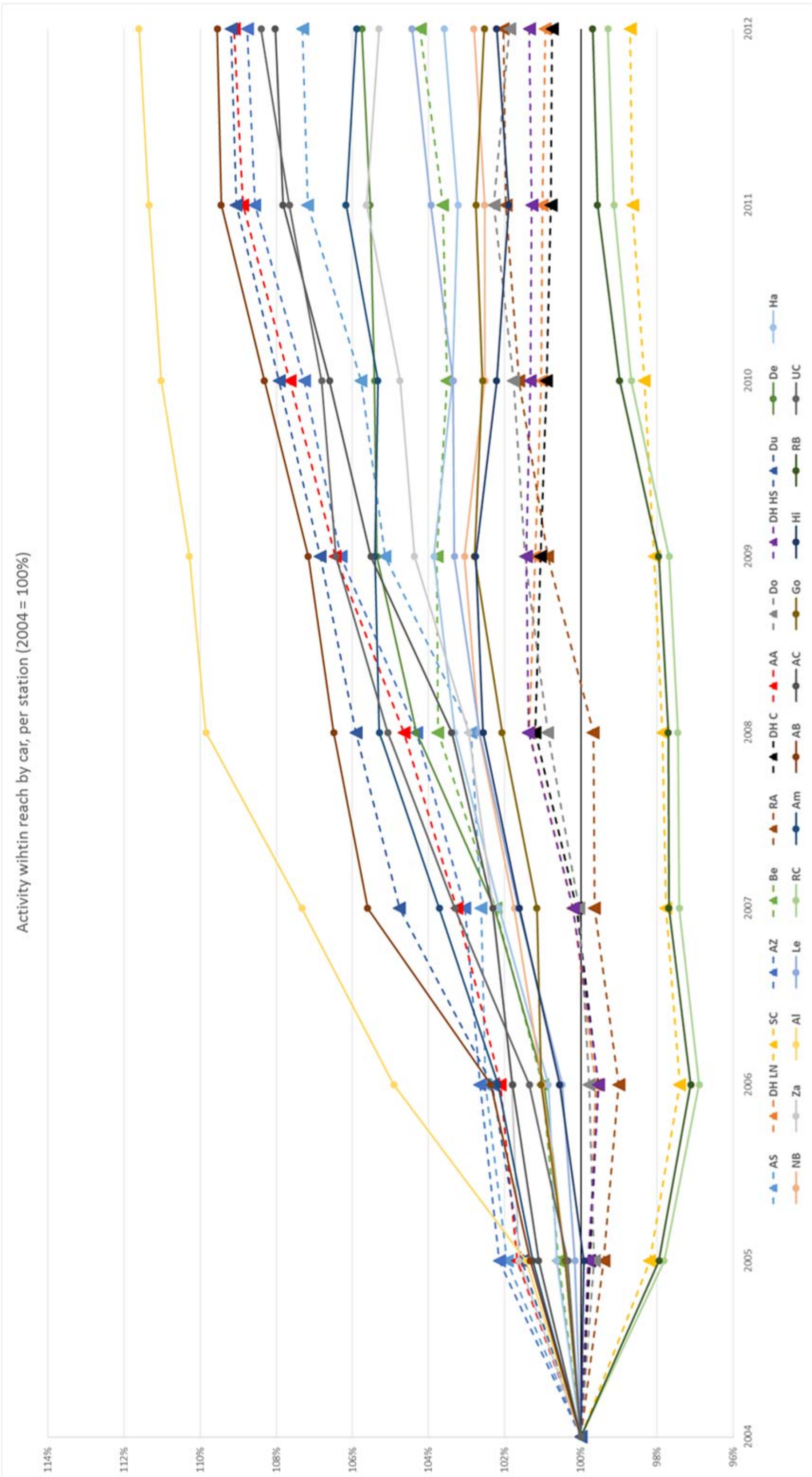

Train Users per station (2004 = 100%)
300%
290%
280%
270%
260%
250%
240%
230%
220%
210%
200%
190%
180%
170%
160%
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
2004
2005
2006
2007
2008
2009
2010
2011
2012
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC

