RADBOUD UNIVERSITY

The role of TOD characteristics in creating corridors of opportunities: A study on the equity aspects of TOD

A quantitative analysis of the relation between location choices of employment sectors and node-place characteristics in the Randstad region

SEPTEMBER 2021

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ABSTRACT

Transit-Oriented Development is a swiftly growing strategy within the field of transportation. In the Netherlands, the corridor approach, introduced in 2013, has swiftly become the accepted method of planning transit. As cities continue to align their development with this strategy, there is a need to assess it for equity aspects, given the large literature that discusses the inequitable consequence of incomprehensive TOD planning. In this research the equitability of the RandstadRail metro line E is analyzed for the composition of employment sectors by studying the relation between node-place characteristics of TODs and location choices of businesses within the station catchment area. The results show that the characteristics do a play a role in orchestrating the composition of employment sectors along the railway corridor and accordingly influences the equitability of job opportunities in the regions' most accessible locations.

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LIST OF ABBREVIATIONS

CBD: Central Business District

CBS: Statistics Netherlands

MNL: Multinomial Logistic Regression

NWB: Nationaal Wegen Bestand (Data Source)

OSM: OpenStreetMap

P&R: Park and Ride

PBL: Netherlands Environmental Assessment Agency (Data Source)

PT: Public Transport

RR-E: RandstadRail metro line E

TOD: Transit-Oriented Development

TSC: Two-Step Cluster Analysis

US/USA: United States of America

UK: United Kingdom

1. INTRODUCTION

1.1 Background and Problem Statement

The transport sector of a country is considered to be the backbone of its economy (Rail Technology Magazine, 2013). It connects people with places, businesses with markets, and facilitates the movement of goods, however at the cost of the environment. The transport sector is a top contributor to pollution, producing 21% of the greenhouse gases worldwide (Ritchie, 2020; Friedrich, Ge, & Pickens, 2020; EPA, n.d.). Although that value is representative of all transport modes, passenger transport by road accounts for the highest share of carbon dioxide production by generating almost half of the total emissions of the sector's total (Ritchie, 2020).

Growing concerns about the degradation of the environment and the unsustainable nature of conventional transportation systems have pushed governments to look for alternatives to transport planning methods. Rapid expansion of urbanization and urban population have driven countries to turn to sustainable forms of urban planning to counteract growing levels of traffic congestion and global warming. Propelled by this need, the concept of Transit-Oriented Development (TOD) has made a resurgence (UN environment programme, n.d.). Its potential in curbing, both, growing urban traffic and the resulting increase in pollution has made it a preferred mode of transport planning in cities of many countries across the globe (Ibraeva, Correia, Silva, & Antunes, 2019; Staricco & Brovarone, 2018). Rail transit, in particular, plays a pivotal role in TOD because of its advantages over other forms of mass transit. It reduces traffic congestion, covers longer distances over a shorter time period and its emission output is low for its passenger capacity (Ritchie, 2020).

Literature on TOD raises awareness about the need for comprehensive TOD planning for the outcomes to be entirely functional (Chapple & Loukaitou-Sideris, 2019; Kim, 2021; Litman, 2020), which otherwise can affect social equity of a society by creating undesired consequences from the distribution of the benefits of transport planning. The advantages of TOD, such as reduced urban sprawl and car-dependency, decreased traffic levels, and improved job accessibility, can be counterweighted by byproducts such as increased land-values that put low-wage or lower educated individuals at a disadvantaged end (Kim, 2021). For example, the study of Tornabene & Nilsson (2021) on the impact of rail transit on economic changes in cities in the USA concluded that most small businesses that existed in pre-TOD neighborhoods have experienced displacement from rental prices becoming unaffordable. TOD literature emphasizes on the importance of an all-inclusive planning strategy to ensure that such downsides are controlled and that benefits are not accrued just by the higher educated and higher income groups of a population.

Much of the available research on the drawbacks of TOD are based in cities in the North American continent, which have studied post-development impacts of TOD in the region (Papa & Bertolini, 2015). TOD is not an unknown concept in Europe and given that laws in countries differ the impacts may also vary in type and intensity. The Netherlands, particularly, is an interesting area of study because of its rich history in spatial planning (Alpkokin, 2012) and the different approach the country has recently taken towards planning TODs (van Lierop, Maat, & El-Geneidy, 2017). Although the volume of Dutch-based TOD literature is relatively lower, works such as Pojani & Stead (2014), Thomas, et al. (2018), Singh (2015), Huang, Grigolon, Madureira, & Brussel (2018) paint a picture of the journey of the concept to its current position and its contribution to the economy in the Netherlands. Currently, there is a scarcity of information about the impacts of the relatively new approach to TOD planning, the corridor approach introduced in 2013 (Vereniging Deltametropool, 2014).

The corridor approach was first applied to assess train stations in the Randstad region, the economic hub of the country (Vereniging Deltametropool, 2014). The region comprises of the four big cities of the Netherlands – Amsterdam, Rotterdam, Utrecht, and the Hague – along with other neighboring cities. The development of the region's transportation system has been one of the priorities of the Dutch government since the 1990s (Geurs, van Wee, & Rietveld, 2006). Its economic position and rising population meant renovations and upgradations of its railway lines and urban areas to warrant unhindered progress (ibid.). Today, cities in the Randstad enjoy the country's most advanced public transport system; a system comprising of bus, ferry, metro, train, and tram services.

Since its introduction in the Randstad region in 2013, the corridor approach has gained popularity by becoming widely accepted in the Netherlands as an appropriate method to planning TODs, with different provinces devising comparable TOD models (Vereniging Deltametropool, n.d.). Recent studies that analyze TOD corridors in the Netherlands can be categorized into themes – level of TOD (or TODness) based on certain characteristics (Singh, 2015; Lukman, 2014) and impact of TODness on property prices (Huang, Grigolon, Madureira, & Brussel, 2018; van der Zwet, 2019). A topic less studied in this arena is the influence of TOD on location choices of businesses. If TODs do not consist of opportunities that cater to the transit dependent low-wage communities then they are disadvantaged by the lack transit services, which are highest in central locations and decrease with distance (Pritchard, Tomasiello, Giannotti, & Geurs, 2019). Findings from the research of Pritchard et al. support the argument that centrally located low-wage opportunities can alleviate the inequity consequences of TODs.

1.2 Research Objective

With the intention to assess the equity aspects of rail transit corridors in the Netherlands, the goal of this research is to understand and explain the role of TOD characteristics in location choices of employment sectors. The relation between TOD characteristics and industrial sectors is analyzed to identify what combination of TOD characteristics attract what sectors of industry. Hence, the hypothesis tested in this study is,

> H1 = *TOD characteristics have an impact on the types of employment sectors located within its catchment area.*

The railway line chosen for the analysis is the RandstadRail metro line E (further referred to as RR-E), which connects the municipalities of Rotterdam and the Hague, the southern agglomeration of the Randstad region. This line comprises of 23 rail stations, of which 3 are also train stops.The RR-E line comprises of nodes that connect diverse neighborhoods – the two Central Business Districts (CBDs) of the province of South-Holland, the subcenter of Pijnacker (City Population, 2019), residential areas such as that around station Slinge, the port in Rotterdam (Wilhelminaplein), and city centers as in Zuidplein. The different types of neighborhoods along RR-E makes it an interesting line for the purpose of this research. Besides the neighborhood mix, RR-E is the only rail line that connects them. Research conducted in the UK and Norway have related the use of trains and cars with higher income households, and bus and metro services with lower income individuals (Gates, Gogescu, Grollman, Cooper, & Khambhaita, 2019; Fearnley & Aarhaug, 2019). RR-E being the only metro line, thus, becomes crucial for a study on equity. Accessibility to transport increases the chances of gaining employment in the Dutch setup (Bastiaanssen, Johnson, &

Lucas, Does better job accessibility help people gain employment? The role of public transport in Great Britain, 2021). While previous research in different countries have achieved mixed results, most show that access to transport does enhance the probability of being employed (ibid.).

1.3 Research question

What is the role of TOD characteristics in the composition of employment sectors around the rail stations of the RandstadRail metro line E (RR-E)?

- What are the node and place characteristics associated with TOD that influence the location choices of employment sectors? What measures are used to quantify these characteristics? (theoretical)
- What is the composition of business sectors in the catchment area of the nodes? (theoretical/GIS)
- What are the typologies of the stations composing the RR-E?
- What is the relationship between the station categories and the types of employment sectors within their catchment area?

1.4 Significance of Research

1.4.1. Societal Relevance

The recent shift from node-based to, the nationally accepted, corridor-based TOD planning in the Netherlands has made it imperative to study the equity aspects of transit corridors to avoid any consequence that aggravates social inequity in the future. Rotterdam and the Hague are the biggest employment centers in the Randstad's south wing (EURES, 2021). The employment sectors in the region vary from public sector services in the Hague to mostly business and port services in Rotterdam (Hausleitner, Sanz, Meyer, & Klapwijk, 2018). The large number of opportunities and the supporting transport infrastructure makes both cities attractive to reside in. By analyzing the RR-E corridor for its composition of employment sectors provides a starting point for understanding how employment equity over a railway corridor can be enhanced. The findings from this research can guide stakeholders and transport planners in their decisions on further development of station areas, other public transport routes, and in identifying favorable locations for different industries, eventually creating a region with opportunities for people of all backgrounds.

Analyzing the corridor for its equality is intrinsically socially relevant. The development of a corridor with varying employment opportunities can support the livelihoods of people from different financial backgrounds, communities, ages and educational qualifications, significantly impacting the lives of those dependent on public transport for a living.

1.4.2. Scientific Relevance

From Pojani et al.'s (2014) discussion on the revival of TOD in the Netherlands, to Singh's (2015) work on creating a framework to identify different TODs, Huang, et al.'s (2018) study on the complementarity of TOD stations in a railway corridor and van der Zwet's (2019) research on the impact of type and level of TOD on property values the growing acceptance of TOD and the corridor-approach in the country is evident. The importance is also reflected in the works of organizations, as in Vereniging Deltametropool's (2014) *Maak Plaats!* or ITDP's TOD-Radar (Provincie Zuid-Holland, n.d.), who have developed TOD models for the assessment of station areas in different provinces. There is, however, much that is yet to be explored about TOD corridors in the Netherlands.

Though TOD has been present in the Dutch history of planning but disguised under other titles of planning methods, an area of TOD research that is less explored is the relation between TODs and businesses around transit areas. In relation to location choices of businesses, the work of Willigers et al. (2011) looks into the role of high-speed rail in attracting economic activities to the region, and Botelho's (2019) thesis investigated the influence of TOD characteristics on investments made by the horeca (catering industry). Findings from both research were based on stated choice experiment. This research contributes to existing literature on Dutch TOD in two ways. The research adds content on the employment aspect of the corridor approach to TODs in the Netherlands. And, the statistical analysis undertaken for the research provides a purely quantitative interpretation of the results.

2. LITERATURE REVIEW

TOD is a not a new concept per se. In the Netherlands, it has been a strategic element in the country's Compact City development style, that focuses on promoting economy while maintaining the limits of urban boundaries (van Lierop, Maat, & El-Geneidy, 2017). At present, one can observe an evident pattern of mixed-used development around, mostly, multimodal transport hubs that are well connected by quality and reliable transport systems across the country (ibid.). TOD specific policies emerged in the 90s when Luca Bertollini introduced the Node-Place model (Vereniging Deltametropool, n.d.). Randstad's south wing was the first to implement this model with the Stedenbaan in 2006.

Relatively new to the Netherlands, is the corridor approach to planning rail transit. To optimize the contribution of transit nodes to the region's economy, a shift in planning TODs to the corridor approach began in the early 2010s (Galetzka, 2015). Following the introduction and application of the Butterfly Model in the province of North Holland in 2012 (Vereniging Deltametropool, 2014), similar models such as the Kwadrantmodel and TOD-Radar, have been implemented by different provinces to assess rail transit station areas within the territory. The use of such models by different provinces across the country indicates the interest in corridor planning of transit. All models work on the same principal of analyzing the balance between transit characteristics and built-environment characteristics of a node.

The remainder of this section is divided into 3 sub-parts – TOD, Business location choices, and Equity. Each part provides a background on the topic, that reasons the choice of variables used in the analysis and the purpose of this research.

2.1. Transit-Oriented Development (TOD)

TOD is a compact mixed-use development of a station area in order to encourage active mobility and improve accessibility while promoting sustainable mobility (Chorus & Bertolini, Developing transit-oriented corridors: insights from Tokyo, 2016; Griffiths & Curtis, 2017; Transit Oriented Development Institute, n.d.). Though literature misses a concrete definition of TOD, we find a list of features to identify one with such as (Griffiths & Curtis, 2017; Hong, et al., 2015),

- a defined catchment area for walking and for cycling,
- housing units, offices, retail outlets, services all within the station's catchment area,
- an active center,

- high quality public transport,
- adequate parking space for cars and bikes to support the use of transit.

A TOD is usually a circular development of, an internationally accepted, radius between 400m to 800m around a transit station (Hong, et al., 2015). The area within this radius is termed as 'catchment area' and the radius is reckoned as acceptable for walking to or from a transit station. The Netherlands is an exception in this matter as the approved radius is 2 to 3 km due to the widespread use of bicycles (TUDelft, OIR, Nordregio, 2016).

There are three identified approaches to planning TODs that are distinguished by the level at which they are planned. When development is planned for a single neighborhood in a circular pattern, within an approved radius of a rail station it is referred to as a 'single node TOD' approach (TUDelft, OIR, Nordregio, 2016). With a similar planning approach but upgraded to the regional level is the 'multi-node TOD'. In this approach, more than one neighborhood is developed in circular or semi-circular patterns around transit stations. The third approach is called the 'corridor TOD'. This type is found in urban areas, where transit stations are close to each other resulting in a linear or ribbon-like development along transit paths (ibid.). Though the approach taken at any level of TOD-planning is important to the development of the region, the corridor approach maximizes the overall efficiency (Thorne-Lyman & Wampler, 2010).

Commonly, TOD planning practices are restricted to solo station areas. However, Chorus and Bertolini (2016) argue that station areas should be coordinated at the regional level to enhance the contribution of individual TODs and generate long-lasting effective benefits. As defined by them, a railway corridor consists of an urban regional level railway line and the land surrounding the constituent stations (Chorus & Bertolini, Developing transit-oriented corridors: insights from Tokyo, 2016). Planning further development of individual nodes in relation with other nodes along a railway line builds a synergistic cooperation among them and an efficient transit system (ibid.). For the synergistic functioning of the nodes, it is important that they are designed to have complementary activities. Thus, nodes comprising a railway corridor are different from each other depending on their built environment factors, that determine its purpose and course of development (Huang, Grigolon, Madureira, & Brussel, 2018).

2.1.1. TOD: a concept based on land-use and transport integration

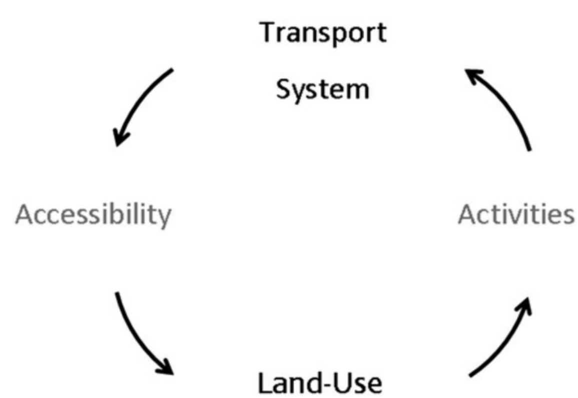

Figure 1: Land-use Transport Feedback Cycle (Straatemeier & Bertolini, 2020)

As described in the introduction to this section, TODs are developed taking into consideration the people component, business component and transit component. A basic understanding of the relation between these components can be gained from the land-use transport feedback cycle. Figure 1 is a simplified version of the cycle. It depicts the causal relationship between both elements and reasons the need for integrating their planning processes for useful and successful outcomes or, in other words, the need for TOD planning.

Designating a land to specific uses results in the spatial distribution of activities and generates demand for transportation in order to access them. However, as transport systems are further developed accessibility to these locations is improved which, in turn, influences the land-use and the spatial distribution of activities. The history of transportation and mobility is proof to this cyclic relationship as seen in the period when automobile production experienced a boom. The surge in the use of private automobiles after the second world war, encouraged the expansion of highways and suburbanization causing decentralization of activities to different locations (Straatemeier & Bertolini, 2020). The continuous expansion of highways provided access to urban fringes promoting further suburbanization (ibid.).

Highway expansion and suburbanization have further encouraged the use of automobiles, causing traffic and pollution. TOD is based on building a neighborhood of diverse uses that reduces the need to travel. Apart from the environmental benefits from reduced car usage, by integrating land-use and transport planning accessibility to activities is also improved.

2.1.2. TOD: an accessibility-enhancing strategy

The provision of accessibility is the core objective of a transport system. There are two recognized strategies to create and enhance accessibility to a location, mobility- and accessibility-enhancing strategies (Straatemeier & Bertolini, 2020). Of the two strategies, mobility-strategies has been the conventional mode of establishing accessibility (Handy, 2002). When planning to enhance mobility, the transport system of an area is planned around the current uses of land within it (Straatemeier & Bertolini, 2020). Contrary to that and the less commonly, and more recently, adopted planning strategy is the accessibility-enhancing strategy. The goal is to increase the opportunities for interaction (Handy, 2002). Such strategies are focused on diversification of land-use such that destinations are brought closer to individuals. Planning transport by prioritizing accessibility helps to identify locations of risks and of opportunities for further development (Straatemeier & Bertolini, 2020), thereby containing urban sprawl, reducing the need for expansion of roadways and containing the growth of the region within suitable and desired locations. Whether it be a mobility- or an accessibility-enhancing strategy, both provide access to locations, and an accessible location has the potential to generate economic benefits by being an attractive choice for firms and businesses to locate in (Credit, 2019; Giuliano, Redfeam, Agarwal, & He, 2012).

