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Tracking Apartment Appreciation

An Analysis of the Effects of a New Tramway on the Housing Market in Tampere, Finland

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Abstract

In this master's thesis, we study if the new tramway affects the housing prices in Tampere. We analyse the housing unit transaction data from the Finnish Federation of Real Estate Agency with the hedonic Difference-in-Difference method. We find a significant positive effect on square metre prices, showing an increase of 7.4%, following the announcement of Tampere's new tramway within 800 metres of walking distance from the closest tram stop. Additionally, the tramway effect persists until 1,600 metres from a tram stop. We use the walking distance instead of the more generally used straight-line distance to determine the distance from a house to the closest tramway stop, which portrays more accurately the distance a resident must walk to reach the closest one.

We divide the study period into two periods according to the two sections of the tramway. Both sections have a clear anticipation effect on the housing prices within 800 metres of the tramway stops. Interestingly, Section 2 of the tramway yields a higher premium of 11.8%, while Section 1 yields a slightly lower premium, with an average treatment effect of 6.0%.

In this study, we examine the net effects of the average treatment effect, including various factors explaining apartment prices during the construction of the new tramway. These factors include enhanced accessibility to the city centre and other service hubs, increased supply of new residences, urban development, environmental considerations, and changes in the neighbourhood dynamics.

Our primary motivation for this study was the curiosity to find if large public transit infrastructure projects positively impact housing unit prices in Tampere, where the public transit system differs greatly from the capital area of Finland. Furthermore, this study could be utilised as part of an individual house buyer's process when looking for a new home or an investment.

Keywords Difference-in-Difference, Housing market, Tramway effect

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Tiivistelmä

Tässä Pro gradu -tutkielmassa tutkitaan, vaikuttaako Tampereen uusi raitiotie alueen asuntojen hintoihin. Analysoimme Suomen Kiinteistönvälitysalan Keskusliiton asuntokauppatietoja hedonisella Difference-in-Difference-menetelmällä. Löydämme merkittävän positiivisen vaikutuksen neliöhintoihin, joka osoittaa 7,4 prosentin nousua asuntoihin 800 metrin kävelyetäisyydellä lähimmästä raitiovaunupysäkistä, kun Tampereen uusi raitiotie julkistettiin. Lisäksi raitiotie vaikuttaa asuntojen hintoihin aina 1600 metriin asti raitiovaunupysäkistä. Käytämme kävelyetäisyyttä yleisesti käytetyn linnuntien sijasta määrittääksemme etäisyyden asuinpaikasta lähimpään raitiovaunupysäkkiin, mikä kuvaa paremmin matkaa, joka asukkaan on käveltävä päästäkseen lähimmälle raitiovaunupysäkille.

Tutkimme raitiotien vaikutusta myös kahden rakennusvaiheen mukaan. Molemmilla osuuksilla on selvä ennakoiva vaikutus asuntojen hintoihin 800 metrin etäisyydellä raitiotiepysäkistä. Mielenkiintoista on, että raitiotien toinen osuus tuottaa suuremman, 11,8 prosentin preemion, kun taas ensimmäinen osuus tuottaa hieman pienemmän preemion, ja sen keskimääräinen vaikutus on 6,0 prosenttia.

Tässä tutkimuksessa tarkastelemme ratikan keskimääräistä nettovaikutusta, johon vaikuttavat erilaiset tekijät. Ne selittävät asuntojen hintoja uuden raitiotien rakentamisen aikana. Näitä tekijöitä ovat muun muassa paremmat yhteydet kaupungin keskustaan ja muihin palvelukeskittymiin, uusien asuntojen lisääntynyt tarjonta, kaupunkikehitys, ympäristötekijät sekä muutokset naapurustossa.

Tämän tutkimuksen avulla halusimme selvittää, vaikuttavatko suuret joukkoliikenteen infrastruktuurihankkeet myönteisesti asuntojen neliöhintoihin Tampereella, jossa joukkoliikennejärjestelmä poikkeaa suuresti esimerkiksi pääkaupunkiseudusta. Lisäksi tätä tutkimusta voitaisiin hyödyntää osana yksittäisen asunnonostajan prosessia, kun hän etsii uutta asuntoa tai sijoituskohdetta.

Avainsanat Asuntomarkkinat, Difference-in-Difference, Raitiotievaikutus

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1. Introduction

Transit infrastructure projects are lengthy and costly to complete, yet necessary for growing cities where the demand for public transit and the use of cars increases quickly. Furthermore, large projects shape the urban development of cities and, therefore, have a substantial impact on them. A well-functioning transit system is a lifeline for any city centre to be easily accessible for as many residents as possible. In Finland, the focus has been on enhancing the public transit systems, and there have been a few large transit infrastructure projects over the past decades. The more extensive projects, such as extensions 1 and 2 of West Metro and Jokeri Light Rail, had been concentrated in the capital area. That is until the City of Tampere decided to build the tramway after many years of planning and discussing it (Tampere Tramway, 2023). The tramway's total benefit to the city can only be evaluated when the years pass, even though there are also short-term benefits to residents living near the tramway stops. In this master's thesis, we focus on the effects of the tramway on housing unit values in Tampere. We find a positive effect on the property prices within 400 metres and 800 metres from a tramway stop, with the effect gradually diminishing as one moves further away from the closest tramway stop.

Generally, municipalities invest in public transit infrastructure projects to enhance their transport network. Therefore, the benefits of such a project might be different for an individual citizen and for the city as, for instance, the Tampere tramway is not necessarily faster than a bus connection when travelling to the city centre. For individuals, the benefits consist of a timelier and more comfortable commute and overall increased accessibility of the city centre. Additionally, this allows the city to decrease the number of buses in traffic as the tram has a larger capacity, which expedites the traffic flow in the city. Furthermore, the tram is more environmentally friendly than the bus or passenger car and home buyers today value green options more than ever. On the contrary, the improved traffic flow should also benefit private car drivers.

Rosen (1974) introduced the hedonic price model, where he demonstrated that different characteristics affect the value of a property, one of them being accessibility to the city centre. An improved transit network also has positive spillover effects. For instance, the housing supply in Tampere is growing mainly along the tramway (Tampere tramway, 2023), and that will lead to other urban development, such as the level of services offered being accelerated. Even though increasing housing supply should decrease property values, ceteris paribus, the factors mentioned earlier, such as urban development and improved accessibility, should have a positive net effect.

Locally and globally, the effects of transit infrastructure projects have been studied widely as each setting is unique as cities and projects vary. Mohammad et al. (2013) summarised the results of 23 studies about railway investments' effects on property values and found that changes in housing unit prices vary significantly between regions. Moreover, the study found that most existing research is leaning towards large transit projects positively affecting property and land values in the impact zone of transit stops. Furthermore, they report that the variation in property and land values is higher in East Asia and Europe in comparison to the North American ones (Mohammed et al., 2013). The research group believe that a plausible conclusion is that the importance of public transit is higher in the first-mentioned areas. In light of our results and the high proportion, 87%, of Tampere residents have already tried out the tramway (Tampere tramway, 2022), the conclusion of Mohammad et al. is in line with our findings.

In Finland, some studies have been conducted about the effect of large transit infrastructure projects on the housing market. For instance, Harjunen (2018) found a positive anticipation effect of the West Metro extension to the housing units in the vicinity of the metro stations until 1,600 metres, while Valaja (2018) found a positive anticipation effect of 2.8% of the Tampere tramway between 2015 and 2018. We are keen to build on these results to see if the effect persisted until and beyond the start date of the tramway. For instance, McMillen and McDonald (2004) found when studying the effect of Chicago's Midway Line, a new rapid transit line, on the property values that initially were increased by the elevated railway and declined between four and six years after the line began its operation. Similarly, we have divided our study into two phases to determine the magnitude of the effect of the tramway line during different periods. We find evidence that there is an anticipation effect of the tramway on house prices. Furthermore, the effect is stronger after Section 1 of the tramway was completed.

The primary motivation of our study is to find if there is an effect of the tramway on property prices as, overall, the subject is curious. Additionally, the study could benefit home buyers outside the academic world. After all, in Finland, real estate is the largest asset class owned by the population, as 69% of Finnish people live in a house they own (Helsingin Sanomat, 2022). Buying a house is, for many, the largest purchase of their lifetime, generally financed with a mortgage. As a result, buying a home can be considered risky due to the drastic outcomes if the property or housing unit is flawed. Our study aims to help some home buyers compare different properties or determine whether the housing unit they are considering buying is worth the asking price. The price of an apartment is determined by its attributes, which we go through more thoroughly in the data section, and the vicinity of the tram stop is only a small part of the price composition. Nevertheless, the realtors' opinion seems quite clear, as many believed the tramway would increase property prices by up to five per cent (Helsingin Sanomat, 2017). Interestingly, our results align with these expectations, while the professionals' views are not necessarily based on academic research.

We study the tramway's effect on the housing market in Tampere with the KVKL's (abbreviation of Finnish Federation of Real Estate Agency, Kiinteistönvälitysalan Keskusliitto) real estate transaction database, Hintaseurantapalvelu (HSP), where approximately 70% of Finnish housing transactions are reported. Our dataset consists of 59,161 transactions across 32 postal code areas in Tampere between 2010-2023. Furthermore, the study area is the city of Tampere, which is located in the inland southwestern part of Finland. From the transaction data, we connect the addresses to the tram stops using Google Maps API and Geopy API, as well as Tampere's spatial data interfaces, while obtaining location data of local schools and public healthcare centres. We utilize walking distances from the housing units to the location parameters to capture the actual distance one needs to walk to reach a particular place, unlike other studies using the straight-line distance (e.g., Zhang et al., 2014; Kim & Lahr, 2013; Valaja, 2018). To obtain our results, we use the hedonic difference-in-difference (DID) analysis to separate the effect of the tramway from other factors that impact the housing market.

1.1. Objective of the study

The objective of our study is to find whether the new tramway affects the housing market in Tampere. We are building our thesis on top of Valaja's (2018) master's thesis, where the tramway effect was studied on apartments sold between January 1, 2015, and May 8, 2018, using a hedonic OLS regression. Valaja found a positive tramway effect of 2.8% on apartments inside an 800-metre buffer zone from tramway stops. However, she concluded that the results needed to be more robust for the tramway to explain the entire effect. In Appendix I, we replicated Valaja's study and found results similar to hers.

This study thoroughly analyses the average net treatment effect of a new tramway's impact on house prices in Tampere. Key differences between this research and Valaja's study are the different methodologies used and the longer timeframe, which allows us to study the anticipation effect together with the tramway effect after its construction and a deeper analysis of what factors drive the effect.

We use the hedonic DID method to study the anticipation effect of the new tramway. With this method, we can especially study causality, ensuring robust results. This method is commonly used in various housing market studies which analyse particular policy or event effect on housing prices, such as Harjunen (2018) about West Metro in the capital area, Finland and Gupta et al. (2021) about Q-train in the New York City, United States.

Additionally, we have a longer dataset that includes Sections 2A and 2B of the tramway, enabling us to compare the tramway effect between different phases: Planning, Construction and Operating phases differ. We utilise several distance bands where the walking distance is used to determine the actual distance a public transit user would walk to the tram stop instead of the straight-line distance generally used in similar studies. The data is gathered using Google Maps API. We control other spatial differences, including Tampere's distances to the closest elementary or secondary schools and public healthcare centres.

Table 1, Comparison between studies

Author	Study description	Year	Study Method	Distance type	Control group area	Apartment type	Impact
Kangas & Viippola	Tramway effect in Tampere, Finland	2023	DID	Walking distance	Distance bandwidth	All types	Positive
Valaja	Tramway effect in Tampere, Finland	2018	OLS	Straight-line	No control group	Multi-storey apartments	Positive
Kauria	Tramway effect in Helsinki and Espoo, Finland	2020	DID	Straight-line	Distance bandwidth	All types	Positive
Harjunen	Metro effect in Helsinki and Espoo, Finland	2018	DID	Straight-line	Regional train stops in Helsinki	Multi-storey and row house apartments	Positive
Gupta et al.	Metro effect in Manhattan, NY, US	2021	DID	Straight-line	Similar areas in the city centre	Multi-storey apartments	Positive
Devaux et al.	Metro effect in Laval, Canada	2017	SDID, repeat sales	Straight-line	Continuous variable without grouping	All types	Mixed
Kim & Lahr	Light rail effect in New Jersey, US	2013	HPM, repeat sales	Straight-line	Continuous variable without grouping	All types	Positive

In Table 1, we have illustrated the most essential reference papers and their study characteristics. At the top of the table is our master's thesis, followed by Valaja's (2018) and Kauria's (2020) thesis about the tramway effect in Tampere and the capital area, respectively. After the two, there is Harjunen's (2018) research paper about the West Metro extension in the capital area. Finally, we have three international studies from Gupta et al. (2021), Devaux et al. (2017) and Kim & Lahr (2013). The main differences between the reference studies and ours are the study method, the manner in which the distance between the housing units and public transit stops is calculated, the control group formation, and the types of properties included in the study. This table also highlights the differences between our study and Valaja's, which is partly made from the same data and infrastructure project.

This master's thesis consists of seven sections. The first section is the introduction, while the second section dives into the existing literature, where we walk through the local and international studies about the effect of transit infrastructure projects on housing markets. The third section explains the institutional setting and sheds light on the city of Tampere and the tramway project in detail. The fourth section explains the data we used to conduct the study. Moreover, the fifth section is about the methodology, where we explain our models. Results follow the methodology section. In the discussion section, we go through the implications of our results and the limitations of our study. Finally, we conclude our study's conclusions section.

2. Literature review

Our literature review consists of three parts. First, we go through the overview of the existing literature and introduce the beginning of the history of the transit infrastructure effects on the housing market and the land value theory. Second, we discuss the local relevant studies to our research. Highlights include a study about the Tampere tramway and a few studies of West Metro's extension. Finally, we discuss the most relevant international research papers in the field of studies.

2.1. Overview of the existing research

The relationship between property prices and large transportation infrastructure projects has been researched in different locations and on different infrastructure projects. The project's locality leads to each research paper presenting a unique setting every time. Thus, a long list of opportunities exists to extend the existing literature. In Finland, similar studies have been done about the western metro extension in Espoo and the new light rail line, Raide-Jokeri, in Helsinki, which commenced operation in October 2023 (Helsingin Sanomat, 2023). The existing literature leans towards large transportation infrastructure projects having a positive anticipation effect on the real estate prices along the tram stops as well as metro stations. However, there are examples where no clear relationship was found (Mohammad et al., 2013).

Property price models began in 1826 when Johann Heinrich von Thünen presented his model of agricultural land use (Fujita et al., 1995). The model was straightforward, but it was the first to explain why transportation costs affect property prices when the distance to the city centre increases. The von Thünen model was viable in the 19th century. However, since then, the world has evolved from agricultural to service-based economies, making the model outdated, even though the basic principles are a good framework for modern theory.

Moving from the theory to recent research about the housing prices, commuting costs and reachability of the city centre, we see that the improved commuting infrastructure generally increases housing prices near new tram stops and metro stations. The main reason for this is the decline in reaching the amenities: the city centre, shopping centres, office parks and other service hubs. Furthermore, timesaving is not the only reason for elevated property values along the transit infrastructure, as other benefits include enhanced safer travelling and the possibility to commute more environmentally than before. Kim and Lahr (2013) find that in the proximity of Jersey City, the Hudson-Bergen Light Rail line, which commenced operation in 2000, the appreciation of apartments increased at an average annual rate of 18.4% higher in the study area compared to those outside of it. Importantly, they found that the appreciation effect vanished by a percentage point every 15 metres (50 feet) away from the stops. Houses outside the 400-metre range tended to appreciate similarly to houses outside the impact zone.