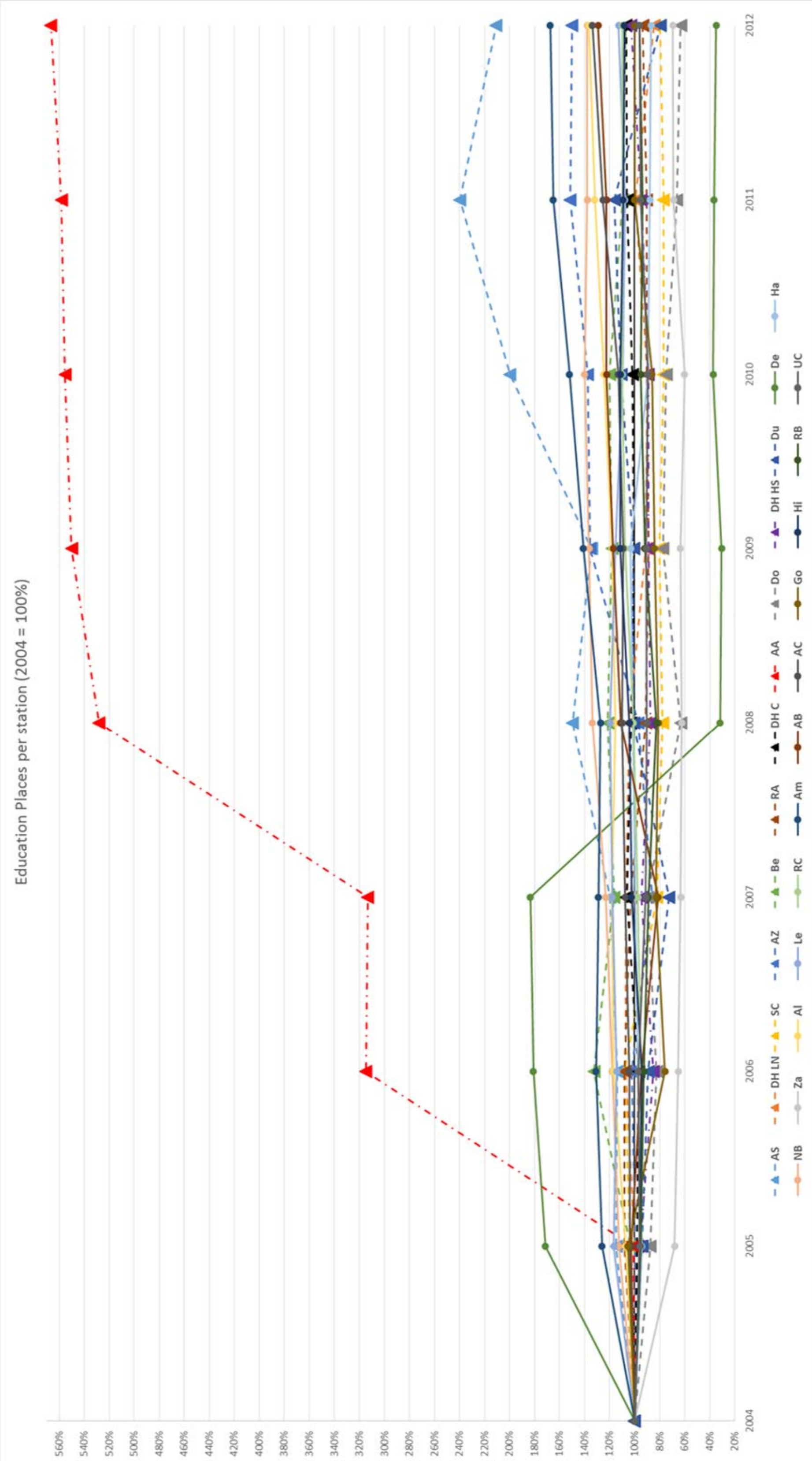

Vacancy per station (2004 = 100%)
500%
400%
300%
200%
100%
0%
2004
2005
2006
2007
2008
2009
2010
2011
2012
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC

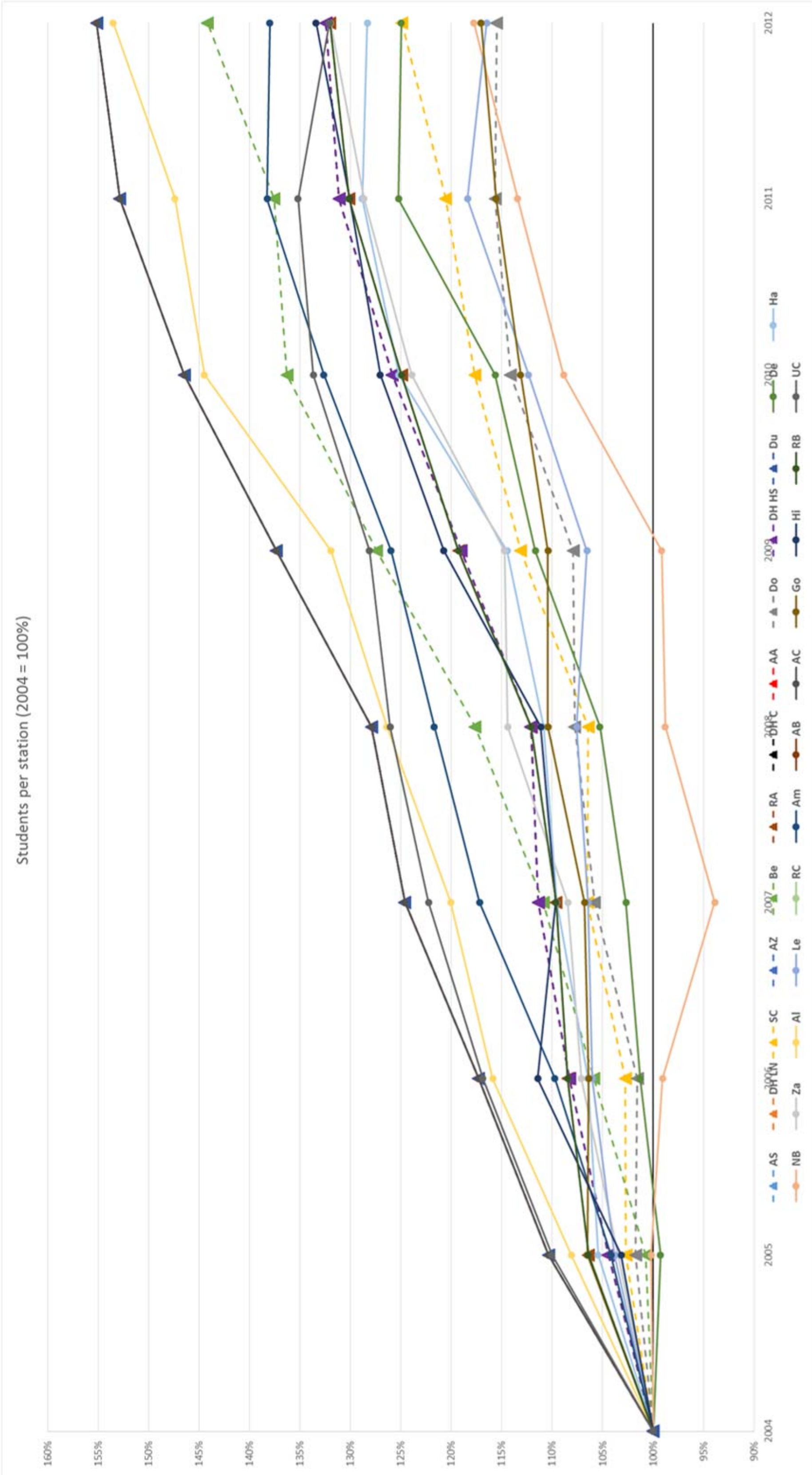

Leisure within station area, per station (2004 = 100%)
270%
250%
230%
210%
190%
170%
150%
130%
110%
90%
70%
50%
30%
2004
2005
2006
2007
2008
2009
2010
2011
2012
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC

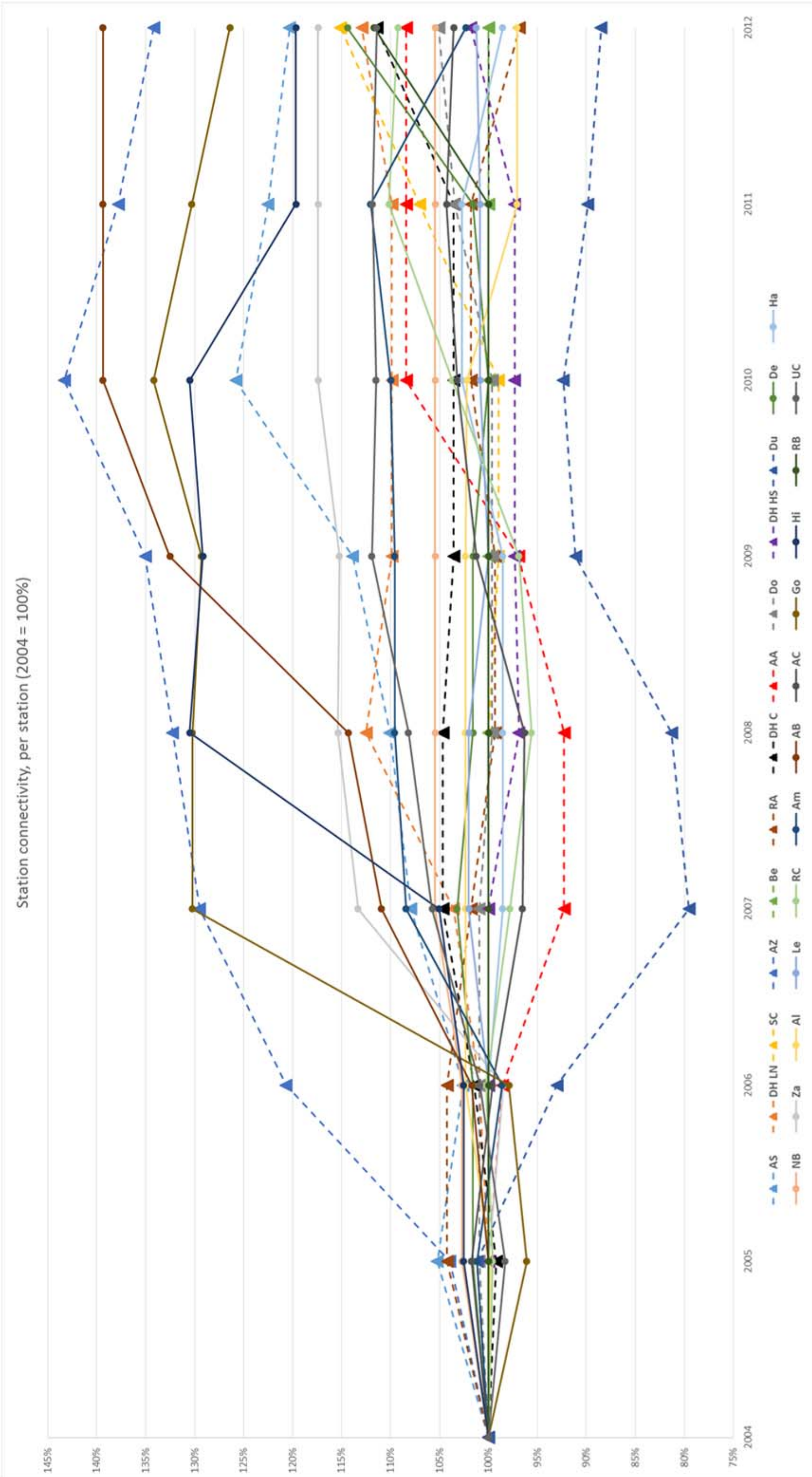

Population within station area, per station (2004 = 100%)
110%
108%
106%
104%
102%
100%
98%
96%
2004
2005
2006
2007
2008
2009
2010
2011
2012
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC

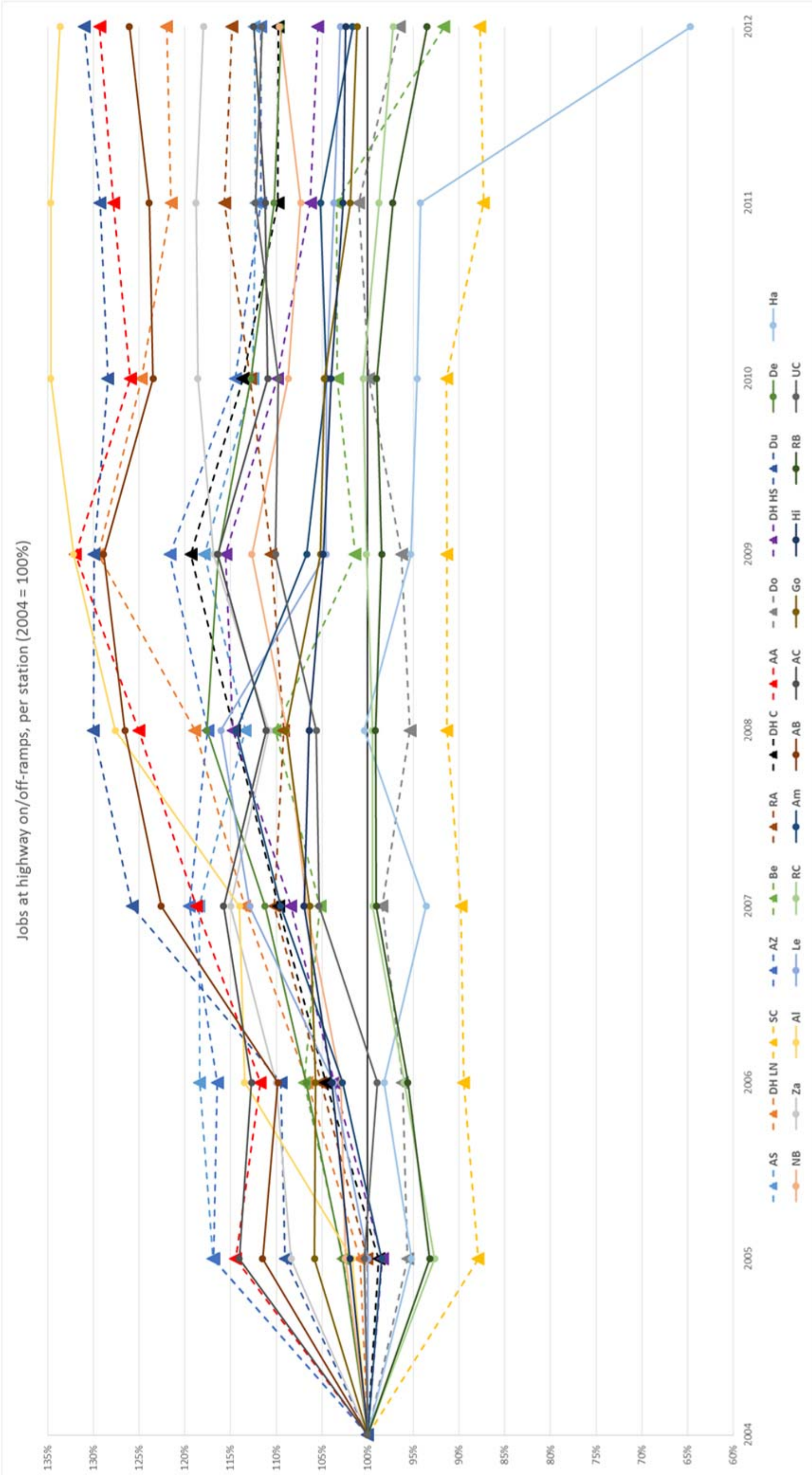

Accessibility by train, per station (2004 = 100%)
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
De
UC
2004
2005
2006
2007
2008
2009
2010
2011
2012
96%
98%
100%
102%
104%
106%
108%
110%
112%
114%
116%
118%
120%
122%