The concept of TOD belongs to the category of 'accessibility-strategies' (Handy, 2002; Straatemeier & Bertolini, 2020). The land-use transport feedback cycle and the motive behind accessibility-strategies imply that the use of land around transit is transformed to diversify the activities located within its catchment area. The spatial redistribution of activities is a result of the economic benefits from increased property values, brought by enhanced accessibility, which drives high-intensity land-use (Credit, 2019). This effect is depicted in (Wegener & Furst, 1999)'s elaborated 'land-use transportation feedback cycle', figure 2,

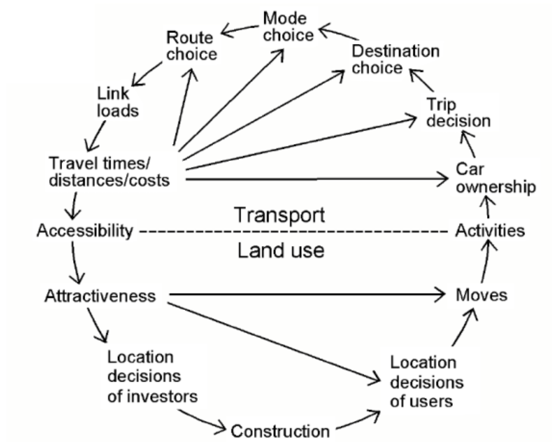

Figure 2: Elaborated land-use - transportation feedback cycle (Wegener & Furst, 1999)

To put it simpler, land use and transport planning are based on choices (Lenferink, 2020). The level of accessibility of a location determines the activities present there, which adds to the attractiveness of the site thereby inducing further investments (ibid.).

2.1.3. TOD and Node-Place characteristics

The evolving patterns of decentralization and centralization of activities has made transit nodes points of potential interaction for people of different communities and backgrounds (Bertolini L. , 1999). According to Bertolini (1999), a balanced node-environment can contribute to creating opportunities for interaction at the node, which he elaborates on through a graphical representation – node-place model (figure 3)– combining both transit and built environment components. The model plays a crucial role in understanding the interaction of transport and land-use in creating efficient transit nodes.

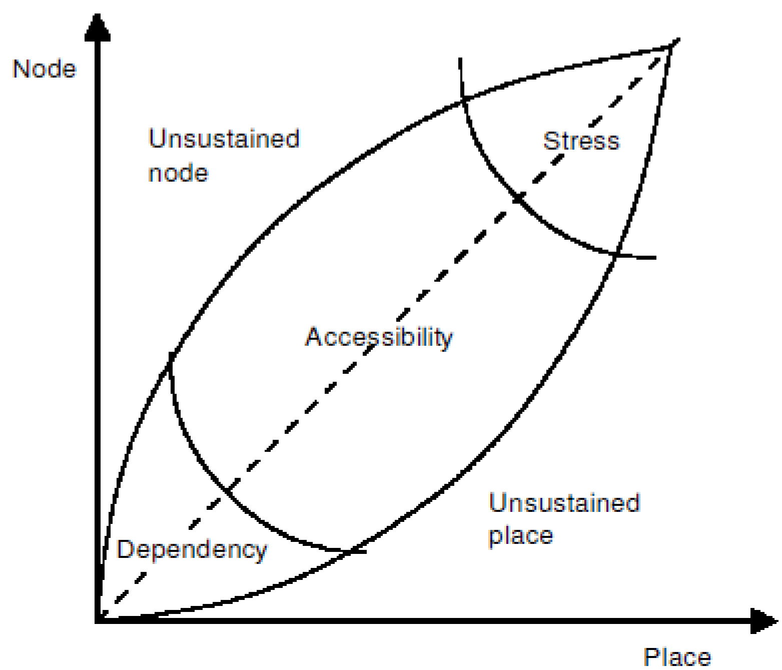

Figure 3: Node-Place model (Bertolini L. , 1999)

Accessibility – which he perceives as a broad concept that can be enhanced and maintained by transport, different activities, and diverse people – is central to the node-place model. The dotted diagonal in the model represents stations with a balanced node (transit) – and place (activities) environment, the number of activities and transit services support the functioning of each other. The top end of the diagonal, "stress", is the region of balanced transit areas that have reached their maximum capacity of node and place services and the opposite end of the line, 'dependency', of transit areas where both factors are present minimally. The region of 'Unsustained node', on either side of the diagonal, represents stations where the presence of either factors, transit or node, is higher than that of the other. A node that belongs in the top-left of the graph is representative of a TOD or station that provides transit services above the required level as it is not matched by the number of activities in the region. Similarly for nodes belonging to the lower half of the graph the functioning of activities around such stations are not sufficiently supported by a well-planned transport system.

Each node has a competitive and complementary position within a single-mode transport network (Bertolini L. , 1999), which the node-place model helps to identify through evaluating indicators that measure the intensity and diversity of transit supply and activities independently. In doing so, the node-place model has become a useful means for understanding the current functioning of nodes and in identifying required measures for their further development (Bertolini L. , 1999). For example, an extension of the node-place model can be seen in the butterfly model (figure 4), that was developed to assess train stations in the province of North-Holland. It has proven to be an indispensable tool in assessing the potential of station areas in delivering certain functions in order to create synergistic rail corridors (Deltametropolis Association, 2016). In figure 4, we see the six node-place characteristics, three for each, by which a station area is assessed and its contribution to a railway corridor identified.

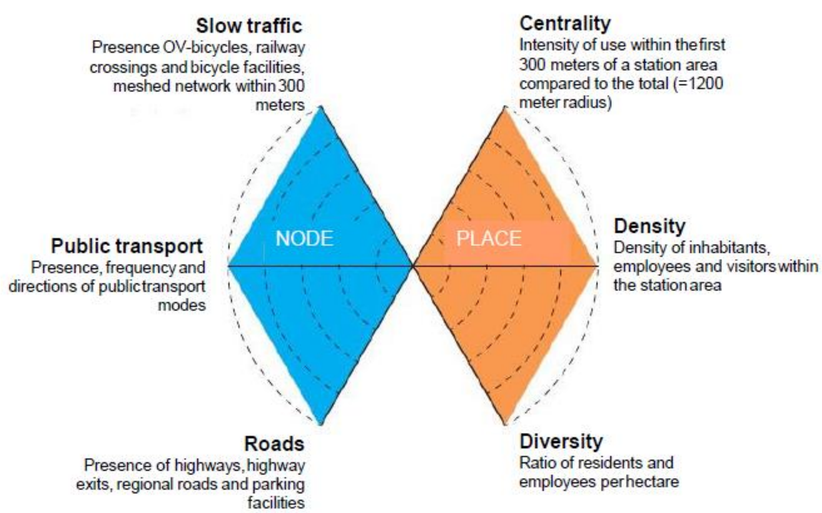

Figure 4: Butterfly model (source: Chorus, 2020)

The node-place model is an important element in the corridor approach. It helps recognize the contribution of individual nodes to a rail corridor. Extended versions of it aid the development of well-coordinated corridors. 'One-size fits all' does not stand true to the design of TODs and neither to railway corridors. Corridors are distinguished into 3 types by the areas they connect (Thorne-Lyman & Wampler, 2010),

1. Destination connector – corridors that comprise of a mix type of nodes, connecting residential areas and activity centers. Such corridors are expected to have high ridership due to the diversity of nodes connected by it.
2. Commuter – corridors that connect a single activity center, unlike a destination connector that provides accessibility to more than one type of activity.
3. District circulator – corridors that enhance the accessibility of locations within an activity center.

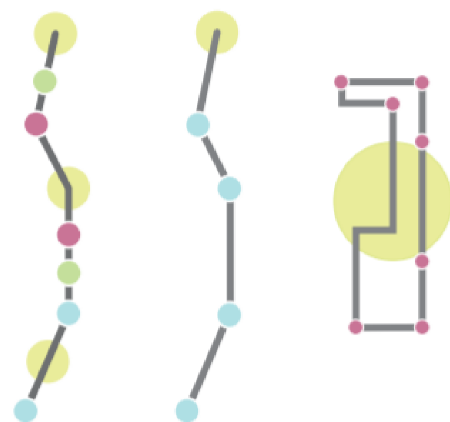

Figure 5: Corridor Types [Left to Right: 1 -> 3] (Thorne-Lyman & Wampler, 2010)

2.1.4. TOD characteristics and their evaluation

The traditional notion of travel being a derived demand stems from the understanding that area characteristics – land-use, design, etc. –generate the need for travel (Cervero & Kockelman, 1997). These characteristics identified as the 3Ds by (Cervero & Kockelman, 1997) are now commonly used to assess TODs (Frost, Appleyard, Gibbons, & Ryan, 2018; Singh, 2015; Huang, Grigolon, Madureira, & Brussel, 2018; Nyunt & Wongchavalidkul, 2020) and are also measures to improve integrated land-use and transport planning (Lenferink, 2020).

The 3Ds – *Density, Diversity, Design* – concern with the built environment of a TOD. *Density* is suggestive of the compactness of a given area (Cervero & Kockelman, 1997). A dense neighborhood that comprises of various activities in proximity to residential locations reduces people's need to travel by car and could encourage active forms of mobility, such as walking or biking. Also, densely developed areas tend to have minimal space for parking (ibid.), making car ownership inconvenient and promoting the use of transit for travels. Common indicators used to study density are population, employment, and housing densities (Frost, Appleyard, Gibbons, & Ryan, 2018; Cervero & Kockelman, 1997).

The purpose of developing a dense neighborhood around transit stations is fulfilled when it is accompanied with diverse activities. A neighborhood with various activities is likely to have a lively and attractive environment drawing residents to the outdoors (Singh, 2015). Studies also show that by bringing regular destinations within short distances of residential locations or having convenience stores located between a transit stop and places of residence can stimulate people to use public transportation or non-motorized forms of mobility (Cervero & Kockelman, 1997; Gehrke & Clifton, 2014). There are several formulae to measure *Diversity*, some of which are termed entropy, dissimilarity index, or vertical mixture (Singh, 2015; Frost, Appleyard, Gibbons, & Ryan, 2018).

The *Design* characteristic is about the navigability of the transit neighborhood. TODs must be easily navigable by foot (Cervero & Kockelman, 1997) in order to support the reduction of the use of cars and encourage sustainable mobility. Architectural characteristics such as street intersections, walkway width, length of cycling lanes play a role in achieving the pedestrian friendly environment that TODs are meant to create (ibid.). Commonly used indicators for measuring *Design* aspects of a TOD are intersection density, length of walkable and cyclable paths (Cervero & Kockelman, 1997; Singh, 2015).

The 3Ds work in combination to create effective TODs. By bringing together diverse activities and services within a compact area which is designed to allow easy mobility of people, the goal of TOD is attained. However, the built environment characteristics is representative of the place-half of a TOD. The node-half is measured by transit characteristics. Transit does not only provide the means of travel and the access to activities within the area of 'compact development' but extends this reach to farther regions. Chorus & Bertolini (2016), in their paper on the implementation of corridor approach to TOD, mention characteristics such as ridership and distance to subcenter to be commonly used measures of transit. The accessibility aspect of public transport, though, is measured through indicators that asses the ease of reaching a destination by transit. In the work of (Singh, 2015) this is done by incorporating transit frequency and the possibility of modal change at the transit station.

2.2. Rail transit and Businesses

2.2.1. Rail transit and economic activity

In general, literature portrays a positive contribution of rail transit to economy in three ways. The first and most apparent impact of transit development is on the prices of surrounding land. Regions that are accessible by transit experience rise in property prices (Credit, 2019). Some studies relate this to the growing preference for such locations and others to its favorable economic conditions (ibid.).

The second effect of transit on economic activity is part of its sustainability characteristic. As urban areas get more populated and road congestion rises, rail transit is perceived as the environmentally friendly alternative to traveling. Its capacity to transport a large number of people, possibly, in a shorter time period than the bus or car helps in reducing traffic congestion and lowering carbon emissions (Yang, Zhang, & Ni, 2014) while improving accessibility to various destinations and boosting economic activity (EMBARQ Network, n.d.).

Thirdly, transit is recognized to indirectly contribute to economies of agglomeration in and around station areas (Credit, 2019). Depending on the nature of the business, firms gain from locating in clustered and accessible locations by being able to share resources and having access to a larger labor force (Noland, Ozbay, DiPetrillo, & Iyer, 2014). Also, businesses that depend on one-on-one interaction favor central locations (Credit, 2019), as high prices of properties are made up for by the expected volume of footfall.

These impacts certainly influence industrial composition around station areas. We could take the example of land-intensive industries, for which increasing land prices would make it expensive to sustain in high-demand locations. However, businesses that are customer-service oriented would benefit from locating in central locations. The following sub-section expands on this discussion with references from literature.

2.2.2. Role of TOD characteristics in business location choices

A combination of factors influences a firm's decision on its choice of location. A rather traditional and elementary list of factors that business-related websites advise to consider when choosing a location are nature of business, cost to rent space, the environment and infrastructure, proximity to competitors and clients, availability of resources and labor, and applicable laws (Business-Marketing, 2012; Fox, 2017).

When looking into literature on economics and urban studies, the factors influencing location choices of businesses intricately increases. Prat & Ferriz (2006) list 45 factors that are categorized as cost, strategic, internal agglomeration, external agglomeration, market, state, legal, and personal factors in their research on Aragon's, Spain businesses. These factors weigh in differently depending on the nature of the business. Focusing on the subject of this thesis, following is a brief discussion on the relationship between business location choices and features of built environment and accessibility based on business sector.

The article by Wu et al. (2019) on the location choice of innovation and high-tech industry in China explains innovation agglomeration and diversity to be major influential factors, among others, when choosing a location. Locations with high level of innovation and availability of highly knowledgeable labor are attractive choices for concentration of tech-firms. They also gain from the presence of diverse clusters of firms from possible knowledge spillovers (ibid.). This was partially confirmed through van Geenhuizen & Reyes-Gonzales' (2007) study on biotechnology firms in the Netherlands. High-tech firms divert away from the traditional factors influencing location choice, unlike the manufacturing industry. The analysis by An et al. (2014) compared the effect of hard and soft location factors on relocation of manufacturing and service industries in Seoul's Metropolitan area. Hard location factors such as good transport infrastructure coupled with reasonable land-values increased the probability of manufacturing firms to relocate to suburban areas. On the contrary, the service industry showed high probability of relocating to inner-city locations as quality of life (referring to locations with basic facilities and services) was the dominant deciding factor (ibid.). The creative industry, as with the knowledge industry, is also drawn towards the city as they benefit from the effects of agglomeration and diversity of firms (Zandiatashbar, Hamidi, Foster, & Park, 2019).

Apart from density and diversity of market at a location, its accessibility plays an important role in attracting offices because it determines the ease at which the market can be reached, be it for goods or labor (Willigers, Floor, & van Wee, 2005). Willigers & van Wee's (2011) stated choice experiment study on the impact of high-speed rail on firm location choices in the Netherlands confirms this as around 65% of the relevant respondents opted for well-accessible places for relocating offices. Additionally, areas within a 10–15-minute walk of the station were also considered attractive for offices, with access-time to station having an inverse effect on the preference for a location (ibid.). Analyzing the impact of a new suburban metro line on different employment industries in the city of Madrid, Meija-Dorantes et al. (2012) found a growth in the density of market-oriented firms and a limited effect on resource-dependent firms around metro stations. Residential areas, those with independent and semi-detached houses, were less favored locations by businesses at large (ibid.).

Overall, transit and built infrastructure have substantial influence on the location choices of offices. Transit has the ability to direct urban form (Meija-Dorantes, Paez, & Vassallo, 2012), and when combined with a favorable built environment, transit nodes become preferable locations for agglomeration of certain employment sectors. An added benefit, a crucial one, of being located in proximity to a station is the reduction in total travel time of employees and clients.

2.3. Equity

In simple terms equity refers to fairness, fairness in the distribution of resources, rights, opportunities. Equality differs from equity as it concerns with the equal distribution of these essentials of life. Equity goes a step further than equality by taking into consideration both components of just and fair. Equitable distribution is vital for a well-functioning society as people's needs differ based on their personal circumstances, making equal distribution of resources insufficient.

Transport and equality are linked on several grounds. The distribution of services and jobs, the location of residential neighborhoods, the degree of accessibility to the transport system itself are factors that contribute to shaping the socio-economic status of people (Gates, Gogescu, Grollman, Cooper, & Khambhaita, 2019). However, having an "equal' approach to diminish socio-economic inequality would only address one-half of the issue. In a society that comprises of, for starters, various classes, working towards an equitable society begins with realizing that not every individual is at the same staring line and does not benefit from equal distribution of resources. The need to analyze the equity aspect of the comes from literature's constant reminder of how the upper and middle classes gain the most from investments in rail transportation, and sometimes at the cost of the transit-dependent poorer communities (Fan, Guthrie, & Levinson, Impavt of light rail implementation of labor market accessibility: A transportation equity perspective, 2012).