Another significant finding was that most-distant properties appreciated faster than those closer to the CBD (Kim & Lahr, 2013). This is known as the Alonso-Wingo theory framework. For instance, Section 2 tram stops are quite remote from the city centre, and based on the theory, it should have experienced the fastest appreciation among the neighbourhoods of Tampere. While commuting might vary for a resident in a neighbourhood further away from the city centre after the tramway started operating, in comparison to old bus connections, at least the capacity of the tram is higher and considered a more comfortable way of travelling (Survey of the Tampere tramway operator, 2022). Additionally, the increased number of passengers should lead to higher business activity and broader service offerings along the tram line, which at least in theory should be increased more in the more distant areas from the city centre.

All in all, the subject has been researched locally and globally with varying results. While recent local studies have been focusing on the extension of the metro system in the Helsinki Metropolitan area, globally, many different settings have been examined in the past two decades. Unsurprisingly, these distinctive locations have led to the use of several different methods to find out if there is an appreciation effect due to large infrastructure projects.

2.2. Local studies

Our study shows new evidence regarding the changes in property prices in Tampere near the tramway. The project's uniqueness makes the research very intriguing as Tampere is the third largest in Finland, and the infrastructure project is the largest in the city in decades. The effects of the tramway on the property values have yet to be researched after the first two tramways have been completed and started operating. While intuitively, a new tramway should increase property prices near tram stops, the evidence from previous studies in various cities is unclear, even though the projects have generally had a positive effect. In Finland, several studies have been conducted about regional trains in the Helsinki Metropolitan Area (HMA) of the metro in Helsinki and later its extension to the west in Espoo.

The anticipation effect of the Tampere tramway on property prices has been studied once before when Valaja (2018) found a positive anticipation effect on apartments less than 800 metres away from the closest tramway stop. Conversely, the results could not specify unequivocally that the price premium was only due to the new tram stops. According to Valaja, the conclusion that the effect would simply arise from only the new tramway cannot be made, but rather that apartments in the vicinity of the tramway are more expensive than further away from it. The study was also limited to data from 2015 to 2018 and consisted of only multi-storey buildings. A comprehensive and long dataset is needed to understand the anticipation effect completely and to distinguish a difference between the property prices before and after the tramway has started operating. This study uses a more extensive dataset, and hedonic DID method to understand the effect more profoundly.

In this study, we find a tramway effect on the property values, especially when closer to the tram stop. As Valaja (2018) studied only the effect of one buffer zone at 800 metres for each tram stop, and they were treated similarly, we used four different buffer zones of 400 metres from 0 to 400 metres, from 400 to 800 metres and so on until 1,600 metres and assign each distance band with a treatment group. Furthermore, we have added schools and hospitals to our hedonic model to enhance it further, as, for instance, Zhang et al. (2014) found that prime schools increased home value by 9% when modelling different vehicles' effects on property prices in Beijing.

Other recent studies about transportation infrastructure's effects on property prices in Finland include a working paper about West Metro's effect on housing market (Harjunen, 2018), a master's thesis on Housing market anticipation effects of West Metro's second phase (Eriksson, 2022), a master's thesis on the effects of the new West Metro line on apartment rents (Meronen, 2020) and a master thesis on the anticipation effect of the new light rail line in Helsinki (Kauria, 2020). All studies find a positive anticipation effect of property price increases near a metro station or a light rail line stop. On the other hand, only Meronen's study has been made with a dataset that includes property sales data after the public transportation line has commenced operation, which, for other studies, leaves out the possibility of observing further price increases. In this regard, this study takes a step forward and examines if the anticipation effect grows stronger and weakens before and after the beginning of operation.

Harjunen (2018) studied in his working paper West Metro's effect on the housing market on the local level. The West Metro was built in two separate phases; the first included eight metro stations, two in Helsinki and six in Espoo. When the extension was completed in 2017, the metro line continued outside the city centre to the west, and the final stop was earlier in Ruoholahti. For instance, new metro stations were introduced in Lauttasaari, Keilaniemi, Otaniemi (Aalto University) and Matinkylä. Harjunen found that inside an 800-metre radius of the metro stations, the property prices have a price premium of around four per cent, even five years before the metro started operation. Harjunen analysed the dataset with the DID method in a quasi-experimental setting, where the treatment group, which consists of property transactions near the metro station, is compared to the control group in which properties are located near the regional train stations in similar neighbourhoods in Helsinki or Espoo.

Similar to Harjunen (2018), in his working paper, Eriksson (2022) finds in her master's thesis that apartment prices increased by almost 8 per cent more in the 800-metre radius of the new metro stations before the second phase of West Metro was completed. Additionally, between 800 and 1600 metres from the metro stations, property prices increased by more than 6 per cent. The second phase includes the extension from Matinkylä until Kivenlahti, the most western neighbourhood by the coastline before the border of Kirkkonummi. In her study, the DID method was used to find the increase in property prices near the new metro stations. The control group consisted of property transactions in the vicinity of railway stations. The dataset consists of 10,722 transactions between mid-December 2014 and the end of 2021. Again, the dataset does not cover any transactions after the second phase of West Metro began its operation in 2023.

In contrast, as Eriksson (2022) studied the second phase of the infrastructure project, the property buyers had time to understand the effects the metro extension had in the neighbourhoods near the metro stations that began operating in the first phase. These include more desirable and safer public transportation and more timely connections to the city centre, as well as negative aspects of the project. For instance, Yle (2018) reported that from the Ala-Soukka neighbourhood in Espoo, the travel time to the city centre of Helsinki was extended by 10-15 minutes after the metro had commenced operation due to changes to the bus connections. As time efficiency is one of the main arguments for metro and light rail projects, together with reducing congestion and adding capacity to the most popular connections, such a finding could lead to higher demand for housing near the new stations or stops.

Using Realia Group's rent data of new rental contracts, Meronen (2020) studied in her master's thesis the effects of the West Metro extension on monthly rents and found a 7% increase in them between the treatment area and control area using the DID method. The dataset includes circa 6,000 observations between 2009 and 2019. Similar to Harjunen (2018) and Eriksson (2022), there was an anticipation effect as rents were lifted already during the construction period. Interestingly, Meronen found that rents decreased by four per cent after the start of the West Metro's operation, while in the study, the results were deemed descriptive rather than causal.

The new light rail line in Helsinki will commence operating in October 2023, and Kauria (2020) studied its effects on the housing market in Helsinki and Espoo. The new light rail line has 25 kilometres of tracks, of which 16 kilometres are situated in Helsinki and the rest, 9 kilometres, in Espoo. Kauria found that property prices increased by 6 per cent in the radius of 800 metres from the new light rail stops compared to the control group properties. His dataset is from KVKL, where most of the Finnish real estate transactions are reported, and it consists of 77,378 transactions between January 1, 2003, and December 31, 2019.

All in all, the results from recent studies in Finland have found that there has been an anticipation effect as large infrastructure projects have increased property prices in the Helsinki metropolitan area as well as in Tampere. In the HMA, the studies have been conducted with the DID method (Harjunen, 2018; Meronen, 2020; Eriksson, 2022), while Valaja (2018) used the OLS hedonic model to study the anticipation effect of the tramway.

2.3. International studies

Considering that all the recent major transit infrastructure projects in Finland and their effect on property prices have been studied, it is unsurprising that similar studies have been conducted worldwide. The setting is different every time since cities are always different from one another, while infrastructure projects vary from metro and bus lines to train or light railway tracks. Moreover, the project can be new, such as the Tampere tramway or an existing public transportation line extension, like the West Metro project in Helsinki and Espoo. The distinctive setting also implies that study methods differ based on the characteristics of the city and the transportation system. As a result, also, the findings differentiate between studies.

One of the most recent research papers regarding the effect of infrastructure projects on property prices in New York (Gupta et al., 2021) examined "the most expensive per-mile expansion in U.S. transportation history" from the perspective of land value and housing prices. The results conclude that apartment prices increased by 8% between 2003 and 2019 compared to the control group. The evidence shows that 5pp. of the total appreciation of 8% was realised already during the construction period 2007-2013, which is in line with our expectation that most of the appreciation is realised before the beginning of operation. The extension was inaugurated as part of the metro network on January 1, 2017. The price change is of great magnitude, and interestingly, larger and newer apartments captured a higher premium than other housing units.

Additionally, Gupta et al. found that residents saved 3-5 minutes in commuting time, which was a reduction of 7.5%, and the amount saved for subway commuters was 14 minutes. Moreover, the movers in the area were more likely to use the extension than the previous residents, highlighting the importance of the project and boosting the demand for housing near the new stations. The research group utilised the DID method for the timesaving of high-frequency geolocation information from mobile phone data. Finally, they concluded that the value appreciation of the housing stock is around 5.5 billion dollars while the project's total cost was 4.5 billion dollars.

Devaux, Dubé and Apparicio (2017) studied the anticipation and post-construction impact of an extension of the metro line in Laval, Canada. Their research found no significant appreciation effect on property values at every station due to the metro line extension. Only property values close to one single station were affected using the DID method. With a population of 443,000, the city is close to Tampere's size; thus, the two cities are comparable. In the study, Devaux et al. divided the project into four phases: the phase before the announcement, from the announcement until the beginning of construction, the construction phase and the phase after construction (tramway commenced operation).

Similarly, we will look closely at the different phases of the Tampere tram project. We will examine the three phases of the project: after the initial announcement of the tramway until the beginning of construction (June 17, 2014 - March 1, 2017), the construction phase (March 2, 2017-

August 8th, 2017) and the operating phase when the tram has commenced operation (August 9, 2021-March 1st, 2023). The division of phases is crucial to capture the anticipation effect of appreciating property values. For instance, Agostini and Palmucci (2008) found that in Santiago de Chile along the new Metro Line 4, the average apartment price increased between 4.2% and 7.9% after the project became public and between 3.1% and 5.5% after the basic engineering phase was announced along the finalised locations of the Metro Line 4 stations. Furthermore, they used a hedonic regression model with, for instance, distance to the nearest school, the closest public hospital and the nearest private clinic as explanatory variables. In contrast, Valaja (2018) did not have schools or clinics as a variable in her model, while we considered public healthcare clinics and schools as essential additions to our regression model. Moreover, the data and methodology sections thoroughly explain our model and explanatory variables.

Distance to schools was also among the used parameters in a study regarding transit development's effect on the housing market in Beijing (Zhang et al., 2014). Their research paper using the OLS hedonic model found that the prime school's proximity to the housing unit increased the value by close to 9%. The research group added prime school dummies to all apartments within a 500m radius of the school. Furthermore, the study extended beyond one transit vehicle as bus rapid transit (BRT), light rail transit (LRT) and metro rail transit (MRT) were all examined, and their relationship with property prices was studied. The impact zones differed between transit methods since the zone extended to 1,600 metres for MRT while the LRT impact zone was only half 800 metres. In the study, the analysis was conducted every 100-metre radius until 1,500-1,600 metres from a transit stop or station. The premium of the LRT stops for housing units was US$ 17.57/m2 for every 100 metres closer to the stop, while for MRT stations, the premium was 39.41/m2. Even though Tampere and Beijing differ in many ways, we argue that distance bands up to 1,600 metres should also be included in our study. On the contrary, in our opinion, the difference in housing density between the cities makes the 100-metre radiuses nonmeaningful for Tampere.

To showcase the uniqueness of each transit infrastructure project, in some studies, no effect of value appreciation was found. These include Camins-Esakov's and Vandergrift's (2017) study on the Hudson-Bergen Light Rail extension to the south in Bayonne, New Jersey, and Gadzinski's and Radzimski's (2016) publication of Poland's first rapid tram line's effect on apartments in Poznan. Camins-Esakov and Vandergrift found no statistically significant effect of an increase in annual prices of housing units when a new light-rail extension was built and introduced. Similarly, when examining the first rapid tram in Poland, Gadzinski and Radzimski did not find a relationship between the new tramway and the appreciation of housing units. Moreover, the study comprised a survey of 300 households and more than 1400 property transactions between 2010 and 2013.

Furthermore, the survey respondents reported being ready to pay more for an apartment near a tramway stop, yet the transaction data did not provide evidence for appreciation. Conversely, some property types might see their values rise while others do not (Gadzinski & Radzimski, 2016). In Clower's and Weinstein's research paper (2002) on light rail stations' effect on the housing market in Dallas, Texas, it was concluded that retail properties were not appreciated due to a new rapid light rail line, while office and housing unit values were not.

3. Institutional setting

Next, we present Tampere’s tramway’s construction process, operation, and city of Tampere. We begin by introducing the city of Tampere and how the tramway operates. In the second and final part of this section, we discuss the construction phases of the tramway and exhibit their timeline, which is a crucial part of our research as we study the anticipation effect of the tramway and its strength over time.

3.1. The tramway and the city of Tampere

Tampere is a city located in the western part of Finland, with 249,000 inhabitants in 2022, and the number is expected to grow to 300,000 residents in 2040 (Yle, 2023). Situated between two lakes, Näsijärvi and Pyhäjärvi, the city has been an essential commercial hub in Finland, yet the only railroad in the city has been the main track from Helsinki. A tramway was first discussed in 1907, but the plan was never realised as the First World War interrupted the preparations (Tampere tramway, 2023). Before the tramway project, public transportation in Tampere was carried out with buses and some regional trains. As a reaction to the growing population and accessibility of the city centre, the city council concluded that the tramway was the best option for the city due to the higher capacity of the tram in comparison to buses.

Figure 1, Tram network in Tampere after completion of section 2A (Tampere Tramway, 2023)

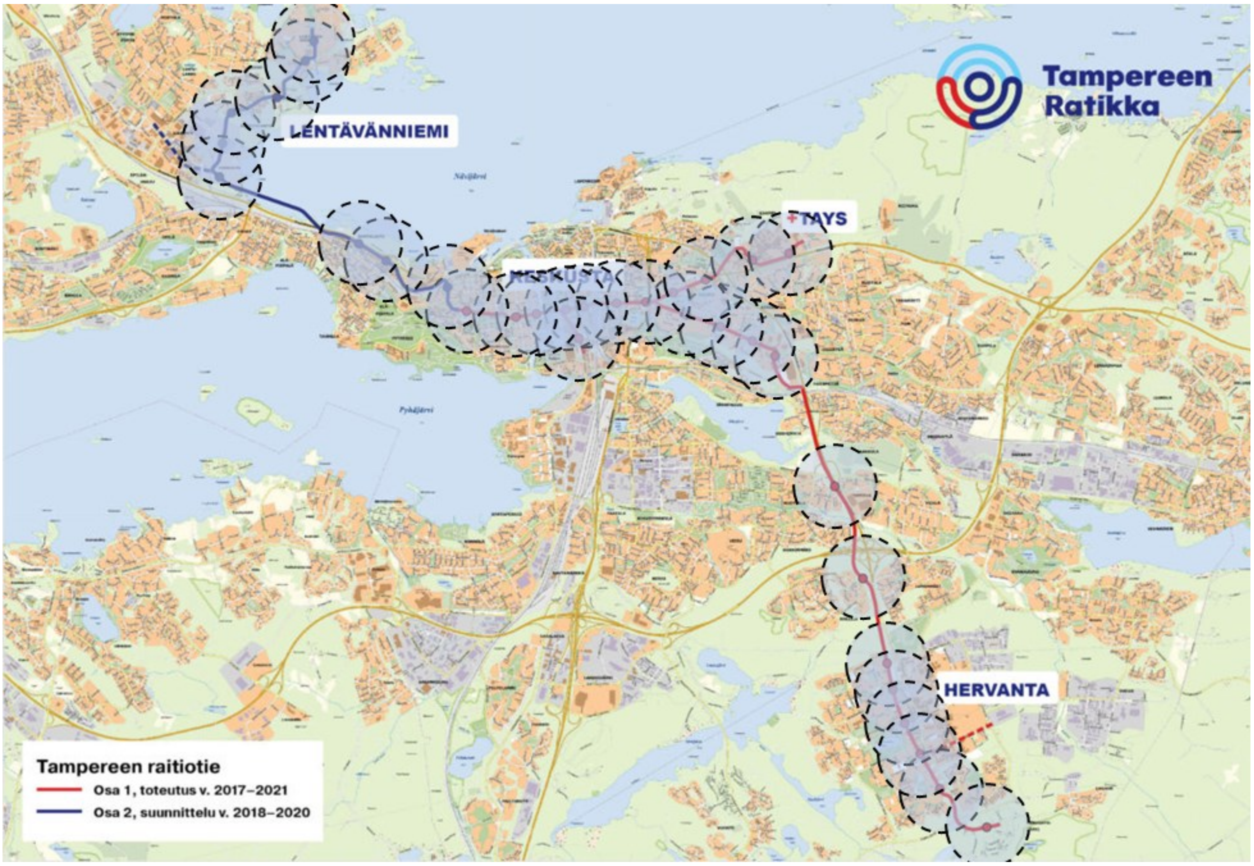
The timeline of the first part of the tramway project was set out in 2014. On June 16, 2014, the general plan of the tramway was approved by the city council and on June 7, 2016, the construction of the tramway was approved by the City Council, with 41 voting for and 25 against the project (Tampere tramway 2023). The construction of the tram started in March 2017, and the tramway commenced to operate on August 9, 2021. These dates also mark important milestones in our research as we divide the tramway project into three different phases: 1st phase before the announcement of construction, the second being the construction phase and finally, the third phase after the tramway had commenced traffic. The project itself is far from complete, as Section 2 of the tramway to Lentävänniemi will be finished in 2025, and the subsequent phases to Ylöjärvi and Pirkkala are expected to be built in 2040 at the latest. The impact of the tramway is easily recognised in the city due to the accelerated construction of housing near the tramway. It is estimated that 70-75% of residential construction will occur near the tramway during 2016-2040 (Tampere tramway, 2023).

