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Railway Mobility Hubs: A feature-based investment return analysis

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The authors declare that they are the sole authors of this thesis and that they have not used any sources other than those listed in the bibliography and identified as references. They further declare that they have not submitted this thesis at any other institution to obtain a degree.

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Abstract

While there has been considerable research regarding the role of Mobility Hubs in cities and transport networks, significant investment is required to develop these facilities. It is the correlation between investment, new users' attraction and revenue generation that is the key for a sustainable development of Mobility Hubs and this investment must, therefore, be correctly assessed and targeted. This study aims to develop a methodology to determine the viability of investing in Mobility Hub features, weighing the investment on different Hub features and services against expected potential benefits and revenue generation, addressing the question: Can investment in Mobility Hub features be justified and, if so, which features maximize its expected positive impact?

Based on a review of literature and definition of possible Hub features as variables, secondary research data was compiled to enable the analysis of expected impacts of each variable/feature in terms of new user's attraction and revenue generation, which was then used to develop individual Net Present Value analysis of each feature. The result of these analysis demonstrates and concludes that different Hub features have the potential to generate substantially different investment outcomes, and that each feature should be analyzed individually prior to investment decision. It was also concluded by this research that the proposed assessment methodology can be used for future research on other listed Hub features, albeit with the constraint that primary data will be required when secondary research data is not available.

Keywords

Mobility Hub; railway stations; features; intermodal passenger transport; commuting; passenger satisfaction; park and ride; car sharing; electric bicycle; electric bike; e-Bike; bike share; rail link; investment; retail; smart cities; revenue; railway operators; raiclway infrastructure

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1. Introduction

As the concept of Smart City is more and more the way forward for both established metropolis and growing big cities, effective means of public transportation and the drastic reduction of private cars is one of the cornerstones of the concept. Due to its high reliability, punctuality and comfort (National Rail, 2015), the railways, in its various forms (light rail, metro, suburban rail and high-speed rail) are among the preferred means of transportation by a substantial number of people and the smart-city concepts present now opportunities to overcome some of the historical drawbacks of railways.

The first mile/last mile problem, probably the number one issue for the people who do not use the railway, needs to be tackled in a connected world, where users expect convenience and a technological approach on their everydayness. The development of "Mobility Hubs" (one of the many names referring to the concept of the state-of-the art, convenient, public intermodal transport interchange facility) is currently being explored and tested into practice (Metrolinx, 2008). Deeply interrelated to the next generation of smart railway stations, these Mobility Hubs are proposed as urban transit interchanges spots where users can commute and enjoy themselves: riding an e-bike from work to the hub, shopping there, and taking a high-speed train back home would be an example of what users would expect.

The high investment required to build and run a railway infrastructure, always representing a very substantial effort for Public budgets, is probably the main reason why many railways are not even built in the first instance or are not properly explored and operated. The potential revenue that Mobility Hubs can generate not only to Railway Operators but also to retailers, car-sharing companies, and other types of businesses that can take advantage of these locations with high-people rotation, can be the solution to establish proper public-private cooperation schemes, where both sides can benefit, and secure substantial private funding for the new railway infrastructure.

1.1 Problem Discussion

There has been considerable research regarding the role of Mobility Hubs and its optimum location in cities and transport networks. However, significant investment is required to enable the development of these facilities (Project Connect, 2016) and it is the correlation between investment, new users' attraction and revenue generation that is the key for a sustainable development of Mobility Hubs in railway networks:

a) Funding can be provided by public entities, however running costs should be analyzed beforehand to evaluate potential long-term losses. A comparison of cost with the improvements in passenger satisfaction and number of users can be made, and the practicability of a fully state-owned system explored.

b) The possibility of attracting private investments is also to be evaluated: what potential do these Mobility Hubs have as revenue generators due to its high-rotation of people? A correlation between increase of users / revenue / investment should be sought.

c) Within the scope of private investment, owners of station and airport retail facilities, external companies or providers of mobility services (e-bikes, carsharing…) could be potential investors in the development of these interchange stations based on the expected correlation between Hub features and expected revenue generation.