Transport equity refers to the fair distribution of the benefits and costs of transport-planning impacts (Litman, 2020). Policies and decisions made in the field of transportation have an influence on individuals' social lives, access to economic opportunities, and travel time and costs as well as on land prices and economic development of the area. Increased land value from TOD can gentrify the neighborhood and induce displacement of low-income households from station areas (ibid.). This effect is not restricted to households alone.

Research carried out in American cities have found small businesses and low-wage jobs to undergo displacement due to unaffordable rents at and high-demand for such sites (Khabazi & Nilsson, 2021; Tornabene & Nilsson, 2021; Guthrie, 2018). A shift in the pattern of employment locations was also observed by Tyndall (2021) in four US cities, where a large increase in rate of employment in station neighborhoods was accompanied by a decrease in peripheral areas. A similar outcome was obtained by Guthrie (2018)'s analysis on TOD and social equity, that saw low-wage jobs being replaced by high-wage employment opportunities in transit areas. Khabazzi and Nilsson's (2021) study on the impact of light rail on commuting patterns in North Carolina, US, concluded that the benefit of TODs, such as reduced travel time and increase in employment opportunities, work in the favor of high-wage earners.

Research provides sufficient evidence on unfavorable impact on equity when TOD planning is not complemented by policies that support the risk-group. Low-wage and low-educated individuals dependent on public transit for a living are affected by the possibility of losing affordable housing and suitable jobs from central locations, having detrimental impacts on their social lives (Litman, 2020). Thus, it is argued that equity aspects be included from the beginning stages of transit planning to minimize inequitable outcomes.

2.3.1. Studying equity through employment sectors

The transit network and system of a region play an important role in creating an equitable society. Besides enhancing mobility, they dictate transit users' accessibility to essential services such as schools, hospitals, retail shops and leisure establishments. Transit equity is divided into two dimensions. The Horizontal dimension, one, concerns with the distribution of transportation planning impacts among equally abled individuals and groups (Welch & Mishra, 2013). The Vertical dimension, two, refers to the distribution of impacts among specific groups of society (ibid.).

Most research on transit equity is focused on assessing vertical equity, mostly through gentrification and displacement, using socioeconomic and demographic factors of population in transit communities (Khabazi & Nilsson, 2021). Most of the times, these measure changes ensued in household characteristics within a given perimeter subsequent to the opening of a rail line (Guthrie, 2018; Ermagun & Tilahun, 2020; Chapple & Loukaitou-Sideris, 2019). (Khabazi & Nilsson, 2021) analyzed employment equity aspects by studying changes in commuting patterns post rail transit implementation by using income as a factor. A widely employed approach that measures equity through accessibility to jobs is the cumulative or gravity-based opportunity method, the categorizes opportunities by job types (Fan, Guthrie, & Levinson, Impavt of light rail implementation of labor market accessibility: A transportation equity perspective, 2012; Kelobonye, Zhou, McCarney, & Xia, 2020).

In this thesis, the aspect of equity for the chosen rail corridor is assessed for employment through the composition of the types of employment sectors present within the catchment area of the nodes. 'Employment sectors' is used as a determinant of the nodes equity performance as average salaries is found to vary per sector in the Netherlands (I Am Expat, 2021; Statista , 2021), for reasons such as required level of labor productivity or education (Kouvavas, Kuik, Koester, & Nickel, 2019). From a corridor level, the differences in the composition of type of employment sectors across nodes demonstrates the current distribution of employment opportunities along the line and provides a basis for equitable planning of nodes.

2.3.2. Equity from the perspective of accessibility

Addressing transport equity issues has resulted in a growing interest of researchers and the like in understanding the importance of having access to essential activities (Curl, 2018) in creating an equitable society or, at the least, limiting the inequitable consequences of transport planning. Methods measuring accessibility, based on opportunities reachable within a certain distance or time, provide empirical details neglecting a subjective aspect of it.

Accessibility is perceived differently among members of society (Curl, 2018). As learned from previous research on transport poverty or inequality, the perception on accessibility is a variable of many factors such as gender, age, physical abilities (Tennakoon, et al., 2020; Bastiaanssen, Transport poverty in South, 2012), in other words different factors shape an individual's necessities which in turn deems what one perceives as "accessible". Moreover, employment industries are seen to be gender specific. According to Bastiaanssen (2012), the hospitality and housekeeping industries are mostly employed by women and the construction and transport sectors by men. Departing from the subjective aspect of accessibility, equity issues also surface when development of public transit is focused along main railway corridors. This results in restricted accessibility to surrounding regions of employments for carless households. Moreover, studies have shown lower travel times to have a positive contribution to uptake of jobs (Bastiaanssen, Johnson, & Lucas, 2021), implying that an incompetent transportation system can deter the employment rate of a region or nation.

2.3.3. Transport Poverty

A study done on transport equity is incomplete without a discussion on transport poverty and transport justice. Transport poverty is experienced by individuals whose access to transport resources is below adequate levels in comparison to a given population (Jeekel & Martens, 2017). This poses as a limitation on an individual's potential mobility which is argued to negatively affect their participation in society. The source of such poverty can be financial (unaffordability of a car), legal (not being licensed to drive), or personal (inabilities of the body or mind) (ibid.).

Transport poverty does not always imply accessibility poverty (Jeekel & Martens, 2017). For an individual residing in a location that identifies as a mixed-use development, he or she is less dependent on transport-related resources to get to their destination. Transport poverty equates to accessibility poverty location of the desired destination requires the individual to use some form of transportation to cover a significant distance to get there. Conversely, poor land-use planning can cause accessibility poverty for an individual who faces no restrictions in mobility (ibid.).

Transport and land-use planning are two sectors that governments influence or control through policies. They are both vital in shaping cities and, consequently, the spatial distribution of inequalities within them (Pereira, 2018). The role of transport policies in determining accessibility has been the basis of transport poverty discussions, the rationale being that the government is responsible for ensuring that their people have access to basic transportation facilities to meet their daily needs. Jeekel and Martens' (2017) correlate access to transportation services with healthcare, education, and housing, arguing that it is as crucial as the other three in supporting an individual's social life. They imply that it is every individual's right to have access to respectable quality public transport, emphasizing on the concept of transport justice.

Since this study focusses particularly on the equity aspect of node-place characteristics in influencing the employment sectors in the region, analyzing data for transport poverty is beyond the scope of the research objective. The concept of transport poverty, though, is a reminder of the pivotal role of mobility and accessibility in an individual's life and why the possible undesirable consequences of TOD need to be managed in early stages of planning.

Transport equity, thus, is a tapestry of several individual significant elements that are interlinked. This research only touches the surface of this topic, based on the fact that the distribution of jobs interconnects the fields of transport and socio-economic equality (Gates, Gogescu, Grollman, Cooper, & Khambhaita, 2019), by analyzing how equitable are the easily accessible locations (city-centers) in terms of sector-wise employment opportunities, irrespective of demographical and other characteristic-based variables of population. Equitable, here, does not refer to equal composition of employment sectors but to an employment market not overpowered by certain sectors. It is known that low-income earners are dependent on transit for their mobility to regions beyond walkable distance. In the Netherlands, the provision of social housing in central locations of cities should be supported by the availability of jobs of different educational levels within reach or it defies the purpose of both, enhancing transit systems and provision of social housing in central locations. As explained by Guthrie (2018), a lack of opportunity within the station area would render supporting housing policies futile.

3. RESEARCH METHODOLOGY

3.1. Research Philosophy

Research philosophy guides a researcher's approach to data collection and analysis based on their belief and availability of data (Ramsberg, 2018). It also gives the reader of the article an impression of the nature of the work employed by the researcher. There is a spectrum of philosophies, with positivism at one end and interpretivism at the other (Ramsberg, 2018). Positivism is rooted in science, researcher's base their analysis on logic and proof. In contrast to it, Interpretivism investigates a phenomenon through understanding individuals' experiences of it (ibid.).

To identify the philosophy that guides this research, we go back to the research question to understand the objective of this study. Answering the research question entails the statistical testing of a hypothesis by studying the relationship between two fields using numerical and categorical data. The absence of any subjectivity, through interviews, surveys, observations, and my personal view in the data collection stage, aligns this research with the (post-) positivism philosophy. Through the confirmation of the hypothesis, the analysis seeks to logically reason the location choices of different occupational sectors around transit areas.

3.2. Research approach

Researchers can take one of three approaches to their research - deductive, inductive or abductive (Dudovskiy, 2020). A deductive approach uses a general theory to formulate a hypothesis. The hypothesis is tested through observations for a particular circumstance which, then, either confirms or rejects the theory (ibid.). Deductive research narrows from a broad area of general theories to applying them to a specific situation. Research that results in the development of a generalizable theory based on a specific situation is an inductive research. Such research exclude hypothesis testing as the aim is not to confirm an existing theory, rather a researcher starts with making observations in order to explain some apparent pattern and conclude with a new theory (Dudovskiy, 2020). Abductive research is aimed at identifying the most reasonable explanation of a fact which cannot be reasoned by existing theories (ibid.).

The hypothesis tested in this study is informed by previously done research on the impacts of rail transit on firms' location choices. Because a general theory is being tested for a specific region, Den-Haag – Rotterdam, the approach taken in this research can be identified as deductive.

3.3. Research Methodological Choice

Amongst the methodological choices of quantitative, mixed and qualitative methods this research evidently adopts a quantitative analysis. To obtain an answer to the research question, the two fields (TOD characteristics and employment sectors) are expressed through variables for which data are sourced from the country's databases and websites of travel-service providers. The relationship between the fields is analyzed through the variables in a statistics software, which runs basic equation to determine the effect of the independent variables, characteristics, on the dependent variable, employment sectors. This differs from qualitative research mainly by the type of data used (Dudovskiy, 2020). A qualitative study can also make use of a statistical analysis, however data for it is obtained through interview transcripts, images, recordings, etc.

4. RESEARCH METHOD

Among the 23 stations of the RR-E, Den Haag Centraal, Laan van NOI and Rotterdam Centraal are central stops for different transit modes - metro, train, tram, and bus. Figure is a GIS representation of the overall rail corridor.

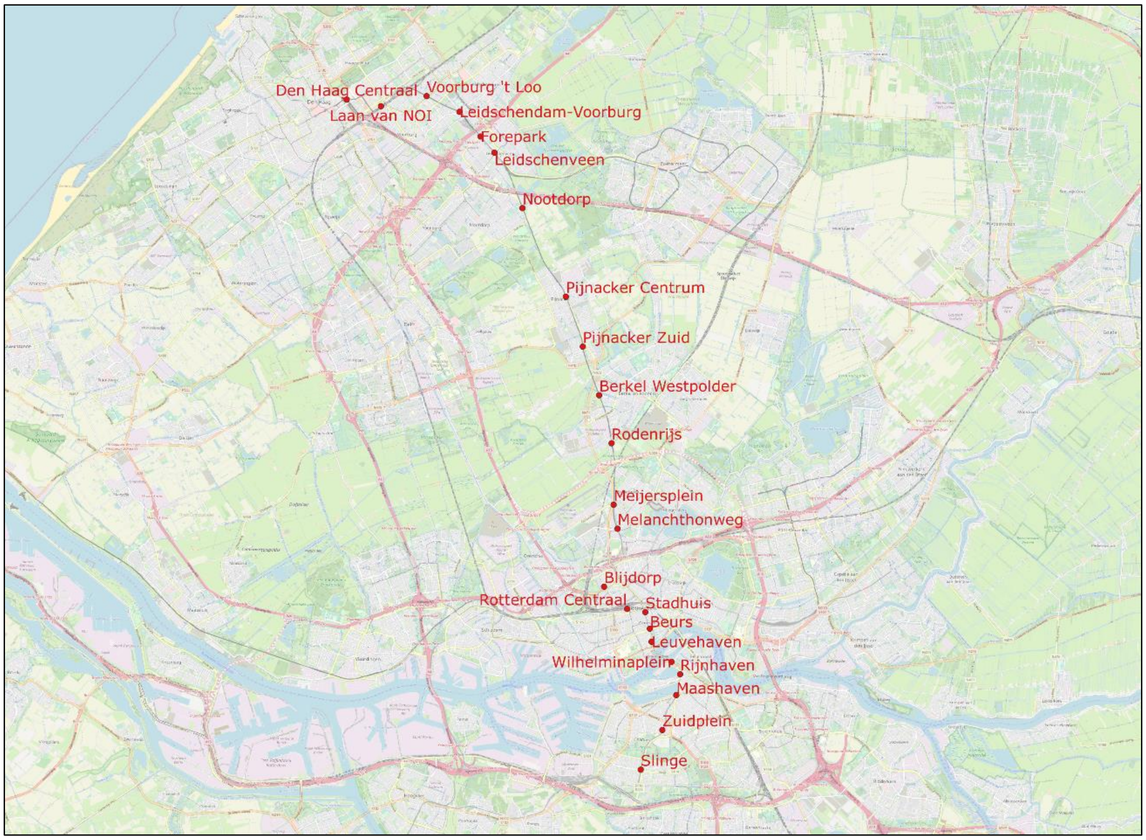

Figure 6: GIS representation of RR-E corridor

Prior to studying the relation between TOD characteristics and location choices of employment sectors, the stations must be identified for their typology in order to identify any existing patterns in the results. For this purpose, the analysis is conducted in two stages. The first stage is a two-step cluster analysis, conducted in the statistical software IBM SPSS, used to group stations of the RR-E that share similar characteristics. Based on literature three built-environment characteristics and two transit characteristics, representing place and node characteristics respectively, are used for the analysis. Each characteristic is measured by a combination of indicators, that correspond with the aim of this research. The data used for the cluster analysis is from the year 2018 as all relevant databases are complete up to then. Data is aggregated and standardized for an area of radius 800m to represent each station's node and place characteristics.

Cluster analysis in transportation has been carried out on stations of a specific transport mode, for example train stations (Chorus & Bertolini, 2011; Bertolini L. , 1999; Reusser, Loukopoulos, Stauffacher, & Scholz, 2008). Bertolini's (1999) node-place model uses a set of node and place characteristics of multiple stations to group highly comparable stations, however the variables employed in the clustering process of the RR-E stations deviate from those. The cluster analysis incorporates the below-mentioned TOD factors and employment sectors, resulting in the grouping of stations according to node-place features and employment-sector accumulation. In doing so, an insight into the dispersal of firms, by sector, quantity and size, around the RR-E is gained.

A two-step cluster analysis (TSC) is chosen for the grouping of stations because of its flexibility to work with categorical and scale data. As the name suggests, TSC conducts clustering in two stages– pre-clustering followed by hierarchical clustering (Reusser, Loukopoulos, Stauffacher, & Scholz, 2008). Based on the Bayesian Information Criterion a fitting number of clusters are generated however the TSC allows the researcher to pre-enter a number of interest (ibid.).

The cluster analysis provides a basis for categorizing stations which guides the selection of stations for the second stage of the analysis. A multinomial logistic regression is carried out in the second stage to study the relation between node-place characteristics and employment sectors found in the region. For this step, data on employment sector and surrounding built environment characteristics is recorded at the 6-digit postcode level for selected stations. The catchment area remains the same, radius = 800m from the transit node. A radius of 1-2km is not opted for in this research because most metro passengers travel to the station by foot. From an equity standpoint, the use of other transit modes from the station to place of work would add to the expense of the traveler. By considering a radius 800m, the last leg of the journey is reduced to the widely accepted appropriate distance for pedestrians. The data used for the logistic regression is from the year 2017. This is done in order to check for the applicability of the results by comparing it with the region's composition of employment sectors in 2018.

4.1. Description of variables

4.1.1. Independent variables

Cluster Analysis

<u>Density</u>

Density is measured by three indicators – population, household and job densities. Population density measures the number of people per unit area and is indicative of the concentration of people in a region (Hummel, 2020). Similarly, housing and job densities represent the concentration of dwelling units and employment opportunities for a given area. Depending on the research goal, these indicators have been employed separately or in combination. By itself, population density or housing density has been used in transit-related research that analyze mode choice of travelers in selected locations (Cervero & Kockelman, 1997; Ewing & Cervero, Travel and the built environment, 2010), or study the degree of TOD (TODness) of a node (Singh, 2015) or the relation between TOD typologies and gentrification (Huang, Grigolon, Madureira, & Brussel, 2018). The use of a combination of density indicators is found in studies that distinguish between urban and sub-urban areas such as in (Hummel, 2020) and (Frost, Appleyard, Gibbons, & Ryan, 2018).

The use of the three density indicators is applicable to this study as the RR-E corridor elongates over a region that comprises of urban and suburban regions. Combined, these indicators include the level of economic activity in the station area for the cluster analysis.

Table 1: Density indicators

Indicator	Calculation method
Population density	Number of inhabitants per square kilometer (km^2)
Household density	Number of residential units per km^2
Job density	Number of jobs per km^2

Diversity

Land-use mix quantifies the various uses of land in an area (Jiao, Rollo, & Fu, 2021). As explained in section 2.1.2, allocating land within a certain area to diverse uses promotes the use of transit or active forms of mobility. Thus, the level of land-use mix is decisive in making for an effective TOD. A commonly used measure of land-use mix is the Entropy index (Singh, 2015; Jiao, Rollo, & Fu, 2021),

$$LU = -\frac{\sum_{i=1}^{k} P^i \ln P^i}{\ln k}$$

Where,

P^i: percentage of land allocated to a certain use in area of analysis *I*, calculated as,

$$P^i = \frac{Area\ of\ certain\ land - use\ in\ area\ of\ analysis\ i}{Total\ area\ of\ analysis\ i}$$

k: total number of land-uses in area of analysis *i*

The index takes a value from 0 to 1, where 1 signifies equal heterogeneity and 0 indicates single use of the area being analyzed (Ewing, Greenwald, Zhang, Bogaerts, & Greene, 2013). The incorporation of land-use mix in this research helps to understand the relationship between area diversity and the type of business sectors it attracts.