The Section 1 of the tramway included two lines: number 1 (L1) and number 3 (L3). The L1 is shorter, with only nine stops, while the L3 consists of 19. Four of the stops in the city's heart served as stops for both lines (Koskipuisto, Railway station, Tulli and Sammonaukio). Both lines have an interval of 7.5 minutes between each tram, leading to a 3–4-minute interval in the city centre between the four multi-line tram stops. The total length of the Section 1 of the tramway is 15.7 kilometres of double tracks. Section 2A of the tramway was completed on August 7, 2023, when the tram operation extended from Pyynikintori to Santalahti. It is expected that the Section 2B will commence operation in January 2025 (Tampere Tramway, 2023). The tram routes after the extension can be seen in Figure 1**.** The tram operator is VR, a government-owned railway company (Helsingin Sanomat, 2019). In 2023, the ticket prices for adults for two zones will include a 90-minute ticket for an adult, which costs 2.70€, and a 30-day ticket, which costs 59.00€. Zone A and B cover the tramway network (Nysse, 2023). Approximately 28% of Tampere's city centre's public transit is travelled by tramway, and on March 31, 2023, the tramway had its record number of passengers, 53,353 individual trips (Tampere tramway, 2023).

The response to the tramway has been positive, and the positivity towards the project has been increasing since the start of its operation. 87% of the respondents indicated their happiness with the tram in 2022, while the number was 81% in 2021. The number increases over time due to the larger number of people who have used the tram; 87% of Tampereans had travelled with the tram in 2022, while the share was 75% in 2021. The most exciting part of the questionnaire is the claims where the most agreeable ones were: "The tram is an ecological vehicle", "The tram enhances Tampere's image", and "The tram increases apartment and real estate prices in the vicinity of the tram". In conclusion, in the residents' minds, the tram modernises Tampere, but more interestingly, there is a clear connection between the tramway and real estate prices. 60% of the respondents agreed strongly with the claim, and only 1% did not agree at all or partly.

When considering the positive feedback of the tramway, one should keep in mind that the tramway is approximately as fast as a bus connection to the Tampere city centre, the former bus route. It begs the question: Why was the tramway built in the first place? Firstly, the population of Tampere will grow in the coming decades. The capacity of the tram car is significantly larger than that of a bus'. Additionally, many buses would be needed to organise the public transportation in the future, leading to congestion in the city centre. Secondly, a decrease in travel time is one of many benefits of a new light rail line compared to a bus connection. Adair et al. (2000) state that ease of travelling consists of travel time, cost, and convenience. Moreover, the tramway is a more convenient way to travel, and due to its benefit of using a separate track system from road transport, it leads to more timely travelling (Tampere Tramway, 2016). Finally, the tramway's pollution levels are significantly lower than those of buses and would be even lower than the ones of electric buses (Tampere Tramway, 2016).

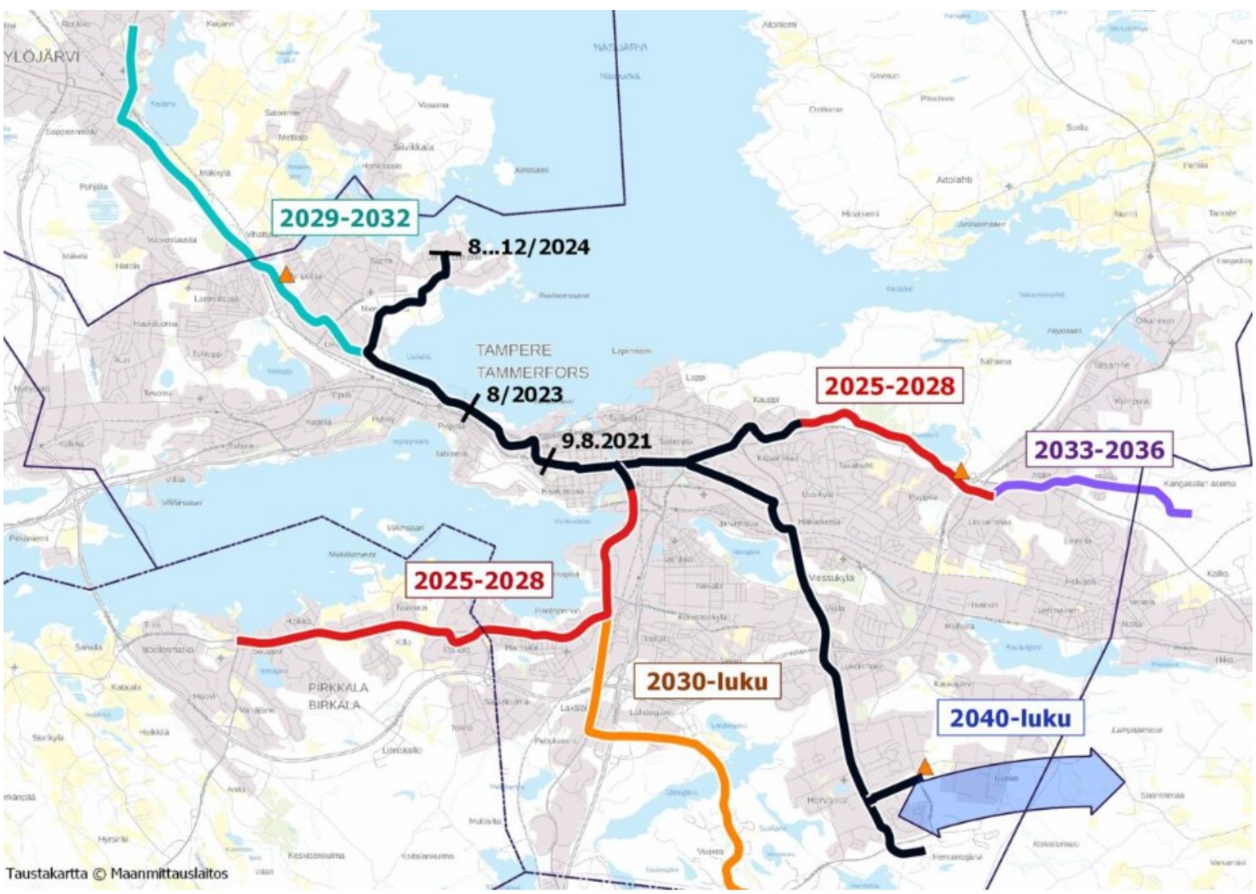
Figure 2, Map of the tram lines and the impact zones, 800m radius (Tampere Tramway, 2023)



The alliance model of building transit infrastructure is very efficient. Considering that this is Tampere's largest infrastructure project ever, it has been executed very well so far; Section 1 of the tramway was completed ahead of schedule, and it cost 238.8 million euros, which is 30 million euros less than initially budgeted (Yle, 2021). It is exceptional since, based on Oxford's professor Bent Flyvberg, only 8.5% of megaprojects, valued at over one billion USD, are finished on time and budget (Aratani, 2023). Even though the Tampere tramway project is outside the billions of USD class, it can be considered a large project, especially considering the city's size. Figure 2 shows the entire tramway network presented after Sections 1, 2A and 2B have been completed. The combined total track length will be 24 kilometres after completion of Section 2 (Tampere Tramway, 2023). The first three stops, in blue, closer to the city centre, are already in operation and part of Section 2A, while the rest of the stops in blue are part of Section 2B. It is expected that the 24 kilometres will be in use on the 7th of January in 2025 when the Lentävänniemi extension will be introduced to the public. Regarding our study, there is a significant number of new buildings in Lentävänniemi as well as along the coastline of Näsijärvi Lake. Furthermore, an artificial island where apartments for 2,500 people are built was finished in 2022 as part of the city planning, and there is a reservation for a tram stop on the island (Yle, 2022).

In 2040, the tramway network, as shown in Figure 3, will look very different as the tramway will be first extended from Pirkkala to Koilliskeskus in 2025-2028. Between 2029 and 2032, the following section will be built from Hiedanranta, a new neighbourhood, to Ylöjärvi, where the foundation of the tracks is planned to be built in Lielahti during Section 2B of the construction. Later, during the next decade, an extension from Koilliskeskus is planned to be built to Lamminrahka, and finally, the extension from Hatanpää to Vuores in the 2030s. In our study, we have only focused on Tampere and the construction phases of Sections 1, 2A and 2B, but one can see that the research can be extended further.

Figure 3, Tramway construction plan as of February 19, 2021 (Tampere Tramway, 2023)

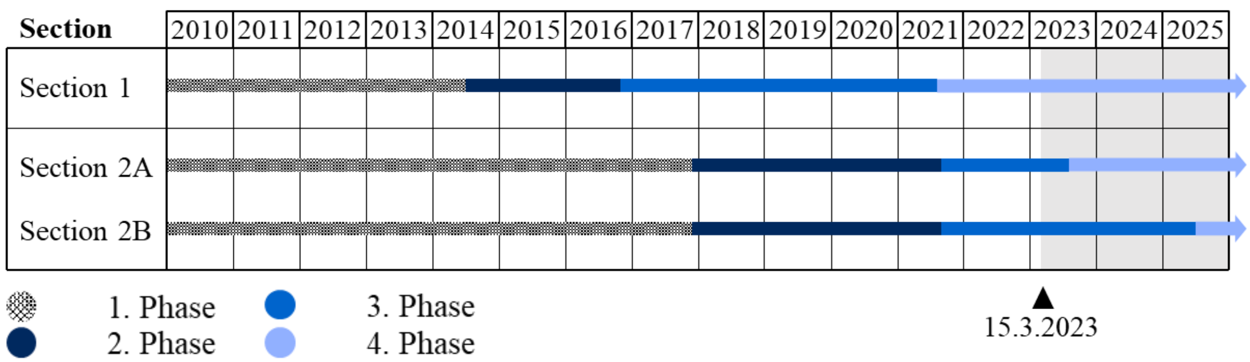


3.2. Phases of the tramway construction

Data regarding the dates of the tramway has been collected from the project website (Tampere Tramway, 2023). The dates are a critical part of the analysis since they are the announcement dates for the project as well as essential points in time that specify our four phases of the project. In ***Figure 3***Figure 4, one can see the different construction phases of Sections 1 and 2. The phases are used to measure the effect of the construction phases to find, for instance, whether the tramway has an anticipation effect on the property values or not. To clarify, for example, the 1. phase of Section 1 of the tramway lasted from January 1, 2010, until June 16, 2014. Furthermore, with the phases, the magnitude of the different periods of the project to the property prices can be studied.

Figure 4, Project phases for Sections 1, 2A and 2B

1. Phase (Pre-phase)
2. Phase (Planning phase)
3. Phase (Construction phase)
4. Phase (Operation phase)



In the pre-phase, action has yet to be taken towards building the tramway section; more precisely, before June 16, 2014, there was no certainty that the tramway would be built. The pre-phase ended on the said date for the Section 1 and the Section 2 on December 17, 2017. The Planning phase lasted from June 16, 2014, until November 7, 2016, for Section 1 and from December 18, 2017, until October 19, 2020, for Section 2. The planning phase starts when the city council has decided to plan the tramway section but has not decided to build it. Now that the tramway is already in operation and Section 2 is being built, it can be considered a confirmation that the planning eventually leads to tramway lines extending to the planned areas. The third phase is the development phase, where the plan goes into action, and the actual building occurs. Section 1 was extended from November 7, 2016, until August 8, 2021, and for both 2A and 2B, from October 19, 2020, onwards, since we collected the property transaction data on March 15, 2023. The development phase is then followed by the operation phase, which for Section 1 was from August 9, 2021, onwards. We explain the effect of the different phases in the data and results sections of this research.

4. Data

We used KVKL's real estate transaction database to represent Tampere's housing markets (KVKL, 2023). The data consists of approximately 70% of all housing transactions in Finland, where the individual transactions are entered by real estate and construction companies. Moreover, the database is maintained by KVKL. We studied the tram's effect on housing prices in multiple phases, meaning the data needs to extend from before the planning period and construction from January 1st, 2010 – March 15th, 2023. The initial dataset comprises 62,868 transactions across Tampere in 36 postal code areas.

The data quality was moderate, as expected considering that individual real estate agents and smaller construction companies are responsible for adding transactions to the database. There were 34 different attributes available in KVKL's database, yet due to a lack of data availability and quality, we ended up using only 15 of those characteristics. Table 2 provides a comprehensive list of all available variables and those employed in our research. Bolding signifies variables that are used in our analysis.

Table 2, Reported variables in KVKL's database

Category	Variables
Location	Municipality, Neighbourhood**, Postal code, Street address**
Property characteristics	**Surface area, Year of construction,** Number of rooms, Apartment description, Floor number, Number of floors, N**ew construction property, Property condition,** Building material, Building footprint on land, Other area, Building rights
Pricing and financial information	Purchase price, Share of debt, **Debt-free price, Price per square metre**, Maintenance fee, Maintenance fee per square metre
Sale and marketing information	**Sale date**, Start date of sale, Sales time in days
Property features and amenities	Waterfront, **Lift, Apartment Rented, Sauna, Balcony**
Land information	**Ownership of land,** Area of land in square metres, Description of the waterfront
Energy information	Source of heat, Energy class

The 15 **bolded** variables were used in our model.

We have excluded data from four postal code areas that are not considered part of the city centre (34240, 34260, 33680, and 34270) even though they technically are part of Tampere. We also excluded transactions where we could not identify the correct street name and number (22 individual addresses) since accurate addresses are vital when measuring distances to the closest tram stop, city centre, public healthcare, and schools. Other eliminations include free-time apartments, transactions where no surface area was available, construction year was not available, or the apartment was not completed yet. Furthermore, some data was inaccurate as the postal code was inaccurate, the price per square metre was under 500€, and transactions were without a room number or plot ownership. Additionally, plot ownership with the option to purchase was changed into rented plots as the transaction price is not significantly affected by the type. The final dataset consists of 59,161 transactions and 7,411 individual addresses.

In addition to apartment characteristics data, we gathered spatial data using Google Maps API and Geopy API, as well as Tampere's spatial data interfaces, to obtain location data of local schools and public healthcare centres (City of Tampere, 2023). We gathered walking distances and times from Google Maps API while straight-line distances were computed using Geopy API.