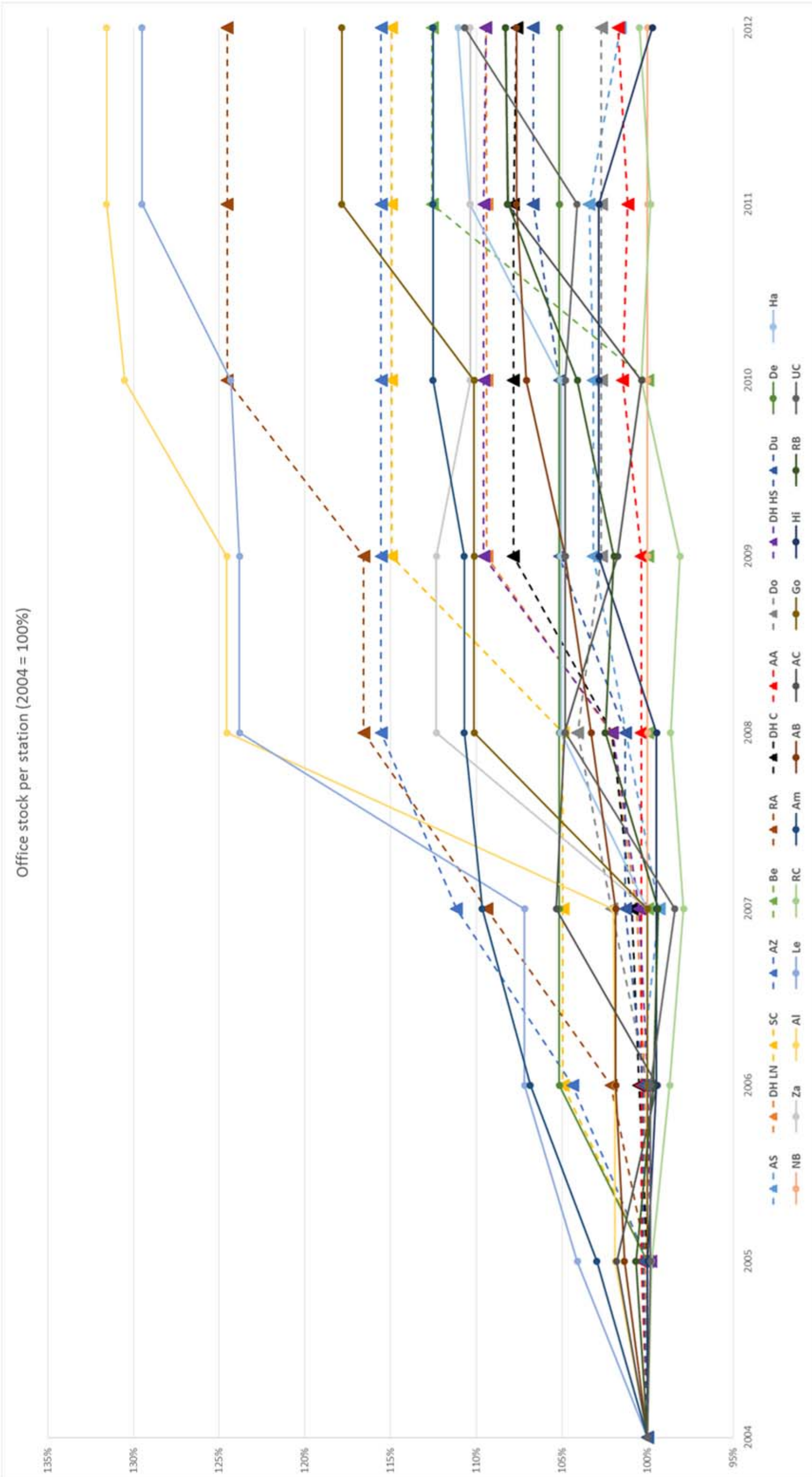

Activity wihtin reach by car, per station (2004 = 100%)
114%
112%
110%
108%
106%
104%
102%
100%
98%
96%
2004
2005
2006
2007
2008
2009
2010
2011
2012
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC


Education Places per station (2004 = 100%)
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC
2004
2005
2006
2007
2008
2009
2010
2011
2012
20%
40%
60%
80%
100%
120%
140%
160%
180%
200%
220%
240%
260%
280%
300%
320%
340%
360%
380%
400%
420%
440%
460%
480%
500%
520%
540%
560%


Students per station (2004 = 100%)
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
De
UC
Ha
160%
155%
150%
145%
140%
135%
130%
125%
120%
115%
110%
105%
100%
95%
90%
2004
2005
2006
2007
2008
2009
2010
2011
2012


Station connectivity, per station (2004 = 100%)
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC


Jobs at highway on/off-ramps, per station (2004 = 100%)
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
HI
RB
UC
2004
2005
2006
2007
2008
2009
2010
2011
2012
135%
130%
125%
120%
115%
110%
105%
100%
95%
90%
85%
80%
75%
70%
65%
60%


Office stock per station (2004 = 100%)
135%
130%
125%
120%
115%
110%
105%
100%
95%
2004
2005
2006
2007
2008
2009
2010
2011
2012
AS
DH LN
SC
AZ
Be
RA
DH C
AA
Do
DH HS
Du
De
Ha
NB
Za
Al
Le
RC
Am
AB
AC
Go
Hi
RB
UC