Design

Within this study, the design characteristic assesses two features of 'street design' in the area of analysis and is measured by 2 indicators - length of walkable and cyclable paths and street intersection density (Frost, Appleyard, Gibbons, & Ryan, 2018; Singh, 2015). The first indicator measures the total length of accessible routes by foot/bicycle around a node which signifies the integration of a node within the developed neighborhood. The second indicator, intersection density, is used in assessing the connectivity and, hence, walkability of an area (Environment Atlas, 2015). In the case of TOD, it relays the ease of traversing to a node by foot or bike, as intersections shorten travel distances. Hence, high intersection density indicates a favorable environment for pedestrians and cyclists.

The inclusion of off-street parking facilities (Park and Ride, parking lots) near transit stations is considered necessary to support the use of transit. The availability of parking spaces for bikes and cars allows passengers to switch their mode of travel and cover major part of their journey by transit. This is mostly beneficial for long distance commuters (Singh, 2015).

From the perspective of businesses, being in proximity to a transit node that is in a locality designed to encourage walking and cycling makes them easily reachable to employees and clients. A P&R may not seem directly useful to businesses. However, they can help reduce the number of cars within the district and allow easy flow of traffic. The availability of parking is important to some business sectors (K&E Flatwork LLC, 2020), and it is known to be an attractive feature to businesses in general. To include this aspect within the theme of this thesis, non-P&R off-street parking facilities in the immediate vicinity of the stations are also considered in the analysis.

It is usual for bike parking facilities to be present at transit stops and around corners of buildings in the Netherlands. Hence it is excluded as a factor. The difference in sizes of bike parking facilities could be a practical indicator to include, but because of the lack of information it is dropped out of the analysis as well. As for car parking facilities, P&Rs and non-P&R off-street parking spaces are not common around transit stations. Hence, car parking is incorporated into the analysis as a categorical variable. The size of the parking lot may not be an appropriate indicator as it would not be suggestive of the built environment characteristics. For example, a P&R in a suburban region may be equivalent in size to an underground parking garage in an urban area. It would be useful to incorporate both types of parking facilities as categorical values when information on parking size (for bike parking) and type (for car parking) is available.

Table 2: Design indicators

Indicator	**Calculation method and Unit**
Total length walkable and cyclable paths	Sum of all applicable path segments in km
Street intersection density	Number of intersections per km^2
Parking facility	Total area of off-street parking for cars in km^2

<u>Distance</u>

The distance between node and 1) nearest CBD and 2) nearest train station is represented by a single variable “Distance between a metro station and nearest train station” in the analysis. The RR-E consist of a mix of train and metro stations that connect urban and suburban areas between Den Haag Central, Den Haag and Slinge, Rotterdam. The metro stations connect areas within the province or municipality, but the train stations connect that region with cities across the country. The train stations are also located in the CBDs (Den Haag and Rotterdam) of the South-Holland region. Thus, the distance to the nearest train station already factors in the distance to the closest business district.

Distance of a node to the nearest business district influences its development (Chorus P. R., 2012). This could be a useful factor in identifying patterns of development, if any, at the corridor level. Section 2.1.2 explains, with examples, why businesses prefer to agglomerate and there is no question as to the importance of including ‘distance to CBD’ as a variable in this research from the angle of business’ location choices.

Distance of a node from the highway is also an important feature of the node-value of TODs, also seen in the Butterfly model (figure 4), as it reflects the multimodal accessibility to the node and its connectivity within the transport infrastructure. Locating offices around highways makes them easily accessible by car. Considering that mobility-enhancing strategies have been or were the preferred approach in transport planning, also encouraging people’s preference for the private vehicle, it is understandable why employment centers choose to locate near highways. (Giuliano, Redfeam, Agarwal, & He, 2012) highlight that this continues to be the situation in the United States. (De Bok & Sanders, 2005)’s empirical analysis based in the Netherlands (that also considers proximity to rail stations) and (Leitham, McQuaid, & Nelson, 2000)'s combination of qualitative and quantitative study in the UK, on discerning the factors that firms considered when choosing locations, confirm closeness to highway being a chief factor as well.

Table 3: Distance indicators

Indicator	Unit
Distance between metro station and nearest train station	km
Distance from metro station to nearest highway	km

<u>Accessibility</u>

Accessibility to and by transit is measured by three indicators – transit frequency, route interchange by same transit mode and mode interchange. Transit frequency considers the temporal factor of transit services. The transit frequency determines the waiting period of passengers and, thus, accessibility by and to transit. Higher transit frequencies positively contribute to the accessibility of transit services. The possibility of switching routes on the same mode provides commuters with connections to destinations on other rail transit lines, expanding their accessibility by and to transit to get to different places. Similarly, the option of switching modes at a node increases accessibility to and by transit and gives users the option to continue their journey by public transport. The three factors put together help stimulate the use of transit.

The frequency of a transit mode is weighed differently prior to summing the total frequency at a station. This is because the user-value of each mode varies (van der Zwet, 2019). To account for this preference, the frequency by a certain mode is multiplied by the corresponding value assigned to each mode, as given in table 4.

Table 4: User-value per mode

Mode	User-value
Bus	0.25
Tram	0.5
Metro	0.75
Train	1

In general, apart from land-intensive industries, accessible locations are preferred location choices of many business sectors. The accessibility provided by transit connects them to the market and labor force. As seen from the literature review, accessibility has been an influential factor in firms' relocation choices. Including the three factors on accessibility in the research will elucidate how transit intensity influences the composition of business sectors around nodes.

Table 5: Accessibility indicators

Indicator	Calculation method
Frequency of transit service	Total frequency of all modes of transit per hour
Route interchange (same mode)	Number of routes
Mode interchange (categorical variable)	0 (no alternative mode), 1 (on-street bus stop), 2 (tram stop), 3 (tram and bus), 4 (bus station) 5 (>2 modes available)

Multinomial Logistic Regression (MNL)

The multinomial logistic regression evaluates the chances of categorical membership on the dependent variable for a set of independent variables (Starkweather & Moske, 2011). The results from the analysis are expressed in terms of odds ratios, that is the values obtained are in comparison to a base category (Beckers, 2020).

Referring to the work by Meija-Dorantes et al. (2012) few factors used for the cluster analysis have been replaced to align them with the goal of this research. The variables measuring the 3Ds are evaluated for a constant area of radius 100m around each establishment.

Population density:

An assumption of the MNL is absence of multicollinearity amongst the independent variables, which otherwise would produce unreliable outcomes. Thus, 'household density' is dropped and 'population density' is retained.

Firm density

Job density is replaced by the variable measuring firm density within a 100m radius of an establishment. This analyzes the role of the number of firms in the location choices of businesses belonging to different sectors. It must be noted that this measure does not account for agglomeration but is simply a representation of the concentration of businesses in a given region.

Diversity

Economic-sector diversity replaces land-uses diversity to incorporate the influence of diversity in businesses on location choices of employment sectors. The entropy index is measured according to the formula (Siegel, Thomas, & Alwang, 1995),

$$Entropy\ Index = \sum_{i=1}^{N} X_i \ln X_i$$

An entropy index of 0 indicates that within the area of analysis income is generated by a sole sector. In a region with balanced diversity of sectors the index takes the highest value of ln *N* (ibid.).

Design

Street density is used in place of the other design measures that are part of the cluster analysis. Neighborhoods with a dense street pattern are considered to be pedestrian friendly (Meija-Dorantes, Paez, & Vassallo, 2012). This factor relates the likelihood of a business sector to locate in a CBD or in a distant locality. Information on the parking facilities for the year 2017 was unavailable at the time of data extraction, hence it was excluded from the MNL.

$$Street\ density = \frac{Total\ length\ of\ streets\ in\ area\ of\ analysis}{Area\ of\ analysis}$$

Distance

Besides 'Distance to nearest CBD' and 'Distance to nearest highway', the MNL includes 'Distance to station' as a factor. The distance of each establishment to the nearest station accounts for the relation between the location choice of a firm belonging to a certain employment sector and the distance to the nearest metro/train station. Since the overall area of analysis is set to 800m the distance of the firms to the nearest RR-E station lies between 0m and 800m, inclusive of 800m. It must be noted that the distance calculated for all three variables for the MNL is the straight-line distance between two points, establishment and endpoint, measured in GIS.

Table 6: Variables for Multinomial Logistic Regression

Characteristic	**Variable**	**Unit**	**Source**
Density	Population density	1000 per km^2	CBS
	Firm density	1000 per km^2	CBS
Diversity	Economic sector diversity	(Index)	LISA
Design	Street Density	per km^2	PBL/NWB
Distance	Distance to CBD	km	GIS
	Distance to station	km	GIS
	Distance to Highway	km	GIS
Accessibility	Frequency	per hour	PBL

Amongst the variables used for the MNL, 'Frequency' is the only variable measured at an aggregate level, it represents the total frequency of transit at the station and is the same as that used for the cluster analysis.

4.1.2. Dependent variable

The dependent variable in the MNL is "Employment Sector". This research works with the number of firms within an employment sector instead of number of full-time jobs as the goal is to find the relation between type of industrial sector with the physical characteristics of the station area or what node-place characteristics attract what industrial sectors. Here, the interest is not in the size of the business, but it is about the existence of an industry in the region; where would a business choose to be located given certain factors. Number of jobs fluctuate based on company performance and requirement. The number will increase or decreased with changes in the market, this would not really relate to objective of this research. By considering the number of firms, and not the number of jobs, changes within a company or organization is excluded from the analysis. Thus, if there is a new business within a particular sector at a given region this is reflected in the data and any small changes like increase or decrease in the size of a business is ignored. This way what could be major fluctuations in data, for example shutting down of a company, does not reduce the numbers by a large amount.

The Netherlands groups its economic sectors, equivalent to employment sectors in this research, into twenty-one categories,

A Agriculture, forestry and fishing
B Mining of Minerals
C Industry
D Production, distribution and trade in electricity, natural gas, steam and cooled air
E Extraction and distribution of water; waste and wastewater management and remediation
F Construction
G Wholesale and retail trade; repair of cars
H Transport and storage

I	Lodging, meal and beverage provision
J	Information and communication
K	Financial Institutions
L	Real estate rental and trade
M	Advice, research and other specialist business services
N	Rental of movable property and other business services
O	Public administration, government services and compulsory social insurance
P	Education
Q	Health and welfare care
R	Culture, sport and recreation
S	Other services
T	Household as employers; undifferentiated production of goods and services by households for their own use
U	Extraterritorial organizations and bodies

Sector T establishments are not present within the region of analysis, and sector U establishments are only found in catchment area of stations Den Haag Centraal and Laan van NOI. The number of firms or organizations belonging to a sector present in a given station area is the determining factor in understanding the role of node-place characteristics in the location choices of businesses.

4.2. Data extraction and collection

This section explains the process used for obtaining the relevant data on the variables used for the statistical analysis.

4.2.1. Two-Step Cluster Analysis

Table 7 includes details on the indicators and their type used as input in the first stage of the analysis.

Table 7: Data sources and units of the independent variables

Feature/ Characteristics	Indicator [Independent variable]	Source	Variable Type
Density	Population	LISA	Scale
	Household	CBS	Scale
	Job	LISA	Scale
Diversity	Land-use mix	BAG	Scale
Design	Length of walkable/cyclable paths	OSM	Scale
	Density of Street intersection	NWB	Scale
	Parking facility	OSM	Scale
Distance	Distance between metro and nearest train stations	GIS	Scale
	Distance to nearest highway	GIS	Scale
Accessibility	Frequency of transit services	PBL	Scale
	Route interchange	9292.nl/OVNL Wiki	Scale
	Mode interchange	PBL/Google Maps	Categorical

Density

The LISA database contains data on employment and economic activities of work establishments in the Netherlands at different geographical levels. Data at the 6-digit postcode level is used for to evaluate the job densities in the area of analysis. The option of "intersection" in GIS extracts the necessary data. The job numbers at each postcode are aggregated per station to calculate the density per square kilometer.

Population and housing densities for each station are acquired in a similar manner. The CBS database provides the required data at the neighborhood level. By using the intersection feature in GIS, the population and number of households that fall within the catchment area of the stations are extracted. These are then aggregated to calculate the population and housing densities for every RR-E station.

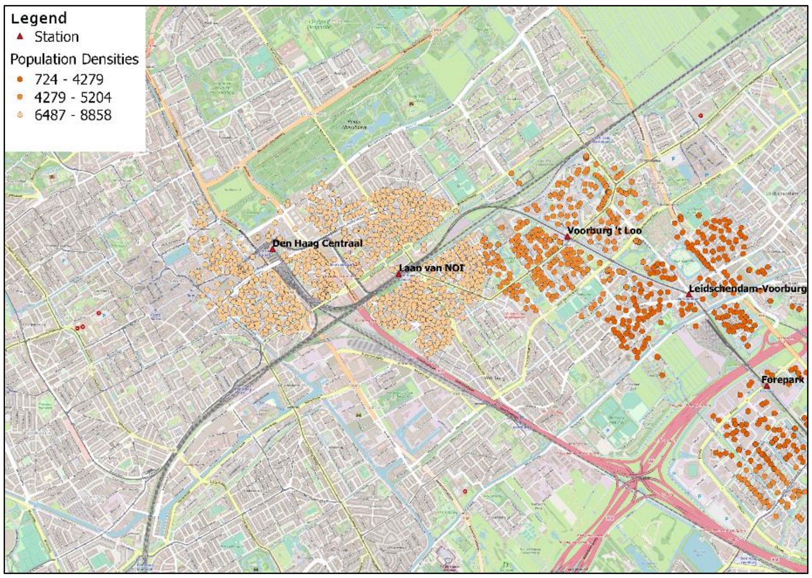

Figure 7: GIS representation of aggregated population densities (per km²) within TOD

Figure 8: GIS representation of neighbourhood household distributions (unaggregated in numbers)

Diversity

Data on the different types of land-use within the area of analysis is available in the BAG database of the Netherlands. The data on land-use within the area of analysis is extracted following the same procedure as conducted for data on density. There are 11 identified functions, as seen in the legend in figure. Since 'celfunctie' is present only in 3 of the 23 station areas, it is omitted from the analysis.

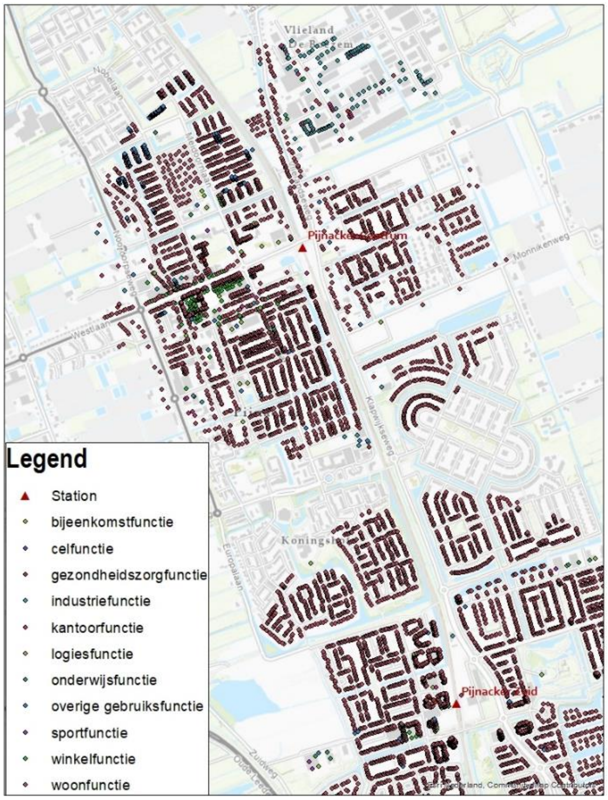

Figure 9: GIS representation of land-use at Pijnacker Centrum and Pijnacker Zuid stations

Design

Length of walkable and cyclable paths:

The road network of South-Holland, classified by type, is available on OSM. To include only the applicable routes in determining the total length of walkable and cyclable paths, the "clip" and "extract by expression" functions are used in order to retain roads classified as *cycleway, footway, living street, path, pedestrian, residential and unclassified* from the road network map for the specified area. This step ensures that roads not suitable for walking and cycling, such as highways and other motorways, are excluded. The selection of classified roads is based on their description in https://wiki.openstreetmap.org/wiki/Key:highway and is cross-checked with van der Zwet's (2019) research. The length of the selected paths is calculated in GIS and summed for individual stations for the total length of cyclable and walkable paths.

Figure 10: GIS output of walkable and cyclable paths

Street intersection Density:

The density of street intersections is also acquired from GIS using data from NWB. Data provided by CBS is not applicable for this purpose as it reflects solely the street network and does not include internal paths as in parks (for example). Prior to the intersection step, it is necessary to dissolve the path segments to exclude intersections that are a result of two joining lines and is not an actual crossing. Using the dissolve and intersection function, the actual number of intersections within the area of analysis is extracted, which is then divided by the area in square kilometers to get the intersection density.