Our methodology utilizes walking distance as a proxy for tram accessibility instead of straight-line distance. We argue that walking distance provides a more accurate estimate, considering that walking is the most common way of transport from homes to the nearest tram stop. Also, in Tampere, highways and waterfronts limit accessibility to tram stops, which can significantly increase the difference between walking distance and the distance as the crow flies. Appendix II, exhibits the relation with linear regression between straight-line distances and walking distances. We can see that, on average, walking distance is 35% longer than straight line distance.

To calculate the distance between the city centre, closest school, and closest hospital, we used straight-line distance by using the Geopy API service. We preferred straight-line distances for these factors since there are more common ways of transportation to these services than walking. There are a total of 11 hospitals and 50 primary or secondary schools. Tampere mainly has mixed schools, combining most primary and secondary schools. Thus, the division between primary and secondary schools is insignificant.

4.1. Data Summary

The data summary provides a comprehensive overview of the data and key variables used in this study. Table 3 exhibits the key variables with definitions. We are using only *surface area* as a continuous variable because they tend to correlate too strongly with each other, resulting in multicollinearity between explanatory variables. Appendix III demonstrates an exhaustive list of discrete variables used in the model and their distributions in the total sample.

Table 3, Descriptive statistics

Symbol	Definition	Mean	Std	25 %	75 %	Count
Square metre price (€)	Debt free sales price surface area	2 966	1 194	2 116	3 600	59 161
Distance To City Centre (Km)	Straight line distance from Tampere's Central Railway Station	4.47	2.79	1.66	6.92	59 161
Distance to Closest Tram Stop (Km)	Walking distance from closest tram stop, in total of 34 different tram stops	2.31	2.27	0.50	3.80	59 161
Distance To Closest School (Km)	Straight-line distance from closest elementary or secondary school, there are 50 different schools in the area	0.61	0.46	0.30	0.78	59 161
Distance To Closest Public Healthcare (Km)	Straight line distance from closest public healthcare centres, in total of 11 different public healthcare centres	1.42	1.01	0.66	1.99	59 161
Surface area (m^2)	Surface area in square metres	66.15	32.45	45.00	80.00	59 161
Apartment Age	Transaction year subtracted by year of construction	31.57	26.14	5.00	49.00	59 161

Table 4 describes the key variables and their distributions. We used several distance dummies to explain the effect of schools, public healthcare facilities, and the closeness of the city centre or tram accessibility. We built our treatment group from housing units within different ranges of 400 and 800 metres of walking distance to the closest tram stop to study the effect of the tramway on housing prices. The different ranges vary between 0-2,000 metres, further explained in the results section. Former studies have widely used similar buffer zones when studying the effect of public transit stops (e.g., Kim & Lahr, 2013; Devaux et al., 2017; Harjunen, 2018).

Furthermore, Valaja (2018) found that apartments within an 800-metre radius of the tram stops were positively affected. In Table 4, we also have our control group's descriptive statistics to exhibit that the two groups share similar characteristics and, therefore, can be compared. On the other hand, there is a noticeable difference in house types in the treatment group; 88% of the total transactions were apartments, while in the control group, the same share was 64%. Thus, we conducted a robustness test including only apartments in regressions. Likewise, our control group comprises housing units more than 2,000 metres away from the closest tram stop, as the treatment effect diminishes when moving further away from it. Thus, by doing this, we decrease the possibility of a spillover effect. Additionally, we have tested in our robustness checks that the spillover effect would unlikely exist beyond the 2,000-metre walking distance.

We use a 500-metre radius to add the effect of schools and public healthcare facilities, as Zhang et al. (2014) used in their research about public transit's effect on the housing market in Beijing. Schools and public healthcare facilities can be considered essential factors for citizens; thus, their effect must be captured in variables. To capture the effect of the city centre, we have used 1.5 kilometres as a radius from the central railway station as a dummy variable. The number of amenities the city centre offers should lead to higher apartment values.

We have several apartment characteristics dummies: Ownership of plot, Lift, Apartment rented, Sauna, Balcony, New Residence, and apartment age, condition, and number of rooms, which we have pooled into individual groups. We use apartment age as a variable rather than the building year since it demonstrates the age of the housing unit more accurately at the time of the transaction (Söderberg & Janssen, 2001). After all, our transaction data extends over the past 13 years and a transaction today for the same building year would not be valued at the same level compared to the housing market as one ten years ago, all else being equal. Furthermore, we divided apartment ages into six groups using ten-year intervals.

The overall distribution of different variable groups is relatively stable. However, it is worth highlighting that within the house condition, a majority, 61%, of properties are categorised as "good". Realtors seem to assign apartment conditions as "good" more likely than other categories. Therefore, we must utilise specific condition dummies as references to avoid a dummy trap, and thus, we use apartment condition "good" as a reference.

Table 4, Descriptive statistics of treatment and control groups

Distance band	**Total sample**	**Treatment Group** 0-800 meters	**Control Group** > 2 000 meters	**Excluded area** 800-2 000 meters
N	*59 161*	*20 632*	*23 814*	*14 715*
Square price (€) (Dependent Variable)	2 966	3 342	2 551	3 108
Surface area (m^2)	66.1	59.1	70.7	68.8
Apartment Age	31.6	38.4	25.8	31.3
Distance To City Centre (Km)	4.5	2.7	6.6	3.5
Distance to Closest Tram Stop (Km)	2.3	0.4	4.7	1.2
Distance To Closest School (Km)	0.6	0.4	0.7	0.6
Distance To Closest Public Healthcare (Km)	1.4	0.9	1.9	1.3
Apartment	73 %	88 %	64 %	67 %
Ownership	51 %	55 %	41 %	63 %
Lift	45 %	65 %	31 %	38 %
Rented	8 %	9 %	7 %	7 %
Sauna	21 %	12 %	26 %	25 %
Balcony	27 %	27 %	27 %	26 %
New Residence	18 %	18 %	20 %	16 %
Rooms 1	18 %	22 %	16 %	16 %
Rooms 2	38 %	44 %	33 %	39 %
Rooms 3	25 %	25 %	26 %	25 %
Rooms 4	13 %	8 %	17 %	14 %
Rooms 5+	6 %	2 %	8 %	7 %
New	11 %	12 %	11 %	9 %
Excellent	2 %	2 %	2 %	3 %
Good	61 %	58 %	63 %	63 %
Satisfying	16 %	20 %	14 %	15 %
Tolerable	1 %	2 %	1 %	1 %
Unknown	8 %	7 %	8 %	8 %

Ownership: the plot of the apartment is owned together with the apartment and is not rented. *Rented:* the apartment is rented out to a tenant when sold. *New Residence:* proportion of transactions, which were initial sales of the apartments. The number of rooms and conditions of the apartments sum up to 100% for each column.

5. Methodology

We studied the price impact on the accessibility of trams by using the variations of the hedonic pricing model (HPM). The HPM, originally formulated by Rosen in 1974, is a widely adopted method for estimating the price of complex goods, such as apartments. The model posits that the price of the apartment can be expressed as a function of its internal and external attributes. These attributes can be divided into location, property structure, accessibility, environment, and neighbourhood characteristics. Additionally, the model incorporates a set of dummy time variables, which account for time-fixed effects. It is essential when examining the impact of the tram system, which exhibits a temporal effect in our transaction timeline, similar to Devaux et al. (2017).

The price of an apartment can be represented as a function of its locational, structural, accessibility, environmental, and neighbourhood attributes:

$$Price = f(Locational, Structural, Accessibility, Enviromental, Neighborhood)$$

A simple approach to studying the tram effect is adding a walking distance to the nearest tram stop as continuous or discrete variables in the HPM. However, such an approach could not assess the timing of external factors, such as the decision to construct a new tramway (Ashenfelter & Card, 1985). We use a hedonic Difference-in-Difference (DID) analysis to address this limitation. DID helps to establish a causal relationship if some specific criteria are met.

DID is a widely used economic method to study the causality effect of a specific event. According to Gibbons and Machin (2008), the approach of using the DID estimator offers an effective spatiotemporal framework for assessing how, over time, evolving amenities impact a situation while appropriately managing unchanging spatial amenities. The DID estimator allows us to compare square metre prices before and after the announcement of the construction of Tampere's tramway, enabling us to identify the average treatment effect associated with the introduction of a new tramway. This comparison is made between a treatment group and a control group. The treatment group consists of transactions within the influence of the tram. In contrast, the control group consists of transactions outside of a 2,000-meter radius from the closest tram stop where the new tramway should not directly affect housing prices. To make the distance more realistic to the homeowners and tenants, we used walking distance to the closest tram stop to identify the treatment group. In a two-dimensional structure, the DID estimator "β_3" is obtained by subtracting the control group "$T = 0$" from the treatment group "$T = 1$", where time before the announcement is marked as "$A = 0$" and the time after the announcement period is marked as "$A = 1$".

$$\beta_3 = \left[E\left(P^i \middle| T = 1, A = 1\right) - E(P^i|T = 1, A = 0)\right] - \left[E(P^i|T = 0, A = 1) - E(P^i|T = 0, A = 0)\right]$$

We used the hedonic DID ordinary least squares (OLS) regression model to analyse the relationship between square prices, noted as *P* in the equation. We applied natural logarithm transformation to square prices to ensure normal distribution, see Appendix IV. *Treatment* refers to the treatment group. *After* the corresponding period after the announcement of the new tramway. Particularly interesting from the result's point of view is that it captures the average treatment effect of the new tram. Xi variables are all explanatory variables such as house characteristics and spatial information, which we have explained in more detail in the data section Table 3. ε represents the error term, which captures any unexplained variation in the apartment prices. In addition, we modified the standard DID approach, as we incorporated a variation where we replaced the *After*-indicator with half-year fixed effects derived from the transaction dates, similar to Harjunen (2018).

$$P_i = \alpha + \beta_1 \times Treatment_i + \beta_2 \times After_i + \beta_3 \times (Treatment_i \times After_i) + \sum_{n=4} \beta_n \times X_i + \varepsilon$$

We employ the Treatment × Year Interaction variation of the DID model to capture time-related dynamics. This method allows us to explore treatment effects over distinct periods and test the parallel trends assumption, which is one of the most critical assumptions in DID analyses (Harjunen, 2018; Gupta et al., 2021)

Combining the treatment effect with the year indicators, we can identify how the treatment effect evolves across different years. This approach is useful to identify time-related changes in the treatment effect, providing an understanding of whether the treatment effect is immediate, or the response is delayed. Furthermore, this methodology allows us to analyse in which phase of the tramway implementation (Planning, Construction, or Operation) the treatment effect is the strongest.

The regression equation follows the same structure as the previous hedonic DID. However, rather than relying on a predefined date to define pre- and post-announcement periods, this approach enables us to capture treatment effects for the individual years. This approach helps us to closely examine whether the treatment and control groups follow the parallel trends in the years leading up to the announcement of the tramway project. Previous studies, such as (Harjunen, 2018; Gupta et al., 2021), have used this method to show the temporal nuances of treatment effects and validate the assumption of parallel trends.

$$\mathrm{P_i} = \alpha + \beta_1 \times Treatment_{\mathrm{i}} + \beta_{\mathrm{n}} \times (Treatment_{\mathrm{i}} \times Year_{\mathrm{i}}) + \sum_{n=4} \beta_{\mathrm{n}} \times \mathrm{X_i} + \mu_i + \varepsilon$$

When researching housing markets, there is a tendency for observations near other observations to be similar to each other, e.g., in a particular neighbourhood, the apartments have similar characteristics. In contrast, the housing characteristics are more likely to differ outside the neighbourhood. Thus, this could lead to spatial autocorrelation, which violates the assumption of traditional statistics, which assumes that observations are independent of each other (Cliff & Ord, 1970). We have considered this by clustering all standard errors by postcode areas. We are grouping the standard errors based on postcodes, which allows correlation within the postcode areas, mitigating spatial autocorrelation.

Below, we list our main assumptions for following the hedonic DID model, which has been commonly used in different DID studies (Meyer et al., 1995; Bertrand et al., 2014; Ryan et al., 2015; Harjunen, 2018; R. Wilms, 2021; Gupta et al., 2021).

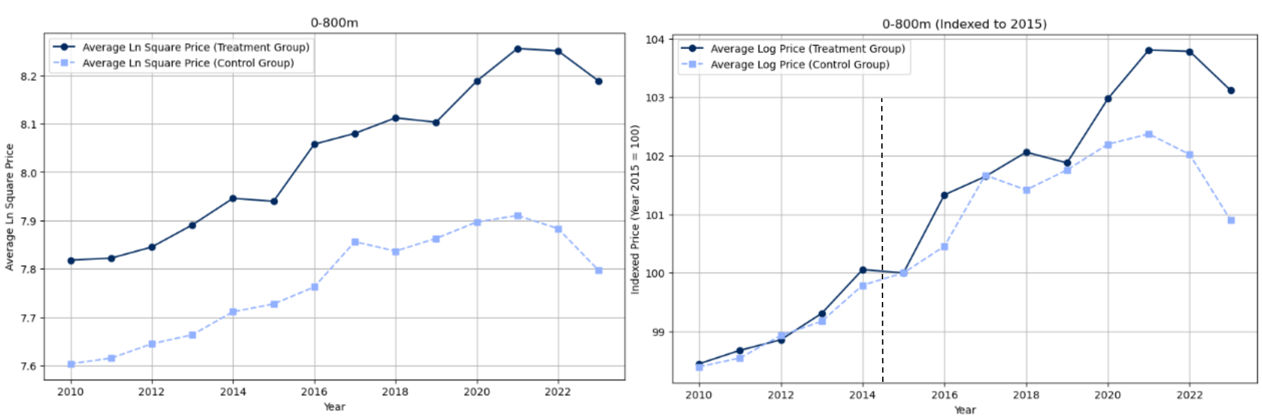
1. Parallel Trends: The most important assumption is that both treatment and control groups follow the parallel trends before the decision to construct a new tramway is made which means that treatment effects are not significant before announcement of the new tramway. $[E(P_{1before} - P_{0before}|T = 1) = E(P_{1before} - P_{0before}|T = 0)]$
2. Consumer preferences do not vary over time: we assume that the relationship between apartment characteristics stays reasonably constant, which means that consumers' value attributes do not change after the effect.
3. Common factor that affects dependent and independent variables simultaneously: Omitting a variable that affects both dependent and independent variables will lead to biased results, also known as the omitted variable bias.
4. No spillover effect: Assuming that the treatment effect affects only the treatment group, not the control group. We control this with robustness tests.
5. Independence of observations: Treatment and control groups' observations within both groups are independent. We are controlling this with clustering standards errors by postcode areas.

6. Results

In the study's results section, we present our main findings and results. The results have been divided into two chapters following our main research questions. Firstly, we exhibit how much the tramway has affected housing prices on average during the past 13 years and the radius of the effect. Secondly, we have individually compared Sections 1 and 2 of the tramway and the Planning, Construction and Operating phases. Furthermore, we conclude when the pricing impact has happened and whether there has been an anticipation effect. In the results section, we present a summary version of regressions, while detailed regressions tables can be found in the appendix. We conclude the results section with several robustness tests.

We began our analysis with a very basic yearly average ln square price development. In Figure 5, we plotted how the average natural logarithm (ln) square prices developed between the treatment and the control groups. The graph on the left-hand side consists of the change of the average ln square prices, while the graph on the right is indexed to 2015, which is the first full year after the announcement. A vertical dotted line demonstrates the announcement date of a new tramway. The treatment group is developing hand in hand until 2015. Based on our visual analysis, there is some positive trend in the treatment group compared to the control group during 2016-2023. Additionally, the treatment effect has been stronger during 2018-2023. Moreover, within this period, the construction of Section 2 was announced, and Section 1 began its operation. Next, we continue by analysing the results of our regressions.

Figure 5, The yearly average natural logarithm square price trends in Tampere



The treatment group is built from transactions within 0-800 metres of the closest tram stop, while the control group consists of transactions beyond 2,000 metres of the closest tram stop. The left graph shows the yearly average ln square prices in 2010-2023. In the second graph, square prices have been indexed to 2015. The dotted line demonstrates the announcement of the new tramway on June 16, 2014.