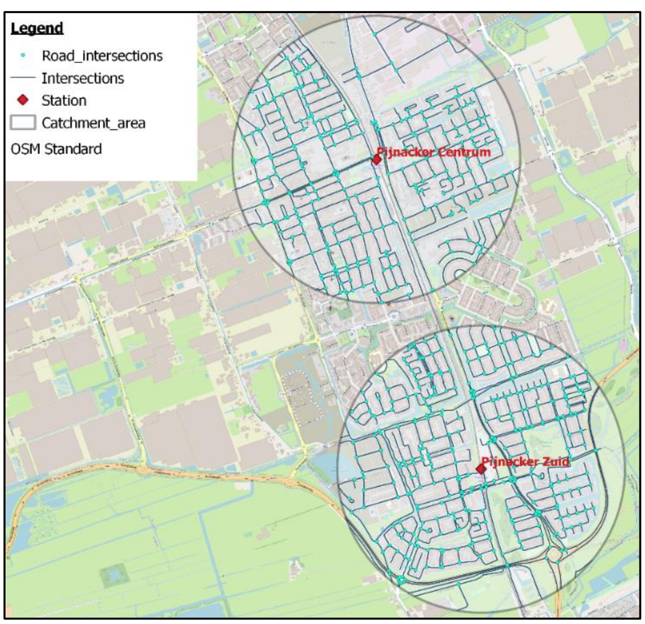

Figure 11: GIS output of road intersections

Off-street Car Parking facility:

The area of off-street car parking facilities is available in the OSM database. The extraction of this data for the selected regions is conducted through the intersection function in GIS. The total area of off-street parking facilities within each area of analysis is obtained separately using the sum function within the software.

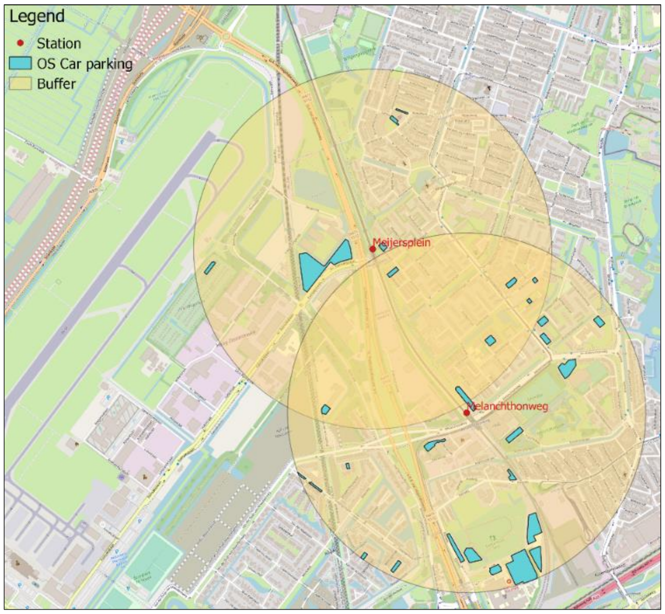

Figure 12: GIS output of P+Rs next to stations Meijersplein and Melanchtonweg

<u>Distance</u>

Distances between metro and train stations, and from metro to the nearest highway are calculated in GIS. The OSM database is used for information on transport infrastructure in the province of South Holland. The method to extract distance between metro and train stations is simple and is done through the "distance matrix" function available in GIS. The result includes distances between every station and the required data is filtered from the resulting matrix.

Distance from station to nearest highway is obtained using the ORS-tools plugin. The straight-line distance between a station a nearest highway does not always represent true information. For example, the straight-line distance between station *Blijdorp* and highway A20 is shorter than A13. In actuality, the distance to travel to A13 from station *Blijdorp* is lesser by approximately 0.36km. By using the ORS-tool, the location of the station(A) and the entry point of the nearest highway(B) are pointed out on the map and the distance of the shortest route between the two points is computed, thus producing tangible results.

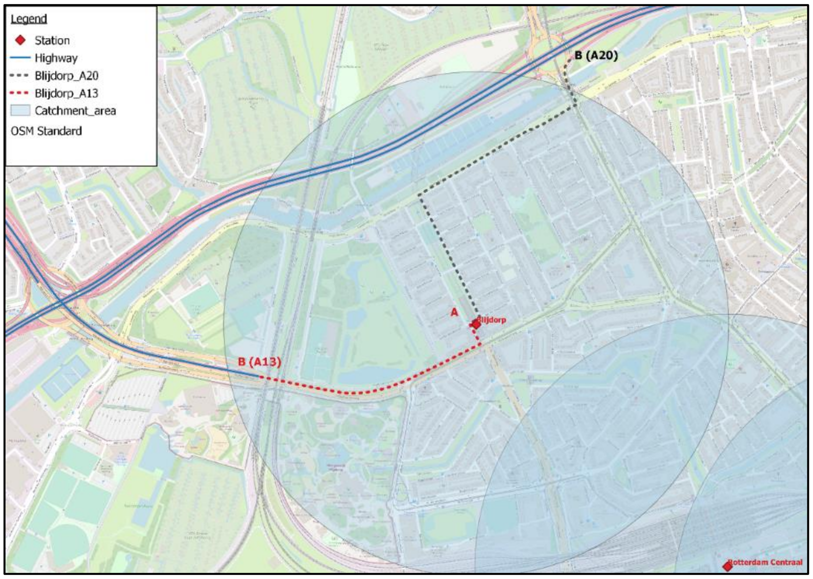

Figure 13: GIS representation of highway distances

<u>Accessibility</u>

Frequency of transit service

Information on the frequency of metro service for each station is obtained from the PBL database. The database contains information on single and return journey frequencies for 24 hours, between 7h00 – 19h00 and 7h00-9h00. Since this study is focuses on employment and business, the departure frequency between 7h00-19h00 as the general business hours are 8:30-17:30 (Business Culture, n.d.). In the 12-hour period, the approximate one-way frequency of metros is 6 for stations from Den Haag Centraal, Den Haag, to Blijdorp, Rotterdam. The approximate frequency increases to 15 for all stations from Rotterdam Centraal to Slinge, except for Beurs with a frequency of 33.

Route Interchange

For information on route interchange by the same mode of transport (metro), the website of 9292.nl and https://wiki.ovinnederland.nl/wiki/Openbaar_vervoer_in_de_stad are referred to. There are 5 metro lines - Lines A, B, C, D, E - that connect the Rotterdam region from East to West and North to South. The connection between these lines is made at the Beurs station. From the 5 lines, Line D runs parallel to the RR-E from Rotterdam Centraal to Slinge. Thus, starting from Rotterdam Centraal station travelers have the option of switching routes by metro. The stations from Den Haag to Blijdorp, Rotterdam are serviced by a single metro, RR-E.

Mode Interchange

The provision of alternative transport modes is available at all stations. Information regarding modal change is available on 9292.nl, Google maps and in the PBL database. Excluding stations Voorburg 't Loo, Voorburg and Forepak, Den Haag, all stations have a bus stop located nearby. Stations Laan van NOI, Den Haag to Leidschenveen, Den Haag are also equipped with tram services. Tram lines are available in proximity to stations Stadhuis, Beurs, Leuvehaven, Wilhelminaplein, Maashaven and Melanchthonweg. The two central stations, Den Haag and Rotterdam, and station Laan van NOI, in the Hague, are the only

3 stations along the RR-E line that have metro, train, tram and bus services at the same station. They are connecting points for the intercity passengers to the RR-E.

Data standardization

Standardizing data prior to conducting the cluster analysis is essential for meaningful results (Listen Data, 2017). A cluster analysis measures distances between variable observations to form clusters. Unstandardized variables will generate biased outcomes, where variables with higher scales will largely influence the grouping process. All scale variables are standardized using the formula (ibid.),

$$x_{std} = \frac{x}{x_{max}}$$

Where,

x_{std} : standardized value of indicator

x : value of indicator

x_{max} : maximum value of x within range

4.2.2. Multinomial Logistic Regression

Data on the variables for the MNL are obtained using the intersection function in GIS for an area of radius 100m around every establishment in the area of analysis (radius = 800m) of the selected stations. For stations with overlapping area of analysis (Den Haag Centraal and Laan van NOI), wherever applicable (such as for ‘distance to station’), repeated data is avoided using ‘nearest point’ option in GIS.

Information of business sectors is obtained from the LISA database. Using the intersection method, data on employment sectors present within the catchment area of the station is gathered. For the cluster analysis, the data is aggregated for the area of analysis. The MNL uses the same data but at the 6-digit postcode level of the selected stations. Corresponding to individual establishments, 6 digit-postcode data on the variables comprising the MNL are obtained from relevant data sources (included in table 5).

5. RESULTS

5.1. Descriptive Statistics

		A	B	C	D	E	F	G	H	I	J
N	Valid	23	23	23	23	23	23	23	23	23	23
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		6.91	.96	34.78	1.35	1.52	87.17	242.65	43.83	94.48	109.70
Median		4.00	.00	35.00	.00	2.00	64.00	147.00	30.00	24.00	59.00
Std. Deviation		7.483	1.609	21.616	2.102	1.275	72.093	237.372	33.629	125.593	105.264
Variance		55.992	2.589	467.269	4.419	1.625	5197.423	56345.601	1130.877	15773.715	11080.494
Skewness		1.527	2.228	.277	1.713	.740	2.203	1.749	.640	1.679	1.347
Std. Error of Skewness		.481	.481	.481	.481	.481	.481	.481	.481	.481	.481
Minimum		0	0	3	0	0	19	32	7	2	15
Maximum		26	6	77	7	5	307	898	111	414	379
Sum		159	22	800	31	35	2005	5581	1008	2173	2523

Figure 14: Descriptive statistics of employment sectors (above: sectors A-J and below: sectors K-U)

		K	L	M	N	O	P	Q	R	S	U
N	Valid	23	23	23	23	23	23	23	23	23	23
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		23.96	23.00	362.04	71.04	7.35	71.65	117.61	106.35	69.39	.57
Median		10.00	10.00	167.00	44.00	2.00	55.00	102.00	51.00	47.00	.00
Std. Deviation		29.939	24.563	352.177	59.680	12.615	47.195	68.394	103.521	55.413	2.313
Variance		896.316	603.364	124028.498	3561.680	159.146	2227.328	4677.704	10716.601	3070.613	5.348
Skewness		1.749	1.421	1.237	1.402	3.223	.627	.504	.946	1.016	4.570
Std. Error of Skewness		.481	.481	.481	.481	.481	.481	.481	.481	.481	.481
Minimum		2	1	59	8	0	13	25	8	2	0
Maximum		102	79	1187	213	58	169	247	331	191	11
Sum		551	529	8327	1634	169	1648	2705	2446	1596	13

Figure 14 provides descriptive statistical information on the employment sectors within the region of analysis. The ‘sum’ values show the number of firms per sector. Some of these values are exaggerated since there are numerous repeated observations due to overlapping of station areas, as seen in the GIS figures. These observations are retained since they are located within the catchment area of more than one rail station. A minimum value of 0 indicates the absence of firms in the respective sector in one or more station areas.

From comparing the minimum and maximum values of the sectors, we see that the predominant employment sector in the corridor is sector M (advice, research and other specialist business services) followed by sector G (wholesale and retail trade, repair of cars). The sector with the least number of firms in the region is U (extraterritorial organizations and bodies and the second-to-last is sector B (Mining of minerals).

In a normal distribution of the data, the median of a dataset is equal to its mean. However, every variable has a median slightly or largely deviating from the mean which implies that there is low or high level of skewness, respectively, in the data. The spread of the number of opportunities per sector varies largely across the stations. As an initial observation it is interesting to see diversity of employment sectors at the nodes, especially for those employment sectors that are present at every station in the corridor. Going back to the minimum and maximum statistics of sectors at each node, it becomes apparent that certain sectors are absent around some station areas of the RR-E. For example, there are 79 businesses belonging to the field of real estate at one station and only 1 at another along the RR-E. There is also a stark difference in the spread of the largest employment sector, sector M. It is widely spread across the region, with firms present at every station area but the quantity varies with the minimum being 59 in Slinge and 1187 in Stadhuis. This information is reflected in the standard deviation values for each sector as well, with larger sectors having higher values. The sum represents the number of firms per sector, the standard deviation is indicative of the quantitative difference of the firms at each station.

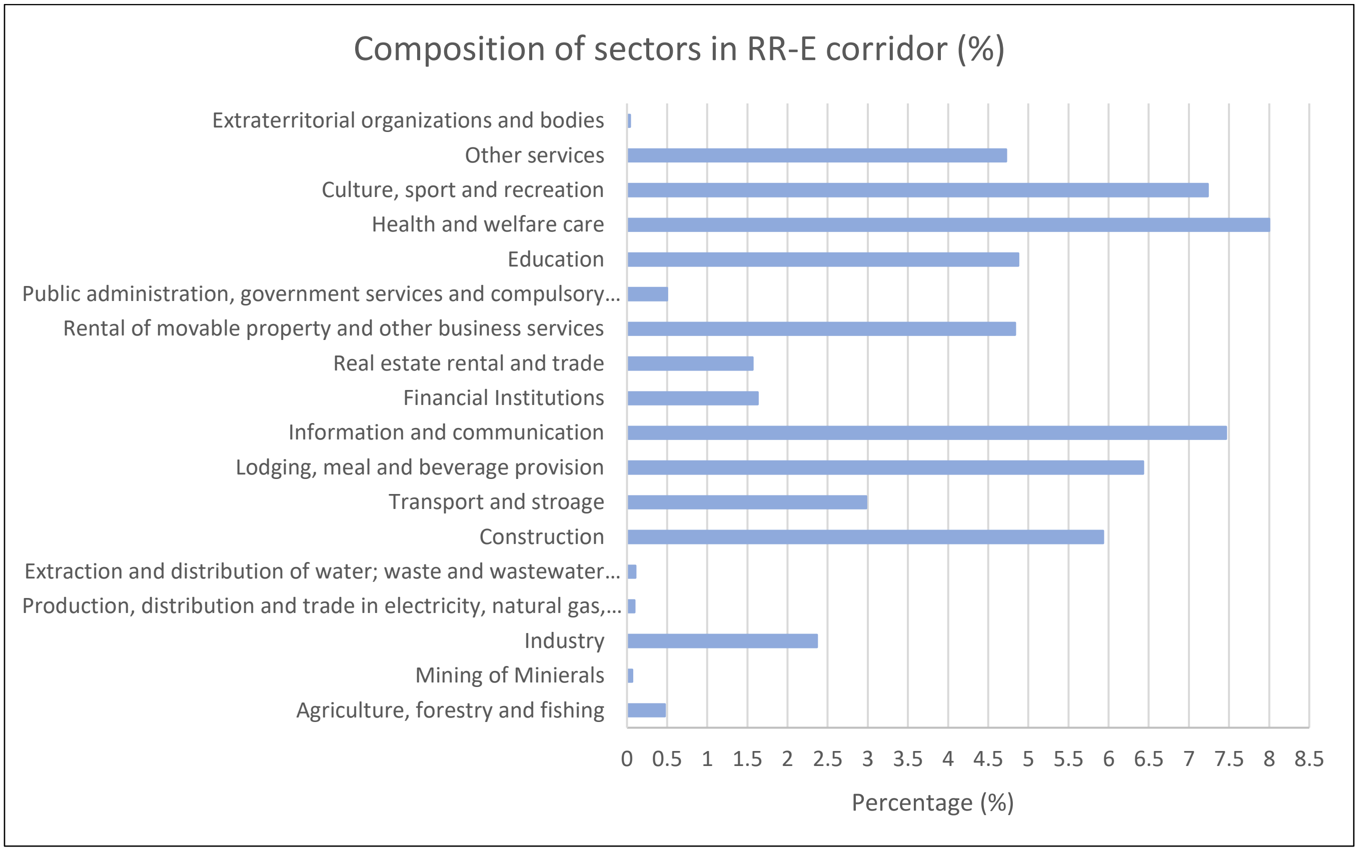

Figure 15: Composition of sectors in RR-E region as percentages

The overall presence of sectors along the chosen rail line is represent as percentages in figure 15. Sectors G and M are not included in the above figure to keep an x-axis range that visibly depicts the information. The two dominant sectors provide nearly 17% and 25%, respectively, of the total jobs within walkable distance of RR-E stations.