6.1. Tramway effect in Tampere

The new tramway has had a positive and significant effect on housing prices on average from 2015 to 2023. In Table 5, column 4, the average treatment effect, exhibited by the interaction term (*Treatment x After*), is estimated at 0.0703. This suggests that apartments within a radius of 800 metres from a tram stop have been associated with a price premium of 7.3%[1] that attains statistical significance at the 1% level.

This implies a significant anticipation effect following Tampere's new tramway announcement on June 16, 2014. The average treatment effect exhibits the total net effect of a new tramway. It includes various effects associated with the tramway construction, including improved accessibility, neighbourhood development, enhanced services, increased housing supply, and various other factors (Harjunen, 2018).

Overall, the explanatory variables have varying impacts on square prices. Surface area is the most impactful variable to the square prices as large apartments generally have lower prices per square metre. Thus, the surface area variable is negative. Buyers appreciate new residences, plot ownership, sauna, rented apartments and lift. Also, apartment age has an inversely proportional impact on the square metre prices. From the spatial point of view, an interesting finding is that the apartments close to schools or healthcare centres did not yield any significant impact on housing prices in Tampere. In contrast, apartments in the city centre area had a price premium of 7.1% compared to those outside the city centre.

[1] $price\ premium = \ e * \ coefficient\ (discrete\ variable) - 1$ (e.g., Gupta et al., 2021)

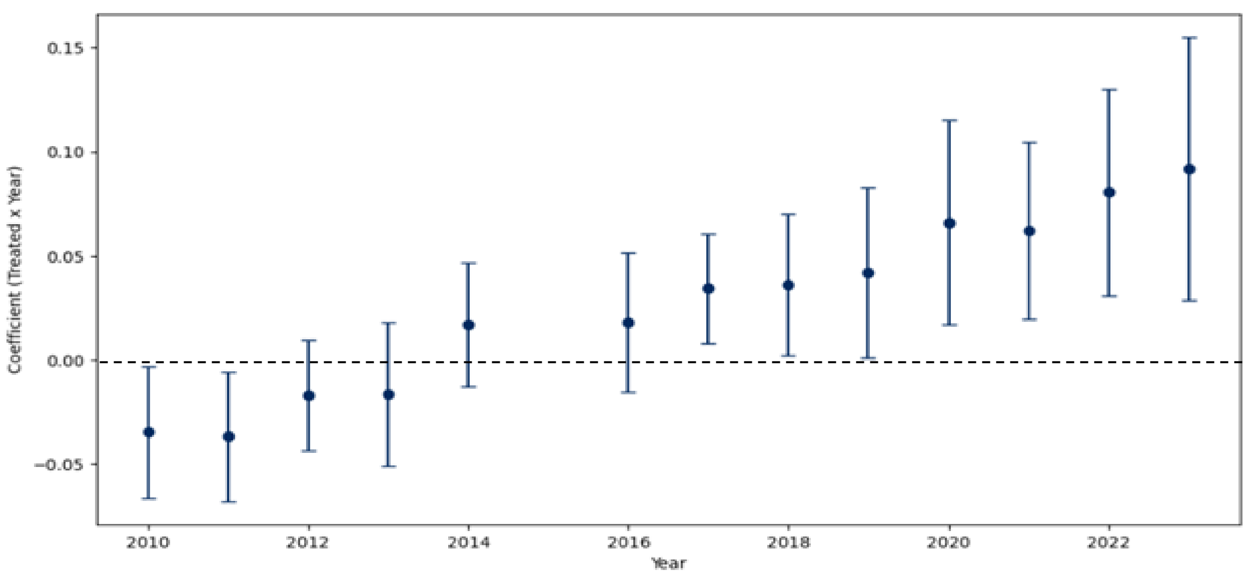
Table 5, Main sample: DID with different explanatory variables, average treatment effect 2014-2023

Distance band	**(1)** **0-800m**	**(2)** **0-800m**	**(3)** **0-800m**	**(4)** **0-800m**
Treatment	0.2200***	0.1705**	0.0322	0.0391
	0.084	*0.071*	*0.024*	*0.024*
After	0.2246***	0.0935***	0.0912***	-
	0.048	*0.018*	*0.01*	-
Treatment x After	**0.0568**	**0.0967*** **	**0.0879*** **	**0.0703*** **
	0.064	***0.029***	***0.019***	***0.017***
Ln (Surface Area)		-0.2835***	-0.2896***	-0.2764***
		0.031	*0.026*	*0.026*
Close to City Centre	-	0.2580***	0.0683***	0.0683***
		0.091	*0.022*	*0.021*
Close to Hospital	-	-0.0075	0.0161	0.0182
		0.041	*0.021*	*0.02*
Close to School	-	-0.0059	-0.0111	-0.0024
		0.023	*0.017*	*0.015*
Ownership	-	0.0883***	0.0427**	0.0396**
		0.036	*0.019*	*0.018*
Lift	-	0.0430***	0.0327***	0.0340***
		0.019	*0.006*	*0.007*
Rented	-	0.0089	0.0195***	0.0163*
		0.011	*0.007*	*0.008*
Sauna	-	0.1021***	0.0754***	0.0277**
		0.018	*0.011*	*0.014*
Balcony	-	0.0103**	0.0388***	-0.0146
		0.016	*0.013*	*0.013*
New Residence	-	0.0482**	0.0519**	0.0768***
		0.022	*0.022*	*0.015*
Constant	7.6353***	9.0094***	9.4403***	9.3984***
	0.039	*0.142*	*0.139*	*0.136*
Apartment Type	No	Yes	Yes	Yes
Apartment Condition Dummies	No	Yes	Yes	Yes
Apartment Age Dummies	No	Yes	Yes	Yes
Postcode Fixed Effects	No	No	Yes	Yes
Half-year Fixed Effects	No	No	No	Yes
No. Observations:	44 446	44 446	44 446	44 446
Adj. R-squared	0.20	0.67	0.81	0.83
Skew:	-0.50	-0.40	-0.78	-0.98
Kurtosis:	3.38	6.02	11.77	14.10
Durbin-Watson:	1.76	1.87	1.77	1.93

The estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. The dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas, and the detailed regression result for column 4 is in Appendix V.

In Table 5, we present our DID estimators alongside several explanatory variables. As expected, adding explanatory variables increases the coefficient of determination (Adjusted R^2). In column 1, one can see that the model's coefficient of determination, even without any other explanatory variables included, is 20%. Adding apartment characteristics presented in column 2, the model's adjusted R^2 improves to 67%. This is expected as hedonic models tend to have high R squared, as apartment characteristics significantly affect housing prices. The model's adjusted R^2 increases when we add postcode and half-year fixed effects, up to 83%. The high coefficient of determination is typical in similar studies (Chin, 2018; Harjunen, 2018; Valaja, 2018). In column 3, the interaction term After captures the fixed effect after the announcement period, while in column 4, half-year fixed effects are used to capture time-related effects.

Figure 6, Main sample: Dynamic DID – Coefficients of yearly estimates, year 2015 omitted



Coefficients of Treated x After estimates with 95% Confidence Interval. Dependent variable ln(Square price). Explanatory variables same as in Table 5, column 4. Regression's results in Appendix VI. Standard errors are clustered by postcode areas.

Figure 6 presents yearly estimates for the treatment effect with a 95% confidential interval. See Appendix VI for detailed regression. The yearly estimates consistently demonstrate positive values after the announcement. Likewise, the treatment effects tend to have a positive trend, implying that the anticipation effect increases as we approach the operating phase. An important assumption for using DID is that the treatment and the control groups follow parallel trends before the announcement of the new tramway. We cannot assert definitively that this assumption holds during 2010-2011, but an examination of the preceding three years of the announcement reveals no significant treatment effects. We will discuss more about the reliability of these results in detail in the Discussion section.

Table 6 summarises how the tram effect decreases when treatment groups are further away from a tram stop. Table 6, column 1, exhibits that after the decision dates in the 400-metre range from tram stops, the housing unit values have increased 7.4% faster than in the control group. We can see that the anticipation effect is still moderately strong in the 400-800 metre range from an apartment, producing an increase of 6.0%. The impact persists until 1,600 metres from the tram stop as housing unit prices have increased in the bandwidths of 800-1,200m and 1,200-1,600m by 5.1% and 4.6%, respectively. Moving further away from the stops decreases the effect and is close to 0 in the 1,600-2,000m distance band. Moreover, the results of the final distance bandwidth are statistically insignificant. Parallel trend assumptions are presented in Appendix VII.

Overall, the results are similar to other studies using the DID method (e.g., Zhang et al., 2014; Harjunen, 2018). Valaja found in her research that the tramway had a 2.8% average effect on housing unit prices during 2015-2018 within an 800-metre radius of the closest tram stop using the OLS method. The difference between the results can also be explained using walking distance instead of straight-line distance to determine the closeness of an apartment to the closest tram stop. Moreover, we estimate the walking distance to be 35% longer on average than the straight-line distance, which means that our 800-metre radius is shorter than Valaja's. Additionally, we have a longer time frame, including Section 2 of the tramway, while Valaja studied Section 1.

Table 6, Main sample: DID with different distance bands

Distance band	**(1)** **0-400m**	**(2)** **400-800m**	**(3)** **800 - 1 200m**	**(4)** **1 200 - 1 600m**	**(5)** **1 600 - 2 000m**
Treatment	0.0715**	0.0287**	0.0108	-0.0016	0.0432***
	0.03	*0.014*	*0.023*	*0.03*	*0.015*
Treatment x After	**0.0712*** **	**0.0586*** **	**0.0500** **	**0.0450* **	**0.0080**
	0.02	***0.023***	***0.024***	***0.027***	***0.008***
Ln (Surface Area)	-0.2704***	-0.2860***	-0.2805***	-0.2619***	-0.2794***
	0.021	*0.025*	*0.021*	*0.023*	*0.023*
Distance to City, School & Healthcare	Yes	Yes	Yes	Yes	Yes
Apartment Characteristics Dummies	Yes	Yes	Yes	Yes	Yes
Apartment Type Group	Yes	Yes	Yes	Yes	Yes
Apartment Condition Dummies	Yes	Yes	Yes	Yes	Yes
Apartment Age Dummies	Yes	Yes	Yes	Yes	Yes
Postcode Fixed Effects	Yes	Yes	Yes	Yes	Yes
Half-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Constant	9.3000***	9.3276***	9.2943***	9.1612***	9.2318***
	0.106	*0.129*	*0.088*	*0.095*	*0.095*
No. Observations:	34 529	30 584	28 782	26 891	25 873
Adj. R-squared	0.83	0.82	0.81	0.82	0.81
Skew:	-0.71	-0.89	-0.48	-0.58	-0.71
Kurtosis:	11.08	9.48	9.48	11.08	9.61
Durbin-Watson:	1.93	1.94	1.94	1.94	1.95

The estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. The dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas, and the detailed regression result for column 4 is in Appendix VII.

6.2. Anticipation effect during Section 1 and 2

Next, we compare different phases and sections between each other. We have described the tram's stages more closely in the Institutional Setting section. First, we compare Sections 1 and 2.

In Table 7, we have included apartments closest to tram stops in Section 1, while in Table 8, we examine apartments closer to Section 2 tram stops. In Section 1, the average treatment effect is 6.0% in 0-800 metres, and the result for 800-1,600 distance band is statistically insignificant, while in Section 2, the effect is 11.8% in 0-800 metres and 9.3% for the radius of 800-1,600 metres. Average treatment effects are significantly higher in Section 2 compared to Section 1. Three key factors primarily explain this effect.

Firstly, the probability of the entire tramway project in Tampere being completed improved significantly after Section 1 was finished. Also, the beginning of construction of Section 1 marked a milestone in the process, which reduced the risk of project failure and accelerated the anticipation effect on property values in Section 2. Secondly, yearly surveys have indicated a significant shift to positiveness in attitudes towards the tram project as it has progressed. As discussed in the Institutional setting section, this improvement in perception has played a substantial role in shaping the overall impact. Finally, the Section 2 tram stops are mainly located in Lentävänniemi. The area is located further from the city centre, which means that accessibility to the centre will improve due to the tramway connection compared to the first phase.

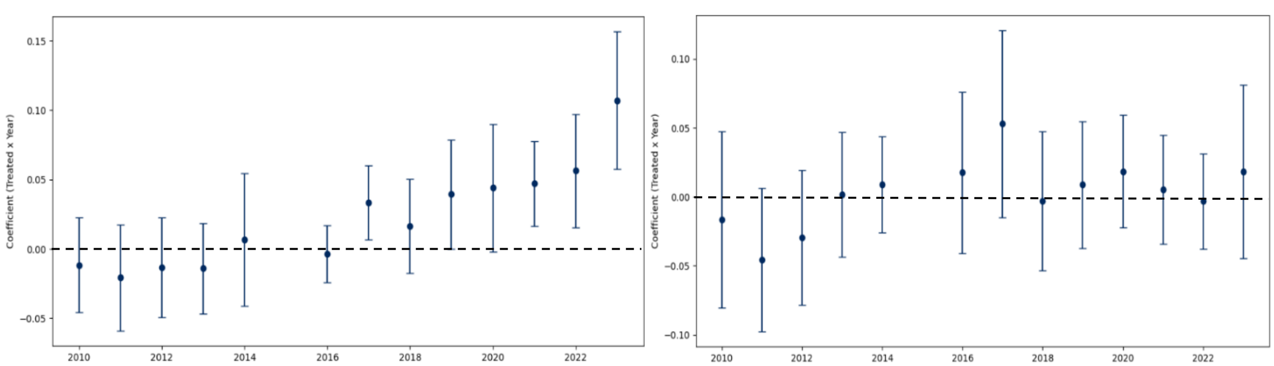
Table 7, Section 1: DID coefficient estimates				
	(1)	**(2)**	**(3)**	**(4)**
Distance band	**0-800m**	**800-1 600m**	**0-800m**	**800-1 600m**
Treatment	0.0707***	0.0272	0.0703***	0.0273***
	0.044	*0.025*	*0.044*	*0.024*
Treatment x After	0.0579***	0.0368	-	-
	0.02	*0.03*	-	-
Treatment x Planning	-	-	0.0381***	0.0298
	-	-	*0.015*	*0.018*
Treatment x Construction	-	-	0.0623**	0.0417
	-	-	*0.021*	*0.036*
Treatment x Operating	-	-	0.0710***	0.0254
	-	-	*0.031*	*0.03*
Constant	9.2794***	9.1049***	9.2806***	9.1050***
	0.178	*0.116*	*0.178*	*0.116*
No. Observations:	34 732	24 889	34 732	24 889
Adj. R-squared	0.83	0.82	0.83	0.82

The estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. Section 2 transactions excluded. The dependent variable is a natural logarithm of the square metre price. Explanatory variables are the same as in Table 6. Standard errors are clustered by postcode areas.

Figure 7, Section 1: Dynamic DID – Coefficients of yearly estimates, year 2015 omitted

Graph 1: Average yearly treatment effect 0-800m for section 1

Graph 2: Average yearly treatment effect 800-1 600m for section 1



Coefficients of Treated x Year estimates with 95% Confidence Interval. The dependent variable ln(Square price). Explanatory variables are the same as in Table 6, and OLS regression results are in Appendix VIII. Standard errors are clustered by postcode areas.

Table 7 andTable **8**, columns 3 and 4 present the average treatment effect of different phases: Planning, Construction and Operating. In Section 1, the average treatment effect is the highest during the operating phase (2021-2023) and the lowest in the planning phase (2014-2016) for housing units within 0-800 metres of a tram stop. In Figure 7, we can see a similar trend. Graph 1 shows that the average treatment effect has been consistently positive from 2017 to 2023, with an upward trend each year except for 2018. In Graph 2, where the treatment effect is exhibited for the treatment group with a distance band of 800-1,600 metres from a tram stop, no significant effects are discernible. Furthermore, the 800-1,600 metre treatment group results are statistically insignificant.