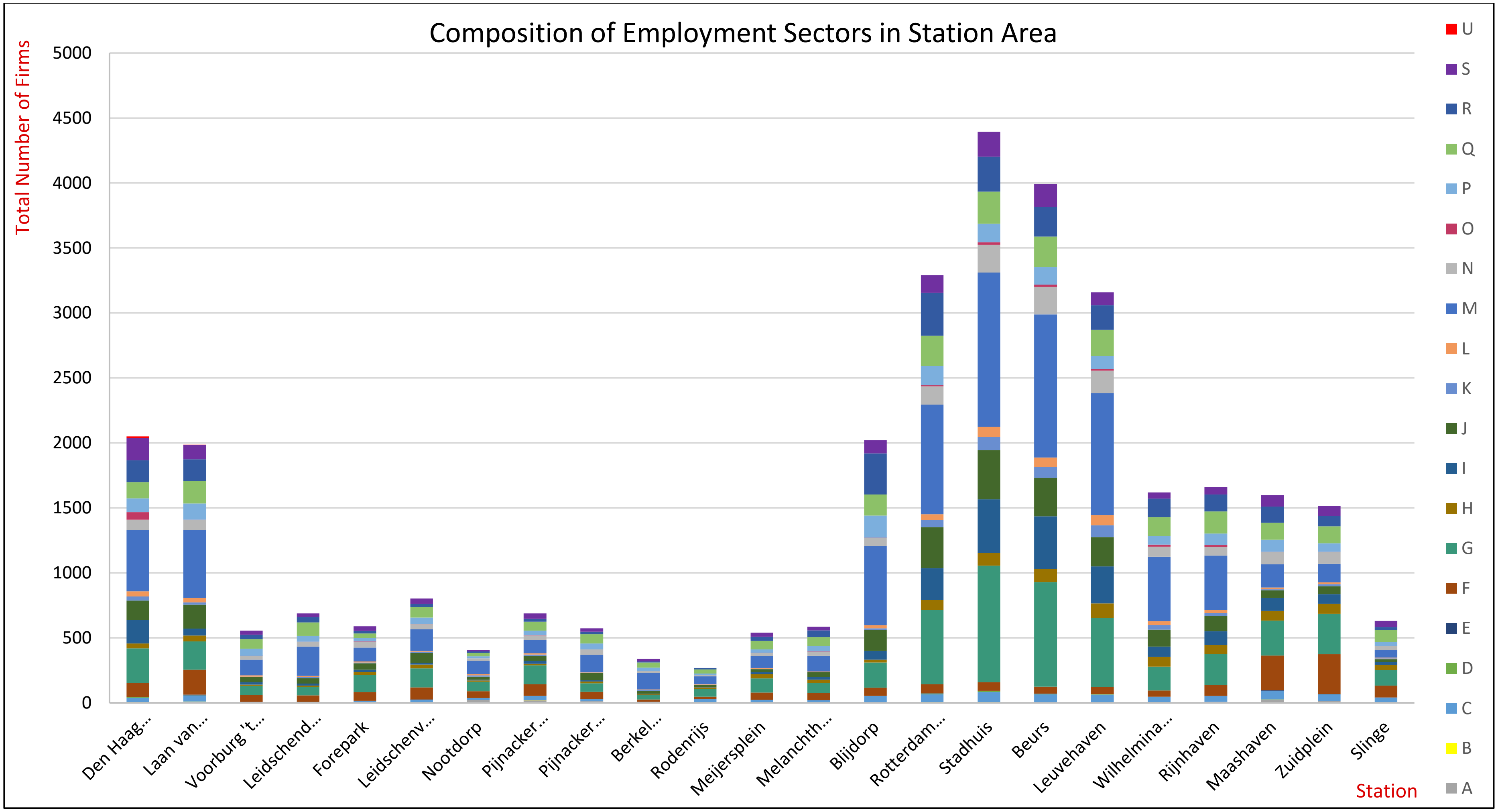

Figure 16: Composition of employment sectors at each RR-E station in 2017

Analyzing figure 16,

1. Sector U is only located around Den Haag Centraal and Laan van NOI of the RR-E line
2. Station Rodenrijs has the least number of establishments
3. Station Stadhuis has the highest number of establishments in the line

5.2. Two-Step Cluster Analysis

Several steps are taken to determine the suitable variables for the clustering of the stations. In the first attempt, only the node and place characteristics are used to determine clusters among the RR-E. The process resulted in a poorly fair grouping of the stations. In the second round, the employment sectors are included in the analysis. The outcome is highly influenced by Sector U, resulting in Den Haag Centraal being a category of its own. Consequently, sector U was excluded from further analyses. Also, the clustering process with the 32 variables (employment sectors and node-place characteristics) lowers the importance of the physical characteristics of the station area and groups them mainly on the basis of the employment sectors in the region. In order to mitigate the influence of the employment sectors or to enhance the role of node or place characteristics in the clustering process, the employment sectors are grouped into 5 sectors (table 7), similar to Bertolini's (1999) classification of economic sectors. Instead of 4 sectors the final classification includes 5 employment sectors that can be differentiated on the basis of level of education attained.

Reduced from 33 variables to 17 variables, the initial run of automatic detection of clusters produces an inconclusive result with 2 clusters. The output for a 3-, 4- and 5-cluster formation are then compared only to achieve depreciating quality of clustering. Excluding the total frequency from the process, alters the clustering and improves the quality of the grouping. Hence, the results from the 3-cluster formation, producing a highly fair grouping of the stations without the inclusion of the total frequency, is chosen for the remainder of the analysis.

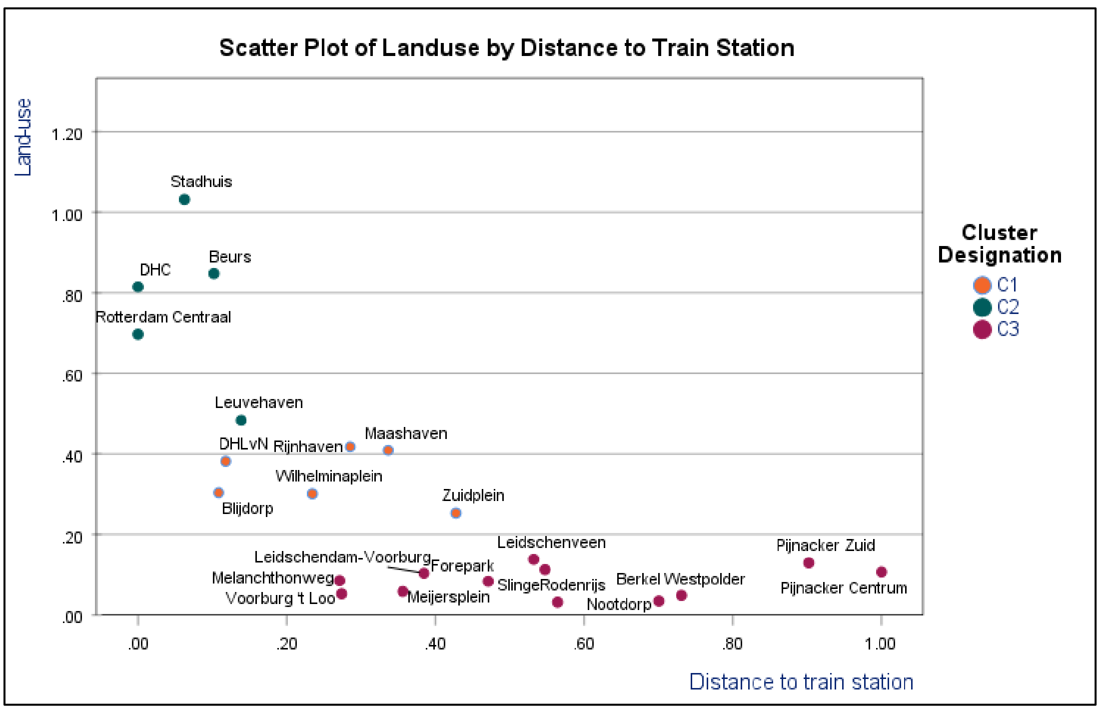

Figure 17: Land-use vs distance to station using the output from the 3-cluster formation of the RR-E stations

Cluster	P1	P2	P3	P4	P5	P6	P7	N1	N2	N3	N4	N5	A	B	C	D	E
C1	0.8	0.54	0.28	1.11	1.11	0.92	0.35	0.25	0.47	0.28	33% (2)	0.28	0.64	0.22	0.61	0.31	0.41
C2	0.74	0.67	0.83	1.29	1.29	1.18	0.64	0.06	0.43	0.51	40% (5)	0.51	0.43	0.71	0.88	0.79	0.85
C3	0.33	0.21	0.06	0.93	0.93	0.76	0.35	0.56	0.5	0.14	58.3% (1)	0.14	0.25	0.08	0.18	0.09	0.14

Figure 18: Mean of clusters for each characteristic (above) and characteristic description (below)

No.	Indicator	Description
1	P1	Population density per km^2
2	P2	Household density per km^2
3	P3	Job density per km^2
4	P4	Land use (entropy index)
5	P5	Total length of walkable and cyclable paths
6	P6	Intersection density per km^2
7	P7	Total area of off-street carparking
8	N1	Distance to nearest train station
9	N2	Distance to nearest highway
10	N3	Number of transferable routes at station
11	N4	Interchangeable modes (categorical)
12	N5	Combined frequency per hour of all PT modes at station
13-17	A-E	Employment Sectors

The clusters are most distinguishable by land use, job density, population density, housing density, distance to train station and 4 out of 5 employment sectors. Differences between factors associated with 'node' are obscure. This could be due to several reasons; the combined frequency and modal capacity between train and metro stations in CBDs vary greatly although they are similar in location characteristics. Station Zuidplein, of cluster type C1, has a combined frequency that is greater than that of the train stations located in CBDs. This is an anomaly given that all metro stations have a lower total frequency than the Rotterdam Centraal and Den Haag train stations. The Laan van NOI train station is also an exception as the collective frequency is equivalent or lesser than a few of the metro stations along the line. Such inconsistencies contribute to a fairly vague grouping of stations by accessibility factors, leaving interpretation of results to the aforementioned factors.

Cluster 1: Station neighboring a business district

Stations belonging to cluster group one (C1) are in the neighboring north or south areas of CBDs, including Laan van NOI. The mix of land uses is not the highest nor the least, within the region, and similar interpretations can be made about job density, population density, distance to train station and employment sectors D to I and B.

Cluster 2: *Station in a business district*

The distribution of variables for cluster group two (C2) stations are the highest for job and household densities, and sectors D to I and B. The population density, residents per square km, is lower in C2 than in C1. This indicates the presence of larger number of apartment-type housing within CBD areas; i.e. there are more residences for a given population in C2 considering space is limited in such regions. The distance to train stations is the least for this grouping.

Cluster 3: Station in a suburban neighborhood

Cluster group 3 (C3) includes the remaining stations that are located furthest from train stations, and compute the lowest job, housing and population densities, along with land use and number of sector D to I and B establishments. Stations categorized as C3 have the lowest total on public transport frequency.

5.3. Multinomial Logistic Regression

The location and public transport features and composition of businesses at selected stations are evaluated to analyze their role in location choices of different employment sectors. The stations chosen for this phase are Den Haag Centraal (2), Laan van NOI (1), Nootdorp (3), Stadhuis (2), Rijnhaven (1) and Slinge (3). Den Haag Centraal and Laan van NOI are consecutive train stations, the first belonging to the cluster 'stations in CBDs' and the latter to 'stations neighboring CBDs'. Station Nootdorp is in a suburban region between the two big cities, Den Haag and Rotterdam. Stadhuis, Rijnhaven and Slinge are metro stations in the Rotterdam region, located in the CBD and in a lesser commercial zone and in a suburban region respectively.

Several models with different combinations of the listed variables are run to obtain a model with a good fit and that which explains predictability of business sector location choices. All models with additional variables improved the goodness-of-fit, although only marginally, the final model includes all variables included in section 4.1.1 – Multinomial Logistic Regression.

Table 8: Final grouping of employment sectors

Consolidated Sectors	**Sectors included**
A: Natural Resources and Infrastructure	A: Agriculture, forestry and fishing B: Mining of minerals C: Industry D: Production, distribution and trade in electricity, natural gas, steam and cooled air E: Extraction and distribution of water; waste and wastewater management and remediation F: Construction
B: Retail and catering	G: Wholesale and retail trade; repair of cars I: Lodging, meal and beverage provision
C: Education, Healthcare and Recreation	P: Education Q: Health and welfare care R: Culture, sport and recreation
D: Public, financial and ICT services	J: Information and communication K: Financial Institutions M: Advice, research and other specialist business services O: Public administration, government services and compulsory social insurance
E: Transport, Logistical and other services	H: Transport and storage L: Real estate rental and trade N: Rental of movable property and other business services S: Other services

The final dataset comprises of data corresponding to 10093 establishments, a combined total of the number of firms located in the 6 chosen station areas among which there are 232 observations with missing data on population density. First, variables measuring the relation between *place* characteristics and employment sectors are analyzed.

Employment_sectors[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp (B)	
								Lower Bound	Upper Bound
A	Intercept	-.648	.416	2.430	1	.119			
	Population Density	.005	.004	1.327	1	.249	1.005	.997	1.013
	Firm Density	-.351	.048	53.494	1	<.001	.704	.640	.773
	Economic Diversity	1.018	.296	11.855	1	<.001	2.768	1.551	4.942
	Street Density	-.329	.064	26.073	1	<.001	.720	.634	.817
B	Intercept	1.715	.299	33.000	1	<.001			
	Population Density	-.009	.003	7.184	1	.007	.991	.985	.998
	Firm Density	.148	.023	40.946	1	<.001	1.159	1.108	1.213
	Economic Diversity	-1.142	.212	28.952	1	<.001	.319	.210	.484
	Street Density	.050	.048	1.122	1	.290	1.052	.958	1.154
C	Intercept	1.285	.315	16.644	1	<.001			
	Population Density	.013	.003	16.447	1	<.001	1.013	1.007	1.019
	Firm Density	-.145	.030	23.701	1	<.001	.865	.816	.917
	Economic Diversity	-.335	.224	2.244	1	.134	.715	.461	1.109
	Street Density	-.198	.050	15.384	1	<.001	.821	.743	.906
D	Intercept	3.117	.279	125.148	1	<.001			
	Population Density	.011	.003	14.652	1	<.001	1.011	1.005	1.017
	Firm Density	.104	.022	21.425	1	<.001	1.109	1.062	1.159
	Economic Diversity	-1.770	.198	79.866	1	<.001	.170	.116	.251
	Street Density	-.090	.045	3.992	1	.046	.914	.837	.998

[a] The reference category is: E.

Figure 19: Results from MNL with place characteristics

The results state the probabilities of each variable in reference to sector E. Only significant indicators are included in the discussion. According to the analysis with only *place* characteristics, population density is a significant indicator (at the level of $p<0.05$) for sectors B, C and D. The probability of firms belonging to sectors C and D are more likely to be found in residential areas than sector E, however the case is the opposite for sector B businesses. Firm density has contrasting effects on sector A and sector C establishments that those in sectors B and D, in comparison to sector E firms. Higher the number of firms per $100m^2$, greater the probability of finding sector B or sector D enterprises. Weighing the presence of sectors by the economic diversity of the location, sector A firms are inclined towards diverse markets than sector E firms. On the other hand, businesses belonging to B and D are less likely to locate in economically diverse areas. This could be an indication of the tendency of these sectors to agglomerate. Lastly, lower street density seems to be a common attribute in sites with businesses categorized in sectors A, C and D.

In the second round of the MNL, the model is extended by the inclusion of variables representing *node* characteristics. Sector E remains as the reference category and the output is interpreted in comparison to it. The collective frequency per hour is incorporated into the model as an ordinal variable. The factor is aggregated at the station level, that is the values recorded are not at the 6-digit postcode level. Since it is associated with the modal capacity of and number of routes available at each station, the other two factors are dropped from the analysis. Figure 20 shows the results from the analysis. It can be seen that the additional node variables make 'Population density' a significant variable in predicting the likelihood of location choices of sector A firms. Among the three distance variables, 'Distance to the station' is not significant at the $p<0.05$ level.

The results from the MNL suggests that the population density of a region is positively related to sectors A, C and D and has the opposite influence on sector B firms with respect to sector E. This indicates that the likelihood of an establishment belonging to sector A, C or D choosing to locate in a residential region is higher than sector E's. Comparing the influence of firm density on location choices of sectors, the coefficients for sector A and sector C are negative and for sectors B and D are greater than zero. The presence of firms is important to sector B and D establishments and the probability of locating such businesses in business parks, for example, is higher than sector E firms. On the other hand, sector A and sector C establishments are more likely to be located in areas away from commercial zones. The MNL output also indicates the preference of sector D businesses to choose a location nearby a transit node irrespective of the neighborhood being commercially or residentially oriented.

With respect to sector E, 'Distance to CBD' is a significant predictor for location choices of sector A and D firms, results being contrary to each other. Sector A firms are more likely to be located away from CBDs and sector D establishments in proximity to them. When looking at the impact of 'distance to the nearest highway' on location choices of the sectors, the indicator is significant in interpreting the choices of sector A and sector B businesses. As distance from the highway increases the probability of finding businesses belonging to sector B is higher and to sector A is lower than to sector E.

Economic diversity is a significant predictor of location choices of organizations belonging to sectors A, B and D. In a region comprising of diverse businesses, the chances of locating sector A establishments are greater than those of sector E. The opposite is true for businesses in sectors B and D, implying that such firms or establishments are more likely to be located in neighborhoods where businesses with similar functions are present in proximity. This signifies the tendency of the 'Retail and catering' industry and 'Public, financial and ICT services' to agglomerate. It is highly likely that companies in these two sectors would opt to locate next to (a) business(es) in their field. The design factor, street density, is significant in interpreting the probability of locating sector A, C and D organizations or businesses. The three sectors are less likely to locate in neighborhoods with higher street densities in comparison to sector E businesses. The output on 'Street density' for sector D establishments contradicts the results obtained on 'Firm density' and 'Distance to CBD'. A high 'street density' is a characteristic of a business district. The countering results may be due to the higher probability of sector D firms being located in both residential and business zones, in comparison to sector E establishments.

'Frequency' is an ordinal variable; the results are evaluated with the highest frequency range as the reference category. According to the MNL, the indicator is a significant predictor of the location choices of sector A, C, and D businesses (a little above 0.05 for sector A). Compared to sector E firms, these sectors are more likely to be located in neighborhoods where public transit is not very frequent. The probability of locating sector D firms is greater also in regions with low transit frequency. To summarize the influence of 'Frequency' is that Sector E businesses, in comparison to sectors' A C and D, are less likely to be located in regions with medium frequency than high frequency of public transport.