The same trend can be seen in Section 2. The average anticipation effect is higher during the construction period (2021-2023) than in the planning phase (2018-2021). In Figure 8, Graph 1, we see that the yearly treatment effects were fairly constant, while for 2018-2019, the treatment effect was not statistically significant. For the treatment group further away from a tram stop, the treatment effect does not have a similar gradually increasing trend. On the contrary, the values for the average treatment effect do not form a clear trend, and for three years, the effect is statistically insignificant.

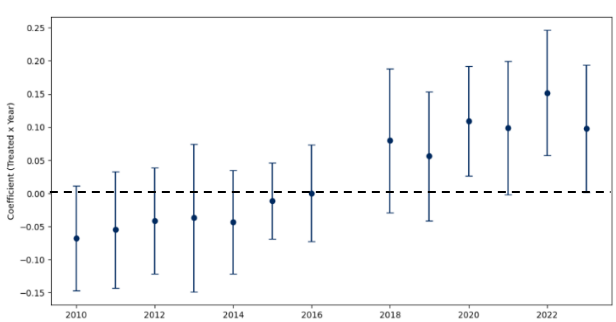
Previous studies found mixed results comparing different phases of transit infrastructure projects. Devaux et al. (2017) did similar research on new metro stations in Laval, Canada. They found that the announcement period negatively affected apartment prices, while the price impact in the construction and operating periods was positive. However, results during the announcement and construction period were not statistically significant and varied between stations. When Agostini and Palmucci studied the Metro Line 4 in Santiago, Chile, they found that the average treatment effect was higher during the announcement period than in the basic engineering (construction) period.

Table 8, Section 2: DID coefficient estimates				
	(1)	**(2)**	**(3)**	**(4)**
Distance band	**0-800m**	**800-1 600m**	**0-800m**	**800-1 600m**
Treatment	0.0085	-0.0273***	0.0080	-0.0272***
	0.045	*0.029*	*0.045*	0.029
Treatment x After	0.1117***	0.0893***	-	-
	0.02	*0.025*	-	-
Treatment x Planning			0.1018***	0.0922***
			0.022	*0.03*
Treatment x Construction			0.1260***	0.0851***
			0.023	*0.028*
Constant	9.5451***	9.4080***	9.4403***	9.3121***
	0.133	*0.119*	*0.144*	*0.128*
No. Observations:	9 714	8 676	9 714	8 676
Adj. R-squared	0.81	0.79	0.81	0.79

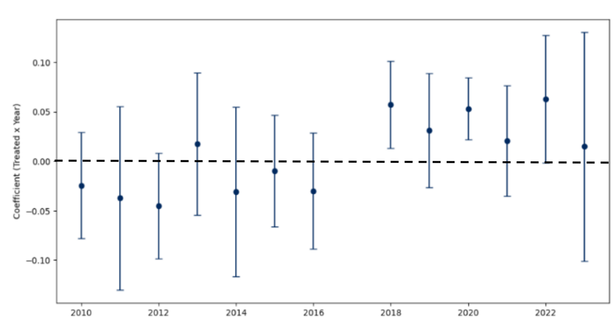
The estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. Section 2 transactions excluded. The dependent variable is a natural logarithm of the square metre price. Explanatory variables are the same as in Table 6. Standard errors are clustered by postcode areas.

Figure 8, Section 2: Dynamic DID – Coefficients of yearly estimates, year 2017 omitted

Graph 1: Average yearly treatment effect 0-800m for section 1



Graph 2: Average yearly treatment effect 800-1 600m for section 1



Coefficients of Treated x Year estimates with 95% Confidence Interval. The dependent variable ln(Square price). Explanatory variables are the same as in Table 8, and OLS regression results are in Appendix VIII. Standard errors are clustered by postcode areas.

6.3. Robustness tests

To ensure the robustness of our results, we conduct multiple tests which we consider to affect the average net effect in Tampere's region. First, we investigate the impact of excluding transactions with specific characteristics that might affect the results. This step allows us to assess the stability of our findings under different model specifications and avoid selection bias. Second, we analyse how the treatment effects and fit of control vary by using different control groups, considering that our choice of control group was arbitrary.

This research focuses on all residential transactions during 2010-2023 in Tampere. There are diverse ways to approach this matter; some studies encompass all transactions, while some concentrate on a certain type of housing apartments or areas. In Table 9, column 1, we present a common approach that includes only apartments, similar to Valaja (2018) and Gupta et al. (2021). The reasoning behind this approach is that buyers' preferences for various characteristics may differ when valuing apartments versus other housing types. Also, Gadzinski and Radzimski (2016) show that different types of properties see their values rise while others do not. Based on our model, the average treatment effect is 5.6%, only including apartments, slightly lower than our main result, 7.4%.

In the second column, we exclude new residences. Harjunen and Valaja used this approach to focus on existing housing explicitly. While including new residences in the main results may present differences in apartment characteristics, we justified this as the tramway tends to increase house building. Thus, the supply of housing increases, which should, all else being equal, decrease housing unit prices. The average treatment effect estimate is 8.6%, which is higher than with the whole sample. Furthermore, other factors for the difference could include that the new housing supply might be concentrated in an area that is not affected by the tramway similar to others or is not otherwise appreciated.

In the third column, we wanted to exclude the transactions in the city centre area. For instance, Harjunen (2018) and Meronen (2018) excluded the housing units in the city centre to address the problem of finding a good control group in the city centre area. In general, they tend to be completely different when considering the wide variety of services, accessibility and urban environment compared to the suburban areas. While the average treatment effect is 6.2%, which is slightly lower compared to the total sample, it provides robustness that including the city centre does not tend to affect results significantly.

Column 4 exhibits results when all previous exclusions are combined, focusing solely on existing apartments away from the city centre. The average treatment effect after the announcement of the new tramway was 6.6%. Figure 9 displays yearly DID estimates, confirming the trend of an increasing average treatment effect as we approach the period when the tram started operating and the second phase of construction began. The parallel trends assumption holds as there was no significant effect during 2010-2014 before the announcement, which increases the reliability of our results.

Table 9, Robustness tests for DID estimator with different explanatory variables

	(1)	**(2)**	**(3)**	**(4)**
Distance band	**0-800m**	**0-800m**	**0-800m**	**0-800m**
Explanatory variables	Apartments only	New Residences excluded	City Centre excluded	All Excluded
Treatment	0.0477	0.0222	0.0315	0.0312
	0.035	*0.025*	*0.024*	*0.037*
Treatment x After	**0.0544*****	**0.0825*****	**0.0605*****	**0.0642*****
	0.021	***0.016***	***0.018***	***0.022***
Distance to City, School & Healthcare	Yes	Yes	Yes	Yes
Apartment Characteristics Dummies	Yes	Yes	Yes	Yes
Apartment Type Dummies	No	Yes	Yes	Yes
Apartment Condition Dummies	Yes	Yes	Yes	Yes
Apartment Age Dummies	Yes	Yes	Yes	Yes
Postcode Dummies	Yes	Yes	Yes	Yes
Time of Transaction fixed effect	Yes	Yes	Yes	Yes
Constant	9.4699***	9.3769***	9.3769***	9.7096***
	0.152	*0.122*	*0.122*	*0.155*
No. Observations:	33 174	35 947	39 163	21 409
Adj. R-squared	0.86	0.82	0.83	0.86

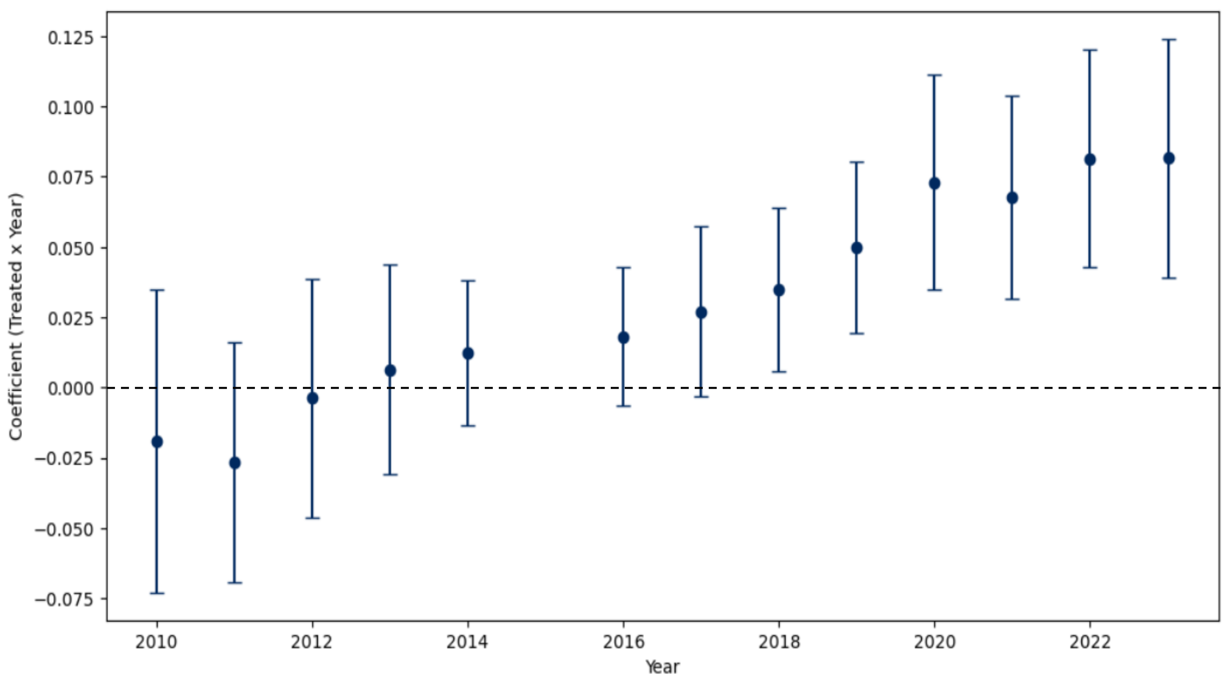
The estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. The dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas.

The control group used in this study consists of transactions located over 2,000 meters away from the closest tram stop. We wanted to ensure no spillover treatment effect on the control group. The following robustness test checks how the treatment effect varies between different distance bands we use for different control groups.

As previously demonstrated in Table 5, the average treatment effect diminishes as the distance from the closest tram stop increases. In Table 10, column 1, we observe that the treatment effect is slightly weaker when defining the control group as all transactions over 800 meters. This suggests that the control group, in this case, may be affected by spillover effects from the tramway. As we can see, one of our critical assumptions is that the control group should ideally not incorporate any spillover effects from the tramway as it affects the treatment estimates.

Figure 9, Only Apartments and Excluding city centre area & New Residences

Hedonic DID – Coefficients of yearly estimates, year 2015 omitted



Coefficients of Treated x Year estimates with 95% Confidence Interval. Dependent variable ln(Square price). Explanatory variables same as in Table 9, OLS regression results in Appendix IX. Standard errors are clustered by postcode areas.

Table 10, Robustness tests for different control groups				
	(1)	**(2)**	**(3)**	**(4)**
Treatment group	**0-800m**	**0-800m**	**0-800m**	**0-800m**
Control Group	>800m	>1600m	>2400m	>3200m
Treatment	0.0181	0.0380	0.0270	0.0355
	0.014	*0.022*	*0.028*	*0.025*
Treatment x After	**0.0556*** **	**0.0699*** **	**0.0695*** **	**0.0707*** **
	0.015	***0.017***	***0.017***	***0.019***
Distance to City, School & Healthcare	Yes	Yes	Yes	Yes
Apartment Characteristics Dummies	Yes	Yes	Yes	Yes
Apartment Type Group	Yes	Yes	Yes	Yes
Apartment Condition Dummies	Yes	Yes	Yes	Yes
Apartment Age Dummies	Yes	Yes	Yes	Yes
Postcode Dummies	Yes	Yes	Yes	Yes
Half-Year Fixed Effect	Yes	Yes	Yes	Yes
Constant	9.3087***	9.3819***	9.4287***	9.4095***
	0.128	*0.134*	*0.135*	*0.138*
No. Observations:	59 161	46 505	42 488	38 237
Adj. R-squared	0.82	0.83	0.83	0.84

The estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. The dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas.

In Table 10, comparing other columns, it appears that when using a control group located over 1,600 meters from the closest tram stop, the average treatment effect is notably consistent, around 7.2-7.3%. These figures align closely with our primary results, emphasizing the robustness and reliability of our findings. This choice of control group, situated sufficiently far from the tramway influence, supports the validity of our estimated treatment effects by mitigating potential spillover effects.

Comparing these results with the total sample, yielding a 7.4% average treatment effect, we conclude that Tampere's tramway has significantly affected housing unit prices after the tramway announcement. Based on the different samples in our robustness tests, for instance, apartments only, we found that the results vary between 5.6 – 8.6 % for the average treatment effect. Thus, we can assume that our results are robust.

7. Discussion

The results of our study are clear, as the tramway has affected the housing market in Tampere. The proximity of a tramway stop has generally increased housing unit prices regardless of the city zone. As always, there are some limitations to this research paper, and we will discuss the issues we have faced during the process.

Generally, selecting a control group is vital when studying the effect of the public transit system on the housing market. The treatment group and the control group should be similar in their characteristics to study the actual effect of the infrastructure project on the housing unit prices along the transit stops and extract robust results from the dataset. Otherwise, the results might be altered by other characteristics affecting the housing units' neighbourhood. Commonly, there is no perfect control group, i.e., the control group is always a compromise. More specifically, the control group should be comparable with the treatment group to examine the tramway's effect on the housing market. Generally, this leads the researcher to decide between different options. In existing research, Harjunen (2018), Meronen (2020) and Eriksson (2022) all studied West Metro's impact on the housing market in Espoo and Helsinki. They all used regional train stations as a proxy to the metro stations for the control group to compare the effect of the new transit infrastructure to an existing one. This was because the regional train stations were located far enough from the new metro line that there was no spillover effect on the housing units near the train stations. On the other hand, the apartments near the train stations were already influenced by the train connection to the city centre.

Ideally, the control group would be formed from similar neighbourhoods without a public transport system. For example, a city might consider two routes for a new metro line, but only one is built. The other planned route and its stations could then be used as a control group to examine the effect of the new metro line on apartments near the new stations compared to the housing units next to the planned but not built stations. The treatment group is then separated from the control group, and the new transportation line has no spillover effect on the control group. Thus, the effect of the tramway can be measured accurately on only the treatment group. This control group selection also assumes that the neighbourhood characteristics between the different transportation routes would be similar. Otherwise, another control group is more fitting to the study.

Since Tampere is a small city between two lakes, there is no alternative route planned for the tramway, and therefore, we could not build our control group ideally. Furthermore, there are not enough regional train stations in the region to use them and their surrounding apartments as a control group in this study. We form our control group from the areas outside our tram stop bandwidths. For instance, Kauria (2020) uses a similar control group formation in his study about the similar tramway in Helsinki and Espoo. There, however, is a difference between the selected control groups as we have left a bandwidth zone of 1,200 metres (a bandwidth between 800-2,000 metres away from the tram stop) between the treatment group and the control group, unlike Kauria (2020). Although we aim to reduce the tramway spillover effect on the housing units away from the tramway, we cannot ensure that the entire spillover effect is excluded. Keeping this in mind, the housing units between the treatment and control groups may have slightly different characteristics, another possible limitation of our control group. Other options for the control group were limited in the Tampere region, and methods such as the synthetic control group seem too sophisticated for our study. Furthermore, we thoroughly review our control group in the data section.

We have also found other control group limitations that separate us from having the ideal control group. Firstly, the tramway could indirectly affect Tampere as a whole and thus increase prices around the city. Therefore, we must assume that the indirect effect is the same for all areas in Tampere. Secondly, the size of the Tampere city centre presents a limitation for the control group quality as the two-kilometre bandwidth in the city centre covers the most densely populated areas of Tampere. Thus, our control group housing units might not possess the same characteristics as the treatment group in the city centre. Finally, we considered other cities and areas in Finland, such as Nokia, Pirkkala and Helsinki, as possible locations to build the control group from, yet their zone, housing market and characteristics differ too significantly to be used for this.