Employment Sectors[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp (B)	
								Lower Bound	Upper Bound
A	Intercept	-.635	.466	1.862	1	.172			
	Population Density	.009	.004	4.567	1	.033	1.009	1.001	1.017
	Firm Density	-.094	.046	4.186	1	.041	.910	.832	.996
	Distance to CBD	.212	.034	39.791	1	<.001	1.236	1.157	1.321
	Distance to station	.329	.262	1.581	1	.209	1.389	.832	2.320
	Distance to Highway	-.393	.056	48.778	1	<.001	.675	.604	.754
	Economic Diversity	.616	.296	4.318	1	.038	1.852	1.036	3.310
	Street Density	-.319	.067	22.911	1	<.001	.727	.638	.828
	[Frequency=1.00]	-.232	.307	.570	1	.450	.793	.435	1.447
	[Frequency=2.00]	.262	.135	3.746	1	.053	1.300	.997	1.694
	[Frequency=4.00]	0[b]	.	.	0	.	.	.	.
B	Intercept	1.272	.338	14.130	1	<.001			
	Population Density	-.009	.003	6.980	1	.008	.991	.984	.998
	Firm Density	.127	.025	26.047	1	<.001	1.135	1.081	1.191
	Distance to CBD	-.047	.028	2.725	1	.099	.954	.903	1.009
	Distance to station	-.182	.193	.886	1	.347	.834	.571	1.218
	Distance to Highway	.163	.043	14.008	1	<.001	1.177	1.081	1.282
	Economic Diversity	-.930	.220	17.932	1	<.001	.395	.257	.607
	Street Density	.046	.049	.909	1	.340	1.047	.952	1.152
	[Frequency=1.00]	.455	.280	2.640	1	.104	1.575	.911	2.726
	[Frequency=2.00]	.054	.104	.271	1	.603	1.056	.861	1.294
	[Frequency=4.00]	0[b]	.	.	0	.	.	.	.
C	Intercept	1.333	.354	14.153	1	<.001			
	Population Density	.012	.003	13.171	1	<.001	1.012	1.005	1.018
	Firm Density	-.177	.033	29.507	1	<.001	.838	.786	.893
	Distance to CBD	-.052	.029	3.238	1	.072	.949	.897	1.005
	Distance to station	.214	.205	1.094	1	.296	1.239	.829	1.852
	Distance to Highway	-.081	.044	3.393	1	.065	.923	.847	1.005
	Economic Diversity	-.411	.230	3.181	1	.074	.663	.422	1.041
	Street Density	-.226	.051	19.397	1	<.001	.798	.722	.882
	[Frequency=1.00]	-.359	.310	1.340	1	.247	.698	.380	1.282
	[Frequency=2.00]	.385	.106	13.113	1	<.001	1.470	1.193	1.810
	[Frequency=4.00]	0[b]	.	.	0	.	.	.	.
D	Intercept	3.153	.314	100.883	1	<.001			
	Population Density	.012	.003	15.217	1	<.001	1.012	1.006	1.018
	Firm Density	.056	.024	5.411	1	.020	1.058	1.009	1.109
	Distance to CBD	-.154	.028	31.199	1	<.001	.858	.813	.905
	Distance to station	-.084	.183	.211	1	.646	.919	.642	1.316
	Distance to Highway	-.072	.040	3.240	1	.072	.931	.861	1.006
	Economic Diversity	-1.670	.204	67.213	1	<.001	.188	.126	.281
	Street Density	-.136	.046	8.835	1	.003	.873	.798	.955
	[Frequency=1.00]	1.092	.266	16.784	1	<.001	2.979	1.767	5.023
	[Frequency=2.00]	.440	.096	21.124	1	<.001	1.553	1.287	1.873
	[Frequency=4.00]	0[b]	.	.	0	.	.	.	.

a. The reference category is: E.

b. This parameter is set to zero because it is redundant.

Figure 20: Results from MNL with node and place characteristics

6. DISCUSSION AND CONCLUSION

The McFadden value of the output from the MNL is low and, thus, the results cannot be generalized to other regions in the Netherlands. However, the final model is significant against the intercept only model. The availability of metro and tram services alongside train and bus services in the region changes how the total 'Frequency' of transit influence's location choices of businesses in the RR-E region compared to other cities in the country, but it also makes it interesting to investigate for any underlying patterns. In this section, the sub-questions are answered leading to an answer for the research question. The section concludes with a discussion on the equity aspect of the line from the perspective of the composition of employment sectors.

What are the node and place characteristics associated with TOD that influence the location choices of employment sectors? What measures are used to quantify these characteristics?

Transit-Oriented Development or TOD is based on the integration of transport and land-use planning. After the boom of the automobile industry, this old concept of development made a reappearance in response to the call for sustainable development. Since, TOD has been a vastly studied field and developing methods of improving its outcome has been an important aspect to researchers. Beginning with (Cervero & Kockelman, 1997)'s identification of the 3Ds, (Bertolini L. , 1999)'s concept of the node-place model to (Singh, 2015)'s measure of TODness, literature on TOD has grown in depth resulting in a multiplicity of variables that measure TOD characteristics. These characteristics generally relate the built environment of a node to the quality of the transport services provided. The indicators and respective measures used in this research are a combination of variables taken from such studies on TOD and from articles that have analyzed the role of built-environment and transit features in the decision-making process of location choices of businesses, such as (Frost, Appleyard, Gibbons, & Ryan, 2018), (Meija-Dorantes, Paez, & Vassallo, 2012), (Chorus & Bertolini, Developing transit-oriented corridors: insights from Tokyo, 2016), (Giuliano, Redfeam, Agarwal, & He, 2012) .

What is the composition of business sectors in the region connected by the RandstadRail metro line E?

The Netherlands identifies 21 employment sectors of which 20 are located in the RR-E region. As individual sectors, not every employment sector is located at each of the station areas. Figure 16 depicts a sporadic dispersion of these industries between Den Haag Centraal and Slinge. Grouping the employment sectors into 5 categories excludes the information on absent sectors at certain stations, however it gives a clearer depiction of the composition of employment sectors.

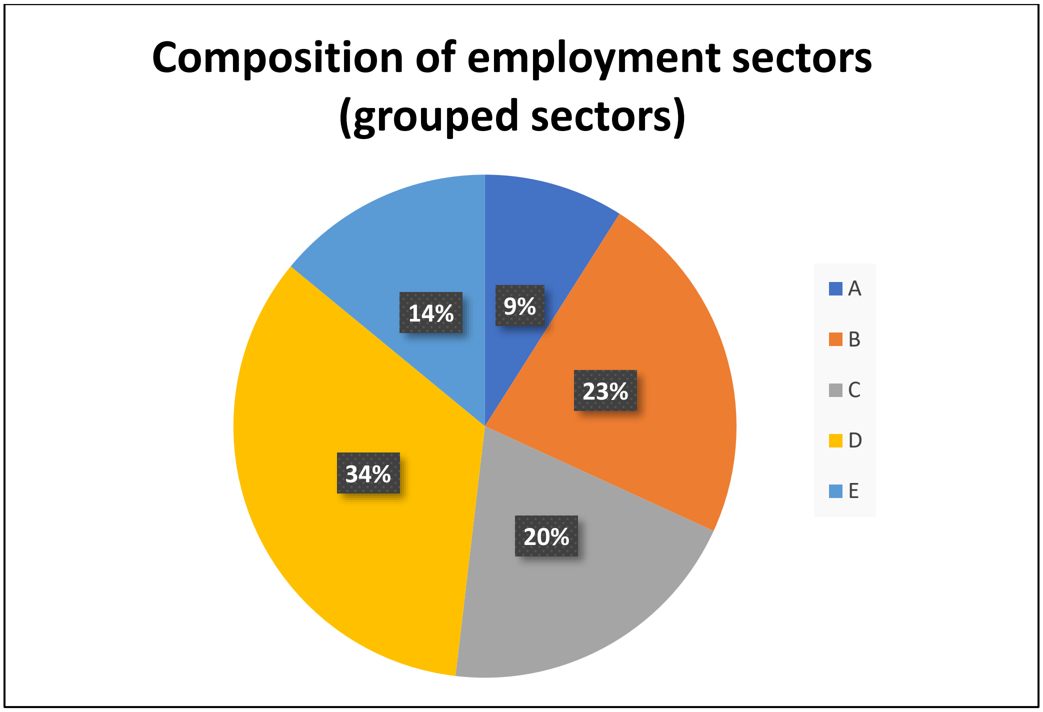

Figure 21: Composition of grouped employment sectors in RR-E region (%) in 2018

The 'Public, Financial and ICT service' is the largest employment sector in the region. This is followed by the 'Catering and Retail' sector (B). Both these sectors include the individual sectors M and G which by themselves are the dominant employment sectors in the region. Sector 'Education, healthcare and recreation' is almost equally present in the region as sector B. The 'Natural Resources and Infrastructure' sector has the least number of firms in the region.

What are the typologies of the stations composing the RR-E?

Based on the TOD characteristics and employment sectors in the region, the two step cluster analysis groups the RR-E stations into 3 categories – station in a business district (C2), station neighboring a business district (C1), and station in a suburban neighborhood (C3). Majority of the RR-E comprises of stations that are classified as C3 (12 out of 23 stations). Except for Slinge, these stations are located in the region between Laan van NOI and Blijdorp. To the north-west of the line Den Haag Centraal and Laan van NOI are the only two stations that belong to different categories, C2 and C1 respectively. The four-station congregation in Rotterdam, Rotterdam central to Leuvehaven, together serve Rotterdam's business district. The surrounding regions, Blijdorp and Wilhelminaplein to Zuidplein, share similar characteristics that classify them as C3 stations.

What is the relation between the station categories and the types of employment sectors within their catchment area?

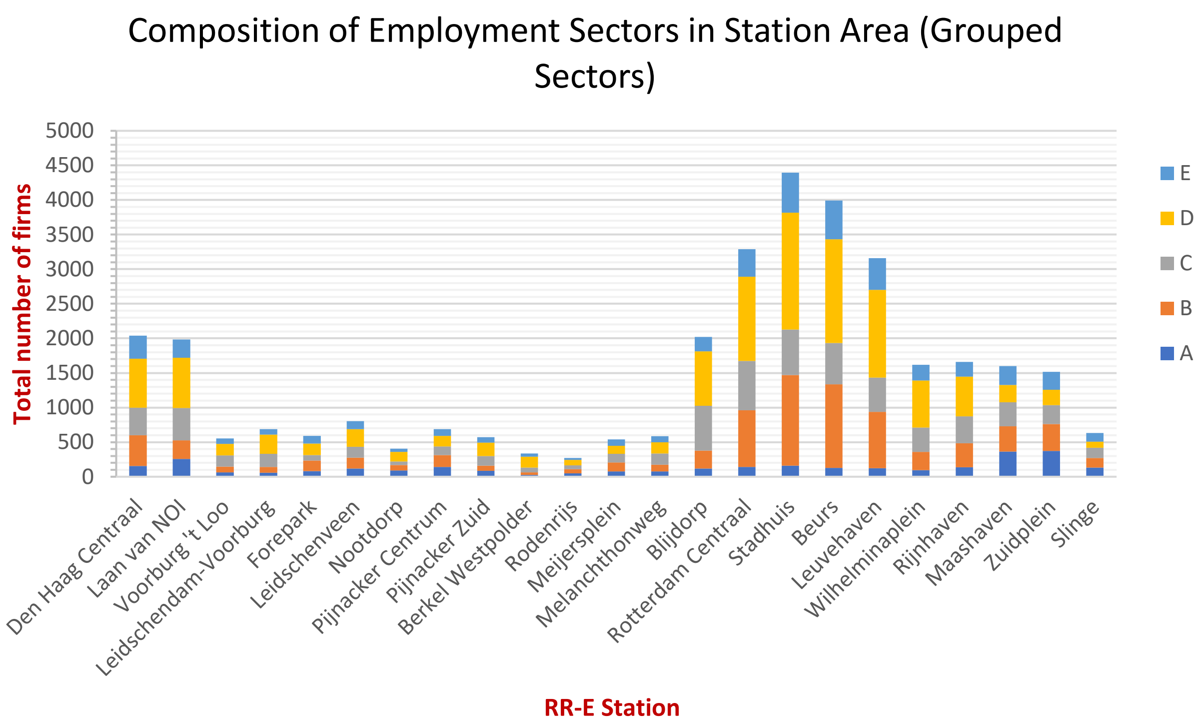

Figure 22: Composition of grouped employment sectors per station in 2018

Sector D is the most dominant employment sector in the region, as stated above. This sector is mostly present in station areas categorized as C1 and C2. An anomaly in this pattern is the large reduction in sector D firms beyond station Rijnhaven, i.e., at all other stations from Den Haag Centraal to Wilhelminaplein the number of sector D firms are in majority but this pattern changes towards the end of the line. Besides sector D, sector B companies are also drawn to locate their establishments in the commercial zones of the region.

As we move away from commercial zones, the number of establishments reduce considerably. The switch from stations belonging to cluster C2 to cluster C3 is drastic especially in the region between Den Haag Centraal to Rotterdam Centraal. Stations belonging to category C3 have a higher mix of economic activities compared to the other two categories. Sector A businesses are significantly present in this region, as seen in the graph for Maashaven, Zuidplein, Pijnacker Centrum and Laan van NOI.

Although all grouped categories are located in all station areas, most opportunities along this line are present from Rotterdam Centraal to Leuvehaven. Between the two nationally identified CBDs, the number of firms in the Rotterdam region is much higher than in the Den Haag region. When comparing the stations for employment sectors alone, the total number of establishments in Den Haag Centraal, Laan van NOI and Blijdorp are comparable.

What is the role of TOD characteristics in the composition of employment sectors around the rail stations of the RandstadRail metro line E (RR-E)?

A comparison of the results from the MNL and figure 22 mostly confirm the output of the analysis. Sector A establishments are most likely to choose a station location that has characteristics of cluster C3 than sector E. The characteristics of 'Station in a suburban neighborhood' such as substantial population density, not in proximity to a CBD, lower firm density, a distributed economic diversity seem to be preferred location features of the 'Natural Resources and Infrastructure' industry, as seen from figure 22 that shows a considerable number of such firms located in Laan van NOI, Slinge, Zuidplein, Maashaven, and Pijnacker Centrum. At these stations, sector E firms are mostly fewer in number than sector A businesses.

The MNL results predict the likelihood of the 'Catering and Retail' sector to choose a location with characteristics that can be associated with those of cluster C2 such as higher household to population density ratio and high firm density, with respect to sector E. This is evident in figure 22, that sector B firms compose a larger share of the employment composition in Den Haag Centraal, Rotterdam Centraal, Stadhuis, Beurs and Leuvehaven. This does not signify that sector B businesses are not attracted to station areas categorized as C1, as there are a considerable number of them in Wilhelminplein and Rijnhaven for example. However, there is an indication of sector B businesses to choose locations that are in or around business districts where there is a low overall diversity of employment sectors.

With respect to sector E, the 'Education, Healthcare and Recreation' sector is predicted to opt for locations that are categorized as C1 and C3. This pattern is less evident in figure 22 as stations belonging to C2 (station in a business district) have a considerable number of sector C establishments or businesses. The result from the MNL does not obviously relate to the overall composition of employment sectors at each station, and it may be that within the 800m radius catchment area of the stations sector C establishments are likely to choose locations in residential neighborhoods over highly commercialized areas.

The 'Public, financial and ICT services' sector are largely located in station areas categorized as C2 and C1. There are sector D firms located in the other regions as well, but the numbers are comparable with businesses belonging to the 'Transport, Logistical and other services' sector. Sector D establishments are most likely to choose locations that are in and around business districts, where they tend to be the largest employment provider. The regions CBDs are attractive to companies categorized into employment sector B or sector D, which has resulted in lower economic diversity in the main commercial zones of the most accessible neighborhoods (with train connections) of the RR-E.

As mentioned in section 5.2, interpreting location choices of sectors based on transit characteristics is tricky as the total frequency of public transport in C1, C2 and C3 are similar among most metro stations. This means that regions identified as suburban have a collective frequency of public transport almost equal to that of business districts. Figure 22 makes apparent the change in employment density as we depart from the region's business districts. This definitely depicts the importance of the quality of public transit in decisions of location choice of businesses as Den Haag Centraal, Laan van NOI and Rotterdam Centraal are the only stations with train connections and highest total transit frequencies. Station Zuidplein is well-connected to other cities and localities by numerous bus lines, making it an appealing choice to sector A businesses.

In RR-E region, although the role of transit characteristics is ambiguous there is an indication of a relation between built environment characteristics and location choices of employment sectors. The interpretations of the association between station typologies and employment sectors in relation to the results obtained from the multinomial logistic regression are not entirely accurate since the regression results are based on a 100m radius neighbourhood of establishments within the catchment area of the stations. But even in a general sense, there are similarities between aggregate station characteristics and composition of employment sectors. Describing the relation between node and place characteristics and location choices of individual employment sectors from the results of the MNL would be inaccurate since they are in reference to sector E.

To address the objective of this research the question arises if whether the RR-E has an equitable distribution of employment opportunities?

Since most part of the RR-E region is connected by metro and bus lines, it is expected that most of the local population walk to the stations. Thus, it is important that the station areas consist of a good mix of employment sectors such that there are job opportunities available to people coming from different educational backgrounds and levels. Especially from the perspective of equity, having diverse employment opportunities in station areas reduces travel costs (last leg of the journey) and time. A 'good mix' cannot be defined as it would vary for different station typologies and neither does it equate to 'balanced', but it refers to a composition that is made of considerable shares of each contributing factor (employment sectors in this case). Figure 21 represents this composition from which it is evident that there is a disproportionate distribution of employment sectors in the RR-E region (as a whole) and within each station area.