We had different ways to execute the analysis when considering how to analyse the tramway effect. We opted out of a two-way fixed effects model, where we would have analysed our data using an event study, considering there were two distinct sections and announcements regarding the tramway. The event study model is generally used in finance research, for instance, to study share announcement effects and abnormal returns, where there is a specific event and a single stock, or a portfolio of stocks, is analysed before and after the event has happened to find if the announcement or event produced abnormal returns.

However, we chose to analyse these sections individually and together, assuming that the whole region of Tampere was affected by the original announcement. Thus, our approach is simpler and easier to understand, benefiting the larger public by examining the results. Additionally, by considering both sections at the same time using a two-way fixed effects event study model, the potential challenges associated with the spillover effects in the areas of Section 2, when the decision of the tramway is yet to be made for Section 2, could drastically affect the results of the study. Thus, we selected to study the two announcements separately.

We have focused on the treatment and control groups throughout the study as the correct group selections significantly affect the study's robustness. Moreover, some biases could affect our study, too. Our data is incomplete, as the database we used has approximately 70% of the Finnish real estate transactions. We are unsure if the share of transactions is higher or lower in Tampere compared to the rest of Finland. Thus, selection bias is possible as there might be a transaction type that is not part of the sample continuously. Our data is suitable for the study, yet we cannot be sure of it. Additionally, we have omitted several data points due to a lack of complete data. Therefore, omitted variable bias may affect our study.

In this study, we examine the average treatment effect of the tramway separately for Sections 1 and 2. As we study the average treatment effect, it is likely that the tramway effect is not evenly distributed between the tramway stops. Firstly, in Section 1, there are more tramway stops than in Section 2. Secondly, the number of transactions varies heavily between the different in Tampere, i.e., the sample is not evenly distributed. Finally, we tried to group the certain tramway stops to study particular areas, for instance, Hervanta, compared to the city centre. The results of these groupings were not robust, and therefore, we did not include them in this master’s thesis.

The most critical assumption in the DID model is the Parallel trend assumption. Our main results show that the treatment effect was slightly negative before the announcement during 2010 and 2011 and not statistically significantly different from zero three years before the announcement. Moreover, this indicates that we cannot be sure that the parallel trends assumption holds perfectly. Nevertheless, in the final three years before the announcement of the new tramway, the treatment group did not have a significant treatment effect. We also demonstrated that the parallel trends assumption holds when considering Sections 1 and 2 individually. Likewise, no significant treatment effects were found before the announcement by focusing solely on apartments and excluding the city centre area and new residences. Hence, our results are robust, and the tramway has positively affected the housing unit prices near the tramway stops.

Finally, we could have used a different method, such as repeat-sales (Devaux et al., 2017), to determine if the results would differ. The model compares unique property sales over time to capture the effect of public transit infrastructure projects on housing transactions. The limitation of using the model is the number of unique repeated sales in the sample size, as unique apartments cannot be identified from our dataset. This poses a problem because two apartments could be considered the same, while their amenities could differ. For instance, one of the apartments could be renovated during the study period, and the tramway could falsely capture the effect in the model. When used correctly, the repeat-sales method provides accurate results as the transactions of housing units are compared over time.

8. Conclusions

In this master's thesis, we study the effects of the new tramway on the Tampere housing market. We found that the property values have increased in the impact zone of the tramway. Our main result is that the tramway effect has increased housing unit prices on average by 7.4% within 400 metres from a tram stop and 6.0% between 400-800 metres from one. Furthermore, there is an anticipation effect on the prices, which is stronger in Section 2 than in Section 1, as the prices have increased by 11.8% and 6.0% respectively within the 800-metre radius. We argue that the risk of the tramways' sections not being completed has decreased as Section 2 was announced when the building of Section 1 was already well underway. Thus, the anticipation effect was more substantial as the risk of the tramway not being built was decreased, and the benefits of the tramway were already present.

Furthermore, the Lentävänniemi neighbourhood in Section 2, for instance, is further away from the city, and the amenities in that area have improved, which could explain the difference between the two sections. Additionally, we believe the positive overall reaction to the tramway (Tampere tramway survey, 2022) has led to faster realisation of property value appreciation. Moreover, we found that the anticipation effect is accelerating the closer the operation phase becomes.

We have also tested the robustness of our results by performing additional regressions on different samples, for instance, excluding all but multi-storey apartments from our data and excluding new residences. As a result of these tests, we can conclude that they conform to our primary results since apartments only yield an average effect on square meter prices of 5.6% in 800 metres of a tram stop while excluding new residences totals an increase of 8.6%. Naturally, there should be some variation between the results as the housing characteristics differ, but one can see that the tramway effect persists between the different samples.

Even though our findings show evidence of the tramway affecting property values, it must be noted that the study could be improved and extended further. Firstly, the data availability restricts the study as our data consists of approximately 70% of the property transactions in Tampere. Secondly, an extended time frame would shed light on the effects of the future sections of the tramway and provide further evidence of how time affects house prices after the tram has begun its operation. Furthermore, Tampere is in a growth stage, and 70-75% of the new properties built between 2016-2040 will be built in the impact zone of the tramway, which could alter the property prices in the future along the tramway stops (Tampere tramway, 2023).

In the future, large transit infrastructure projects will likely be more common in Finland as the larger cities grow and the need for public transit increases. The future projects will again provide a different setting, and the effects on the housing market in general and the impact specifically near the stops and stations can be examined once more. Additionally, following the studies of Gupta et al. (2021) and Kauria (2020), an extending research paper could be focused on the costs and value of the project and how the land and property value gains of the tramway infrastructure are distributed between the homeowners along the tramway and the city through, for example, collected property taxes.

Furthermore, the tramway effect could be studied also from other perspectives. First, it would be interesting to know if the tramway affected the liquidity of the housing market in Tampere. This would be an intriguing subject as the property market is known for its illiquidity in comparison to other asset classes. Second, the effect on rents in Tampere could be studied. For instance, Meronen (2020) conducted her master's thesis on West Metro's effects on the rental market in Espoo and Helsinki. As long as rental data is available, similar research could be done in Tampere, too. Finally, the following sections of the tramway project could be studied to see if the anticipation effect persists over time and in the areas further away from the city centre.

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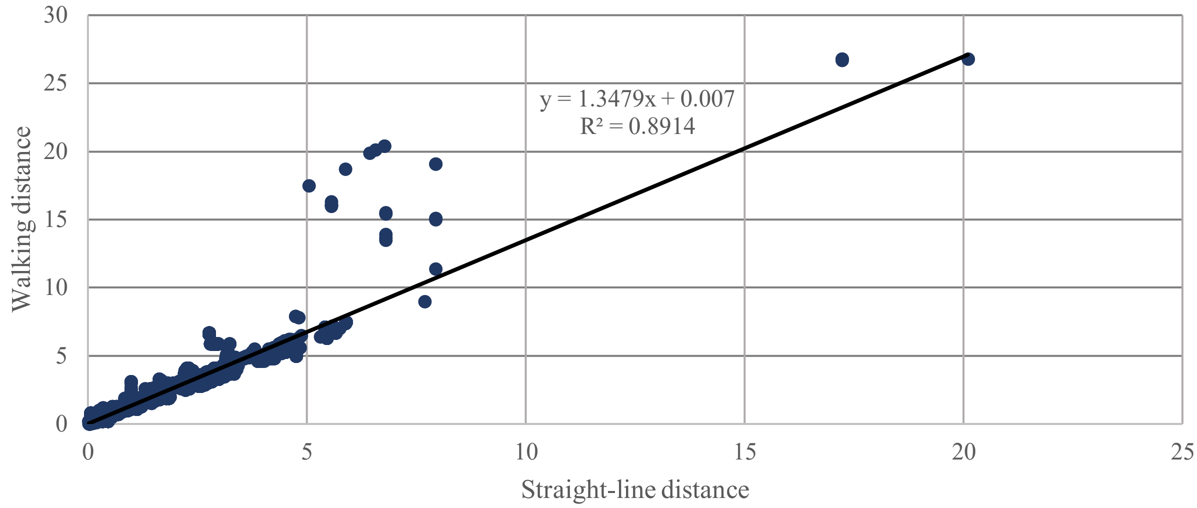
Appendix

Appendix I, OLS regression, (Valaja, 2018) replicated results

	(1) Straight line distance	(2) Walking Distance
800-metre buffer	0.0318***	0.0592***
	0.039	*0.006*
Ln(Surface Area)	-0.3112***	-0.3123***
	0.005	*0.005*
Ln(Distance to City Centre)	-0.1119***	-0.0999***
	0.006	*0.006*
Ownership	0.0465***	0.0451***
	0.005	*0.005*
Lift	0.0156***	0.0141***
	0.005	*0.005*
Rented	0.0043	0.0040
	0.006	*0.006*
Sauna	0.0535***	0.0530***
	0.007	*0.007*
Balcony	-0.0344***	-0.0331***
	0.006	*0.006*
Constant	9.6181***	9.6204***
	0.023	*0.022*
Apartment Age Dummies	Yes	Yes
Postcode Fixed Effects	Yes	Yes
Half-Year Fixed Effects	Yes	Yes
No. Observations:	9,019	9,019
Adj. R-squared	0.84	0.84
Skew:	-0.23	-0.23
Kurtosis:	5.30	5.40
Durbin-Watson:	1.99	1.99

Estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. Dependent variable is a natural logarithm of the square metre price. 800-metre buffer (Valaja, 2018) was used in a previous study about Tampere tramway effects on the housing market.

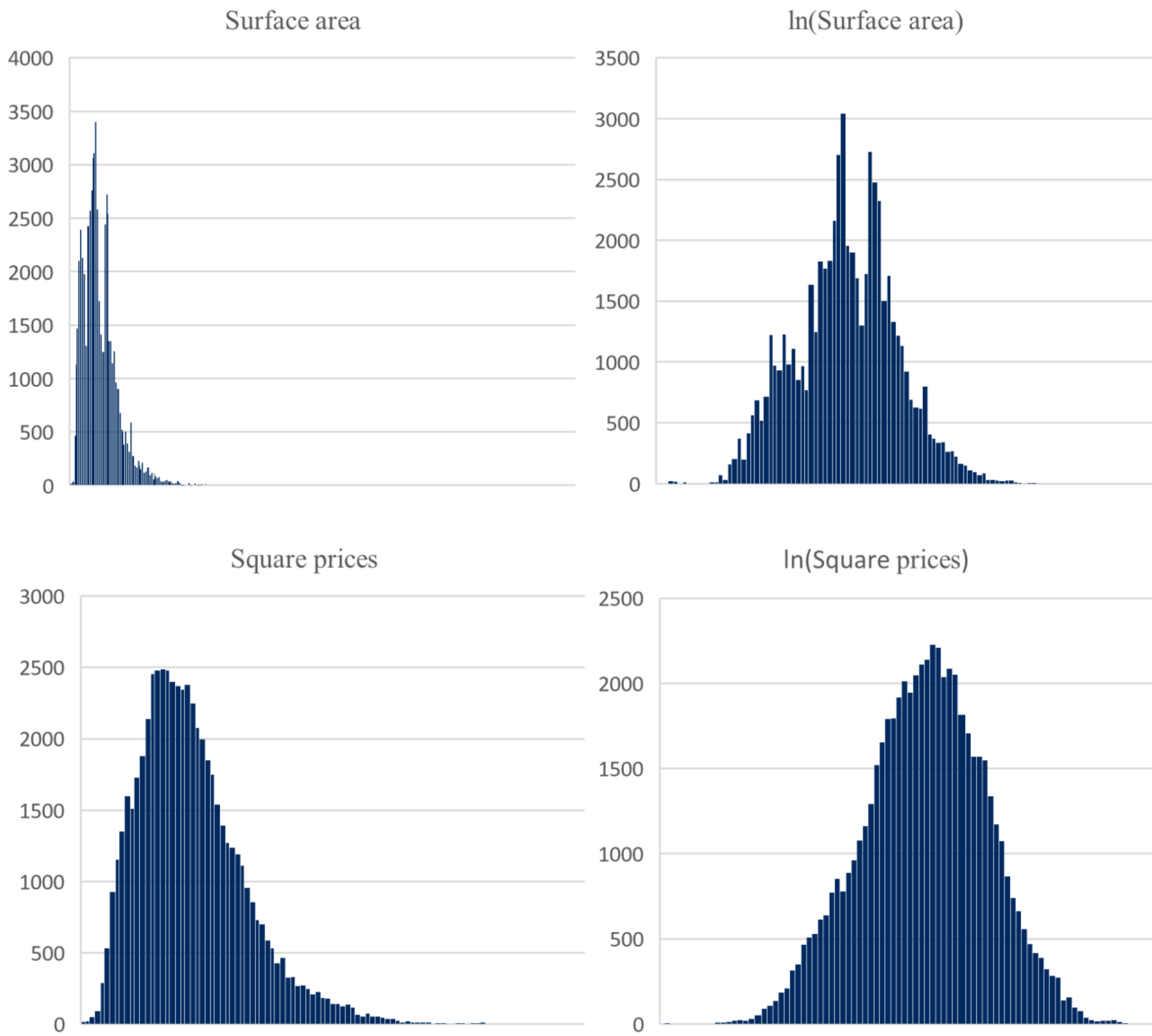
Appendix II, Comparison of straight-line and walking distance to the closest tram stop



Appendix III, Descriptive statistics of explanatory dummy variables

Variable	Yes (1)	%	Variable	Yes (1)	%
Distance dummies			**Conditions Group**		
Close to School (<500m)	28 261	47.8	New	6 534	11.0
Close to Hospital (<500m)	8 690	14.7	Excellent	1 295	2.2
Close to City Center (<1500m)	7 101	12.0	Good	36 234	61.2
Apartment Characteristic dummies			Satisfying	9 615	16.3
Ownership	30 385	51.4	Tolerable	747	1.3
Lift	26 434	44.7	Unknown	4 736	8.0
Rented	4 483	7.6	**Postcode Group**		
Sauna	12 407	21.0	Postcode 33100	5 486	9.3
Balcony	15 797	26.7	Postcode 33180	982	1.7
New Residence	10 874	18.4	Postcode 33200	2 077	3.5
Half Year Fixed Effects			Postcode 33210	1 569	2.7
H1 2010	2 165	3.7	Postcode 33230	2 125	3.6
H2 2010	2 078	3.5	Postcode 33240	381	0.6
H1 2011	2 011	3.4	Postcode 33250	595	1.0
H2 2011	2 000	3.4	Postcode 33270	1 682	2.8
H1 2012	1 983	3.4	Postcode 33300	1 446	2.4
H2 2012	2 129	3.6	Postcode 33310	1 601	2.7
H1 2013	1 899	3.2	Postcode 33330	599	1.0
H2 2013	1 921	3.2	Postcode 33340	1 224	2.1
H1 2014	1 844	3.1	Postcode 33400	2 481	4.2
H2 2014	1 931	3.3	Postcode 33410	1 749	3.0
H1 2015	1 961	3.3	Postcode 33420	357	0.6
H2 2015	1 994	3.4	Postcode 33500	2 955	5.0
H1 2016	2 164	3.7	Postcode 33520	275	0.5
H2 2016	2 381	4.0	Postcode 33530	1 107	1.9
H1 2017	2 492	4.2	Postcode 33540	3 466	5.9
H2 2017	2 620	4.4	Postcode 33560	2 391	4.0
H1 2018	2 411	4.1	Postcode 33580	3 206	5.4
H2 2018	2 622	4.4	Postcode 33610	963	1.6
H1 2019	2 384	4.0	Postcode 33700	362	0.6
H2 2019	2 739	4.6	Postcode 33710	3 920	6.6
H1 2020	2 339	4.0	Postcode 33720	4 924	8.3
H2 2020	2 888	4.9	Postcode 33730	479	0.8
H1 2021	2 833	4.8	Postcode 33800	1 418	2.4
H2 2021	2 744	4.6	Postcode 33820	1 609	2.7
H1 2022	2 316	3.9	Postcode 33840	887	1.5
H2 2022	1 856	3.1	Postcode 33850	765	1.3
H1 2023	456	0.8	Postcode 33870	2 495	4.2
Apartment Age Group			Postcode 33900	3 585	6.1
Age_0-10	17 394	29.4	**Apartment Type Group**		
Age_11-20	4 499	7.6	Apartment	43 023	72.7
Age_21-30	5 985	10.1	Detached House	3 647	6.2
Age_31-40	8 094	13.7	Others	12 491	21.1
Age_41-50	8 591	14.5			
Age_50+	14 598	24.7			

Appendix IV, Natural logarithm transfer due to the skewed continuous variables



Appendix V, Full regression's results for Table 5 column 4

	coef	std err	z	P>|z|	[0.025	0.975]
const	9.3984	0.136	69.251	0	9.132	9.664
TreatmentGroup	0.0391	0.024	1.662	0.096	-0.007	0.085
Treatment_PostTreatment	0.0703	0.017	4.104	0	0.037	0.104
Log_Surface_area	-0.2764	0.026	-10.689	0	-0.327	-0.226
CloseCityCenter	0.0683	0.021	3.226	0.001	0.027	0.11
CloseHospital	0.0182	0.02	0.891	0.373	-0.022	0.058
CloseSchool	-0.0024	0.015	-0.158	0.875	-0.032	0.027
Ownership	0.0396	0.018	2.201	0.028	0.004	0.075
Lift	0.034	0.007	5.051	0	0.021	0.047
Rented	0.0163	0.008	2.131	0.033	0.001	0.031
Sauna	0.0277	0.014	1.993	0.046	0	0.055
Balcony	-0.0146	0.013	-1.14	0.254	-0.04	0.01
New Resident	0.0768	0.015	5.184	0	0.048	0.106
Age_11-20	-0.1461	0.015	-9.945	0	-0.175	-0.117
Age_21-30	-0.2611	0.017	-15.34	0	-0.294	-0.228
Age_31-40	-0.4099	0.03	-13.785	0	-0.468	-0.352
Age_41-50	-0.4824	0.032	-15.086	0	-0.545	-0.42
Age_50+	-0.4055	0.035	-11.547	0	-0.474	-0.337
Condition_Excellent	0.0379	0.022	1.694	0.09	-0.006	0.082
Condition_Unknown	-0.0416	0.008	-5.473	0	-0.056	-0.027
Condition_Satisfied	-0.1248	0.004	-28.078	0	-0.134	-0.116
Condition_Tolerable	-0.268	0.024	-11.162	0	-0.315	-0.221
Detached House	0.2525	0.032	7.786	0	0.189	0.316
Others	0.1658	0.024	6.991	0	0.119	0.212
Postcode_33180	0.1704	0.036	4.67	0	0.099	0.242
Postcode_33200	0.0869	0.018	4.948	0	0.052	0.121
Postcode_33210	0.0631	0.023	2.803	0.005	0.019	0.107
Postcode_33230	0.0408	0.025	1.639	0.101	-0.008	0.09
Postcode_33250	-0.3432	0.026	-13.318	0	-0.394	-0.293
Postcode_33270	-0.2911	0.03	-9.83	0	-0.349	-0.233
Postcode_33300	-0.4351	0.035	-12.513	0	-0.503	-0.367
Postcode_33310	-0.5391	0.034	-15.653	0	-0.607	-0.472
Postcode_33330	-0.5971	0.034	-17.815	0	-0.663	-0.531
Postcode_33340	-0.4748	0.041	-11.585	0	-0.555	-0.394
Postcode_33400	-0.3856	0.035	-11.073	0	-0.454	-0.317
Postcode_33410	-0.5176	0.024	-21.626	0	-0.565	-0.471
Postcode_33420	-0.475	0.031	-15.378	0	-0.536	-0.414
Postcode_33500	-0.035	0.019	-1.86	0.063	-0.072	0.002
Postcode_33520	-0.25	0.026	-9.438	0	-0.302	-0.198
Postcode_33530	-0.2287	0.019	-11.784	0	-0.267	-0.191
Postcode_33540	-0.0881	0.022	-3.963	0	-0.132	-0.045
Postcode_33560	-0.3249	0.034	-9.486	0	-0.392	-0.258
Postcode_33580	-0.3902	0.039	-10.06	0	-0.466	-0.314
Postcode_33610	-0.3975	0.04	-10.036	0	-0.475	-0.32
Postcode_33700	-0.2147	0.033	-6.49	0	-0.28	-0.15
Postcode_33710	-0.4436	0.034	-13.173	0	-0.51	-0.378
Postcode_33720	-0.5625	0.024	-23.099	0	-0.61	-0.515

Postcode_33730	-0.3886	0.038	-10.187	0	-0.463	-0.314
Postcode_33800	-0.4452	0.03	-14.667	0	-0.505	-0.386
Postcode_33820	-0.3485	0.028	-12.497	0	-0.403	-0.294
Postcode_33840	-0.4734	0.033	-14.533	0	-0.537	-0.41
Postcode_33850	-0.6097	0.037	-16.699	0	-0.681	-0.538
Postcode_33870	-0.4206	0.053	-7.922	0	-0.525	-0.317
Postcode_33900	-0.2824	0.04	-7.042	0	-0.361	-0.204
FirstHalfOfYear_2010	-0.0917	0.011	-8.36	0	-0.113	-0.07
SecondHalfOfYear_2010	-0.0641	0.01	-6.262	0	-0.084	-0.044
FirstHalfOfYear_2011	-0.0312	0.01	-3.041	0.002	-0.051	-0.011
SecondHalfOfYear_2011	-0.034	0.013	-2.687	0.007	-0.059	-0.009
FirstHalfOfYear_2012	-0.0108	0.01	-1.037	0.3	-0.031	0.01
SecondHalfOfYear_2012	-0.01	0.012	-0.817	0.414	-0.034	0.014
FirstHalfOfYear_2013	0.0141	0.015	0.916	0.36	-0.016	0.044
SecondHalfOfYear_2013	0.0087	0.014	0.617	0.537	-0.019	0.036
FirstHalfOfYear_2014	0.0294	0.013	2.289	0.022	0.004	0.055
SecondHalfOfYear_2014	-0.0112	0.01	-1.069	0.285	-0.032	0.009
SecondHalfOfYear_2015	0.0088	0.007	1.238	0.216	-0.005	0.023
FirstHalfOfYear_2016	0.0298	0.01	2.962	0.003	0.01	0.049
SecondHalfOfYear_2016	0.0364	0.01	3.765	0	0.017	0.055
FirstHalfOfYear_2017	0.0506	0.009	5.619	0	0.033	0.068
SecondHalfOfYear_2017	0.0701	0.01	6.698	0	0.05	0.091
FirstHalfOfYear_2018	0.1072	0.012	9.171	0	0.084	0.13
SecondHalfOfYear_2018	0.1031	0.013	7.748	0	0.077	0.129
FirstHalfOfYear_2019	0.1195	0.015	8.022	0	0.09	0.149
SecondHalfOfYear_2019	0.1141	0.013	8.862	0	0.089	0.139
FirstHalfOfYear_2020	0.1402	0.016	8.816	0	0.109	0.171
SecondHalfOfYear_2020	0.1628	0.014	11.808	0	0.136	0.19
FirstHalfOfYear_2021	0.1987	0.014	14.255	0	0.171	0.226
SecondHalfOfYear_2021	0.2296	0.013	17.657	0	0.204	0.255
FirstHalfOfYear_2022	0.2535	0.012	21.15	0	0.23	0.277
SecondHalfOfYear_2022	0.233	0.013	17.323	0	0.207	0.259
FirstHalfOfYear_2023	0.1982	0.016	12.227	0	0.166	0.23

Omnibus:	13264.861	Durbin-Watson:	1.927	No. Observations:	44446
Prob(Omnibus):	0	Jarque-Bera (JB):	235198.985	Adj. R-squared:	0.83
Skew:	-0.978	Prob(JB):	0	Covariance Type:	cluster
Kurtosis:	14.098	Cond. No.	297	R-squared:	0.83

Appendix VI, Dynamic Hedonic DID – Coefficients of yearly estimates, year 2015 omitted

Distance band	**(1) 0-800m**
Treatment	0.1535**
	0.065
Treated x Year 2010	-0.0347**
	0.016
Treated x Year 2011	-0.0368**
	0.016
Treated x Year 2012	-0.0170
	0.014
Treated x Year 2013	-0.0165
	0.018
Treated x Year 2014	0.0169
	0.015
Treated x Year 2015 (Omitted)	-
	-
Treated x Year 2016	0.0180
	0.017
Treated x Year 2017	0.0343**
	0.014
Treated x Year 2018	0.0361**
	0.017
Treated x Year 2019	0.0418**
	0.021
Treated x Year 2020	0.0661***
	0.025
Treated x Year 2021	0.0622***
	0.022
Treated x Year 2022	0.0804***
	0.025
Treated x Year 2023	0.0918***
	0.032
Constant	8.9763***
	0.11
Distance to City, School & Healthcare	Yes
Apartment Characteristics Dummies	Yes
Apartment Type Group	Yes
Apartment Condition Dummies	Yes
Apartment Age Dummies	Yes
Postcode Fixed Effects	Yes
Year Fixed Effects	Yes
No. Observations:	44,446
Adj. R-squared	0.80

Estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. Dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas.

Appendix VII, Coefficient estimates of yearly estimates, year 2015 omitted - Parallel trends test before announcement

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Distance band	**0-400m**	**400-800m**	**800-1200m**	**1200-1600m**	**1600-2000m**
Treatment	0.1990***	0.1290**	0.1448**	0.1190**	0.0628
	0.067	*0.063*	*0.066*	*0.053*	*0.044*
Treated x Year 2010	-0.0271	-0.0446*	-0.0166	0.0300	0.0398
	0.02	*0.026*	*0.023*	*0.029*	*0.029*
Treated x Year 2011	-0.0374*	-0.0343*	-0.0107	-0.0043	0.0215
	0.02	*0.021*	*0.021*	*0.022*	*0.036*
Treated x Year 2012	-0.0172	-0.0168	-0.0051	-0.0062	-0.0075
	0.017	*0.017*	*0.018*	*0.023*	*0.035*
Treated x Year 2013	-0.0200	-0.0061	0.0108	0.0081	0.0165
	0.017	*0.028*	*0.023*	*0.025*	*0.028*
Treated x Year 2014	0.0206	0.0089	0.0262	0.0146	0.0346
	0.019	*0.022*	*0.021*	*0.023*	*0.032*
Treated x Year 2015 (Omitted)	-	-	-	-	-
	-	-	-	-	-
Constant	8.9376***	8.9951***	8.9869***	8.9135***	8.9523***
	0.087	*0.103*	*0.086*	*0.096*	*0.093*
Treated x Year 2016-2023	Yes	Yes	Yes	Yes	Yes
Distance to City, School & Healthcare	Yes	Yes	Yes	Yes	Yes
Apartment Characteristics Dummies	Yes	Yes	Yes	Yes	Yes
Apartment Type Group	Yes	Yes	Yes	Yes	Yes
Apartment Condition Dummies	Yes	Yes	Yes	Yes	Yes
Apartment Age Dummies	Yes	Yes	Yes	Yes	Yes
Postcode Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
No. Observations:	34 529	30 584	28 782	26 891	25 873
Adj. R-squared	0.81	0.80	0.79	0.79	0.80

Estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. Dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas.

Appendix VIII, Dynamic Hedonic DID – Coefficients of yearly estimates, year 2015 omitted

Section	**Section 1**		**Section 2**	
	(1)	**(2)**	**(3)**	**(4)**
Distance band	**0-800m**	**800-1 600m**	**0-800m**	**800-1 600m**
Treatment	0.0179**	0.0490**	0.0117**	-0.0084**
	0.023	*0.024*	*0.05*	*0.044*
Treated x Year 2010	-0.0117	-0.0165	-0.0682*	-0.0246
	0.017	*0.033*	*0.04*	*0.027*
Treated x Year 2011	-0.0209	-0.0456*	-0.0549	-0.0374
	0.019	*0.026*	*0.045*	*0.047*
Treated x Year 2012	-0.0134	-0.0294	-0.0412	-0.0450*
	0.018	*0.025*	*0.041*	*0.027*
Treated x Year 2013	-0.0142	0.0016	-0.0372	0.0175
	0.017	*0.023*	*0.057*	*0.037*
Treated x Year 2014	0.0066	0.0087	-0.0435	-0.0307
	0.024	*0.018*	*0.04*	*0.044*
Treated x Year 2015 (Omitted in Section 1)	-	-	-0.0113	-0.0099
	-	-	*0.029*	*0.029*
Treated x Year 2016	-0.0039	0.0175	0.0001	-0.0301
	0.01	*0.03*	*0.037*	*0.03*
Treated x Year 2017 (Omitted in Section 2)	0.0332**	0.0529	-	-
	0.014	*0.035*	-	-
Treated x Year 2018	0.0164	-0.0030	0.0795	0.0570**
	0.017	*0.026*	*0.056*	*0.022*
Treated x Year 2019	0.0393*	0.0087	0.0559	0.0310
	0.02	*0.023*	*0.05*	*0.029*
Treated x Year 2020	0.0439*	0.0184	0.1087**	0.0531***
	0.024	*0.021*	*0.042*	*0.016*
Treated x Year 2021	0.0470***	0.0054	0.0988*	0.0205
	0.016	*0.02*	*0.051*	*0.029*
Treated x Year 2022	0.0562***	-0.0032	0.1519***	0.0628*
	0.021	*0.018*	*0.048*	*0.033*
Treated x Year 2023	0.1071***	0.0183	0.0974**	0.0147
	0.025	*0.032*	*0.049*	*0.059*
Constant	9.4685***	9.2095***	9.2575***	9.0615***
	0.153	*0.113*	*0.117*	*0.113*
Distance to City, School & Healthcare	Yes	Yes	Yes	Yes
Apartment Characteristics Dummies	Yes	Yes	Yes	Yes
Apartment Type Group	Yes	Yes	Yes	Yes
Apartment Condition Dummies	Yes	Yes	Yes	Yes
Apartment Age Dummies	Yes	Yes	Yes	Yes
Postcode Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
No. Observations:	34,732	24,889	9,714	8,676
Adj. R-squared	0.83	0.82	0.78	0.74

Estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. Dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas.

Appendix IX, Dynamic Hedonic DID – Only Apartments and Excluding city centre area & New Residences

Distance band	**(1)** **0-800m**
Treatment	0.0330***
	0.045
Treated x Year 2010	-0.0190
	0.027
Treated x Year 2011	-0.0266
	0.022
Treated x Year 2012	-0.0037
	0.022
Treated x Year 2013	0.0065
	0.019
Treated x Year 2014	0.0123
	0.013
Treated x Year 2015 (Omitted)	-
	-
Treated x Year 2016	0.0182
	0.012
Treated x Year 2017	0.0271*
	0.015
Treated x Year 2018	0.0349**
	0.015
Treated x Year 2019	0.0500***
	0.016
Treated x Year 2020	0.0729***
	0.019
Treated x Year 2021	0.0677***
	0.018
Treated x Year 2022	0.0813***
	0.02
Treated x Year 2023	0.0817***
	0.022
Constant	9.7432***
	0.153
Distance to City, School & Healthcare	Yes
Apartment Characteristics Dummies	Yes
Apartment Type Group	Yes
Apartment Condition Dummies	Yes
Apartment Age Dummies	Yes
Postcode Fixed Effects	Yes
Year Fixed Effects	Yes
No. Observations:	21 409
Adj. R-squared	0.86

Estimated coefficient is statistically significant at *** 1% level, ** 5% level, and * 10% level. Standard errors are marked in italics below the coefficient. Dependent variable is a natural logarithm of the square metre price. Standard errors are clustered by postcode areas. Regression table, Figure 9