The stations with the least equitable composition of employment sectors are the four-station congregation in the Rotterdam region, where most of the economy is generated by the 'Public, financial and ICT services' sector (D) and the 'Retail and Catering' sector (B). It is evident, from the results of the MNL and figure 21, that Sector D firms are a major contributor to the economic activity of the region as there a considerable number of firms in all categories of station areas.

Sector A, 'Natural Resources and Infrastructure, is smallest employment sector within the region and are mainly located outside of business districts. The second to last sector, with the least number of firms, is the 'Transport, Logistical and other services' sector (E), comprising of only 14% of the total number of firms. However, compared to sector A, sector E companies are considerably present in business zones than in suburban neighborhoods of the RR-E line. Relative to the total number of firms, sector C establishments comprise a decent share of the economic activities in most station areas.

While the distribution of employment sectors in the region of analysis may follow the pattern as found in literature, briefly described in section 2.2.2, the share of sector A and sector E firms in the total composition of employment sectors is minimal. The existence of the CBDs in the north-west and central parts of the line has resulted in sector D being the largest employment provider in the region of analysis, and in lesser opportunities for individuals that are suitable to work in the 'natural resources and infrastructure' industry. Although there are not a large number of 'Transport, logistical, and other services' companies, it is interesting to see that they are considerably present in station areas with higher firm densities and household densities such as around Den Haag's Centraal and Laan van NOI neighborhoods, and Rotterdam's business district and neighboring localities (Blijdorp – Zuidplein).

The outcome from the multinomial logistic regression is applicable when studying the relation between node-place characteristics and location choices of businesses in the RR-E region, validating the hypothesis of this research. The different neighborhoods, especially the presence of the CBDs, strongly influences the composition of the employment sectors. This composition strongly varies as we move from suburban to business districts, which is reflected in the economic diversity of each station's catchment area, and shapes the overall equity in the distribution of the job sectors.

To compare the output obtained from the MNL with a previously conducted research, results from Guthrie's (2018) research are used as reference. A comparison between wages, which is the focus of the author's discussion, is obscure given the parameters of this research but a comparison by educational level yields a common discernable pattern. In the US based research, the highly accessible rail station areas experienced a decline in jobs suitable to the less educated and less experienced workers and a growth in employment opportunities requiring highly educated personnel. Similarly, the number of employment opportunities requiring highly qualified employees have risen in most station areas of the RR-E. The growth of sectors C and D between 2013-2018 (span of six years since the opening of the line) is prominent between stations Den Haag Centraal and Rijnhaven. In respect to that growth, jobs that are suitable to the less qualified have only risen by a small amount except at the 3 station areas in the south-east end of the line. Stations Maashaven, Zuidplein and Slinge witnessed a growth in employment sector A firms (see appendix – Number of establishments).

Geurs' (2006) scenario-based study on the impact of intensive land-use on job accessibility in the Randstad region provides us with reasons for creating smaller clusters of economic activities outside of CBDs. Smaller economic centers in neighboring suburban areas helps maintain a business-friendly environment in existing business zones and promotes the use of public transit (Geurs K. T., 2006). This indicates that, based on location choices of the sector and with proper planning and supporting policies the share of employment sectors in the overall composition can be improved. Creating a 'good mix' or 'well-balanced composition' of employment sectors is vital from the standpoint of equity as the Randstad continues to be an attractive region to investors and the working population.

7. LIMITATIONS AND RESEARCH RECOMMENDATIONS

The built environment and transit indicators employed in this study are significant in interpreting location choices of different employment sectors, the only exception being distance to station. Besides the characteristics retained in this research, the decision on location choices of businesses is dependent on multifarious factors. A crucial factor, not represented by TOD characteristics, is the property value at the location. The lack of such input in the analysis limits our understanding on why certain employment sectors opt to be located in certain areas. Restricting the area of analysis to a radius of 800m diminishes the relevance of the role of distance to a rail station in employment composition of the region. It may be that sector A companies are considerably present in parts of the city beyond 800m of the station but just not within walking distance from a station. Thus, the information presented in this research does not speak for the entire city in which a station stands but reflects on the equity aspect by highlighting what type of opportunities are available in the regions' easily accessible neighborhoods.

For results that better explain the influence of TOD characteristics on location choices of employment sectors, it would be useful to include factors that measure co-agglomeration of industries. The economic diversity indicator included in the analysis represents sector agglomeration to an extent, but this study is devoid of the co-agglomeration aspect. Certain industries prefer to agglomerate to be able to share resources and built infrastructure and this is not a TOD characteristic as such but an indirect representation of the built environment of a locality. The results can also be enhanced by using street distances for distance between establishments and 1) station, 2) nearest business district, 3) nearest highway. If, within the 800m radius catchment area of a station, there is a pattern in the location choices of different employment sectors the actual distance would be helpful in recognizing it and providing more detailed information in dispersion of firms by industry.

Studying the relation between station characteristics with number of firms per sector within its catchment area provides insights different from when analyzing the relation with number of sector-wise jobs. By including 'Number of firms' as an indicator in the analysis, the actual availability of opportunities within the catchment area is excluded from the analysis. Thus, from an equity aspect, it would be useful to incorporate the number of full-time jobs in the region as an input in the MNL.

The study uses cross-sectional data which non-linear in nature and poses challenges in conducting a linear regression. Hence, to be able to make predictions an area based longitudinal study would be extremely useful. A longitudinal analysis would help relate changes in node-place characteristics with the changes experienced within the composition of the industrial sectors in a region.

It would be interesting if such an analysis would be conducted for other regions in the Randstad conglomeration, where there is a mix of transit modes connecting diverse neighborhoods or if the RR-E region was extended to include areas that were connected only by train services. By analyzing regions similar to the RR-E, the results obtained for can be confirmed for generalizability. Extending the region of analysis to include more station areas with train stops would help distinguish locations that are business districts connected by train stations from non-CBD locations that have a train station. This would cover a relevant element of the analysis where another, and more common, cluster type would be identified that would represent neighborhoods that have a train station that are not in or right next to a business district.

Lastly, for a study on location choices, it would be indispensable to the research to integrate quantitative analysis with a qualitative study. As there are many factors that influence the decision, taking the qualitative aspect into consideration would contribute to creating a better understanding of how each sector values the different node and place characteristics and what factors are most important to them.

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APPENDIX

Two-Step Cluster Analysis

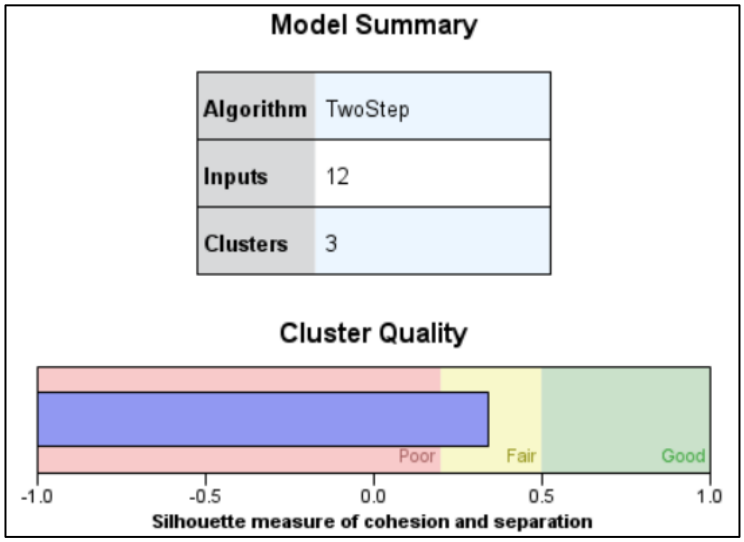

Figure 23: Output from cluster analysis with 12 variables (employment sectors excluded). The quality of the 3-cluster formation is depicted by the bar graph

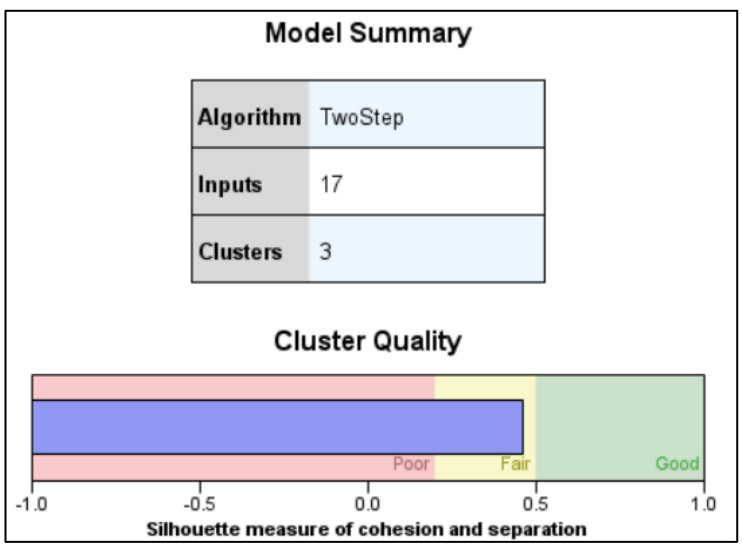

Figure 24: Output from cluster analysis depicting the quality of a 3-cluster formation with an input of 17 variables (final model)

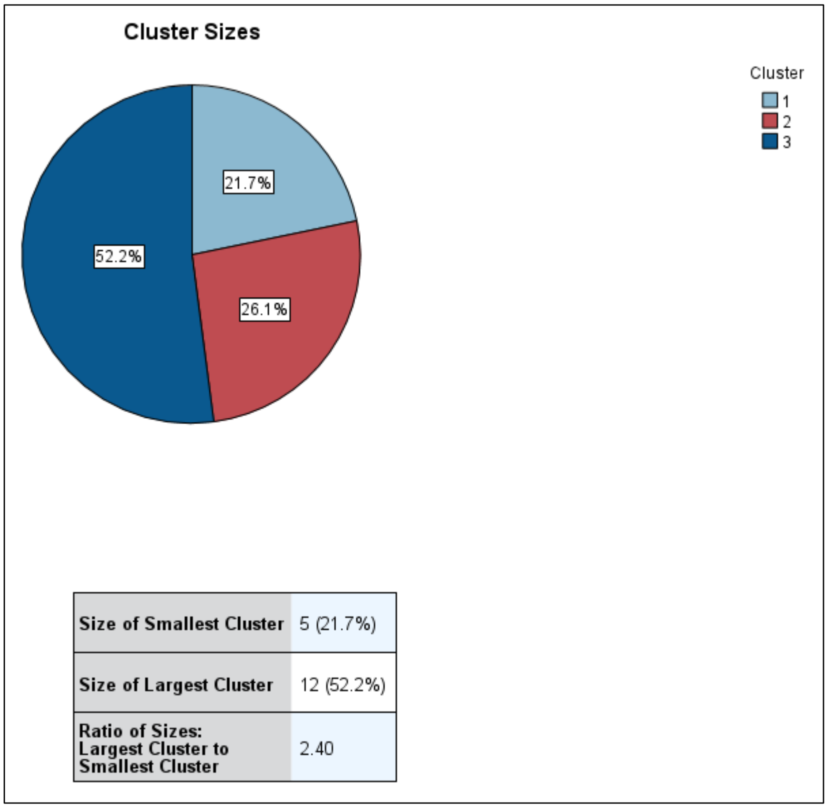

Figure 25: A representation of the cluster sizes of the final model. The largest cluster is the 'station in a suburban neighbourhood' with more than half of the 23 stations belonging to cluster C3 followed by cluster C1 and C2 respectively

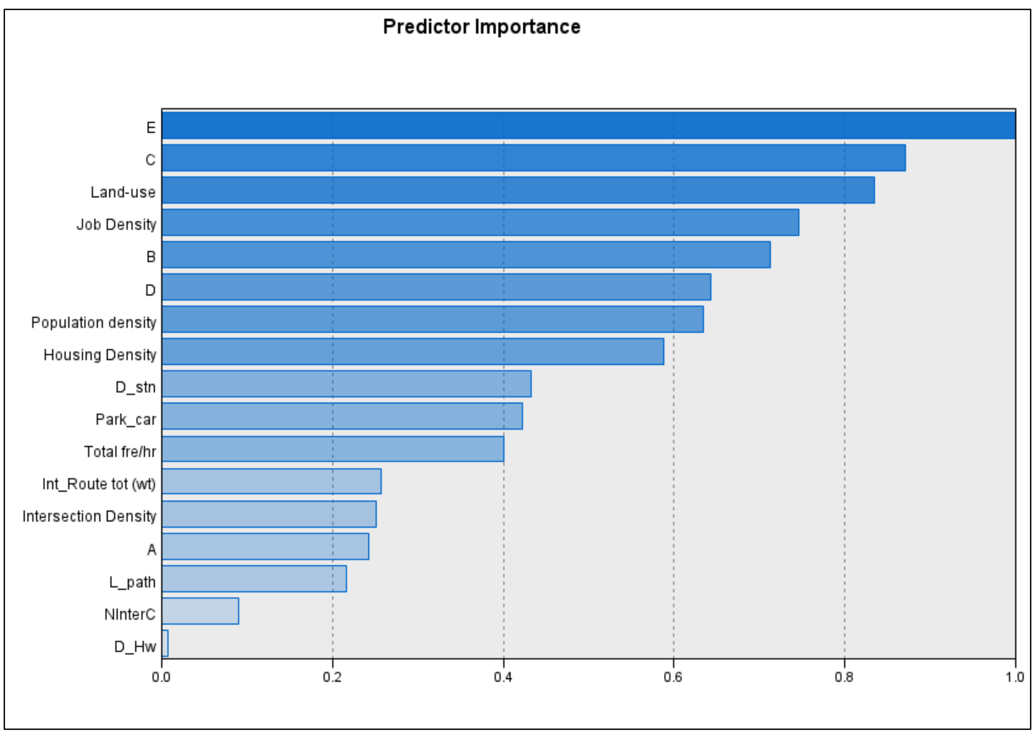

Figure 26: Variables ranked as per importance in the clustering process.

Multinomial Logistic Regression Analysis

MNL Output with place characteristics – supporting tables

Case Processing Summary

		N	Marginal Percentage
Employment_sectors	A	800	8.1%
	B	2370	23.9%
	C	1834	18.5%
	D	3506	35.4%
	E	1387	14.0%
Valid		9897	100.0%
Missing		232	
Total		10129	
Subpopulation		5549[a]	

a. The dependent variable has only one value observed in 4671 (84.2%) subpopulations.

Figure 27: Summarized information on the dependent variable

	Model Fitting Criteria	Likelihood Ratio Tests		
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	23601.409			
Final	22807.323	794.086	16	<.001

Figure 28: Model fitting information

Cox and Snell	.077
Nagelkerke	.081
McFadden	.027

Figure 29: Pseudo R-Square values

	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	23042.753	235.430	4	<.001
Population_density	22889.803	82.480	4	<.001
Firms_density	23100.791	293.469	4	<.001
Diversity_per100m	23018.542	211.219	4	<.001
Street Density	22866.480	59.158	4	<.001

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

Figure 30: Likelihood Ratio Test results

MNL Output with place and node characteristics (full model) – supporting tables

Case Processing Summary		N	Marginal Percentage
Employment Sectors	A	800	8.1%
	B	2370	23.9%
	C	1834	18.5%
	D	3506	35.4%
	E	1387	14.0%
Frequency	0-20	348	3.5%
	20-50	7690	77.7%
	100-150	1859	18.8%
Valid		9897	100.0%
Missing		232	
Total		10129	
Subpopulation		5613[a]	

[a] The dependent variable has only one value observed in 4719 (84.1%) subpopulations.

Figure 31: Summarized information on the categorical variables

	Model Fitting Criteria	Likelihood Ratio Tests		
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	23636.450			
Final	22521.845	1114.605	36	<.001

Figure 32: Model fitting information on the full model

Cox and Snell	.107
Nagelkerke	.112
McFadden	.038

Figure 33: Pseudo R-Square for the full model

	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	22521.845[a]	.000	0	.
Population Density	22597.970	76.125	4	<.001
Firm Density	22678.870	157.024	4	<.001
Distance to CBD	22662.754	140.909	4	<.001
Distance to station	22529.530	7.685	4	.104
Distance to Highway	22645.000	123.154	4	<.001
Economic Diversity	22671.037	149.192	4	<.001
Street Density	22583.581	61.736	4	<.001
Frequency	22601.599	79.754	8	<.001

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

[a] This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Figure 34: Likelihood Ratio Test results

Number of Establishments

Table 9: Sector wise change in number of firms (2013-2018) per station. Highlighted cells mark highest value for each station.

Station	A	B	C	D	E
Den Haag Centraal	41	59	149	219	49
Laan van NOI	70	54	140	198	61
Voorburg 't Loo	8	3	45	25	3
Leidschendam-Voorburg	0	1	71	36	1
Forepark	-4	3	22	51	19
Leidschenveen	-1	8	36	47	15
Nootdorp	9	4	16	31	6
Pijnacker Centrum	29	1	58	25	30
Pijnacker Zuid	18	17	67	73	31
Berkel Westpolder	-1	15	36	57	19
Rodenrijs	-5	9	27	9	-4
Meijersplein	16	20	34	47	30
Melanchthonweg	4	17	51	69	30
Blijdorp	25	71	236	234	54
Rotterdam Centraal	25	75	240	398	49
Stadhuis	47	138	219	536	106
Beurs	19	134	169	394	108
Leuvehaven	25	99	140	277	93
Wilhelminaplein	25	60	146	170	51
Rijnhaven	47	91	171	167	55
Maashaven	146	61	115	80	71
Zuidplein	164	74	64	60	42
Slinge	54	37	43	21	41