This is the framework that has been identified as potentially benefiting from an integrated investment analysis; this would allow to inform investors in their decision-making process, based on the correlation between investment on Mobility Hubs features and the returns they give. Existing mass-transportation networks (such as railways) could benefit from these developments.

1.2 Problem Formulation and Purpose

Based on the framework above, this research aims to develop a methodology to determine the viability of investing in Mobility Hub features, weighing the investment on different Hub features and services against expected potential benefits and revenue generation.

By analyzing which impact Mobility Hub features have on generated revenue, and assessing those against capital investment and operational costs, each feature can be assessed individually to aid potential investors in better scoping the nature and extent on their investment in Mobility Hubs.

Targeted investment can in turn increase passenger satisfaction and the use of the railway, generating this way more revenue to investors which can be used for additional funding, in what would be a virtuous cycle.

This formulation aims to answer the main research problem: **Can investment in Mobility Hub features be justified and, if so, which features maximize its expected positive impact?**

The following sub-set of questions will drive the research:

1) **How long would it take to generate profits after investing in the different features of a Mobility Hub?**

An NPV comparison study will be performed to compare the amount of time required for a Mobility Hub feature to become profitable. The aim for this is to determine if investment on Mobility Hub features is justified, to what extent, and the amount of time it takes to reach the break-even point.

2) **Which Hub features can generate the biggest positive impact on revenue generation and user's increase?**

For the development of the NPV studies this research will also study the expected impact in station users and total revenue generation, by analyzing the expected increase in figures after the installation of the proposed services.

1.3 Delimitations

The expected scope of this thesis is to establish the methods to gather relevant information, including available secondary research data, analyze and treat it to effectively perform the research analysis described above and to obtain a set of results (revenue forecast model, net present value…) that can be used in the decision-making of Mobility Hubs investment for railways.

Due to time constraints, and the impracticability of producing-deploying a primary research data capturing system (e.g. questionnaires to railway users/non-users), this research will be based on the existing secondary research data available (station/shared bikes usage, passenger satisfaction indices, investment and maintenance costs, etc.) which allows the study of two defined representative Hub features – Shared bikes and Retail facilities.

In the decision-making process of investment in Mobility Hubs, besides the financial cost-revenue assessment other secondary or indirect benefits should be taken into account, depending on the specific conditions under assessment (e.g. proposed location, scale of city where Hub will be installed, purchasing power parity of city where Hub will be installed, etc). The list ranges from health savings from a heathier population due to pollution reduction to socio-economic rehabilitation of areas where Hubs are installed and increase in real-estate value. These indirect benefits are not part of the scope of this study and are, where relevant, referenced for future research.

1.4 Thesis' Structure

The Thesis will be structured in the following way:

- An Introduction and a Literature Review section, where the problem under study will be outlined, developed, framed and assessed against the current status of research, based on literature review;
- A Methodology section, where the expected data associated with the research, as well as the analysis methodologies and operationalization will be defined;
- A Data Analysis and Results section, where the gathered data will be treated and analyzed in the defined theoretical problem framework and the applicable results reported;
- A Discussion section, where the outcome of the analysis will be discussed;
- And finally, a Conclusions section, where the overall findings and conclusions established by the research will be presented and argued.

2. Literature Review

2.1 Background

The subject of Urban Mobility is currently one of the key factors that all major cities and metropolitan areas must develop and implement looking towards the future. The global urban population growth can be estimated as two people per second, which means that every day 172,800 new city-dwellers (Arup, 2014) will require ways to move within an urban environment. The same study estimates that by 2050 around 75% of the world's population will live in cities and that the biggest metropolis will reach populations of around 100 million people. These numbers require that mass-transit systems are available in these cities and the railway, in all its forms (suburban, light-rail and high-speed) is experiencing a strong come-back after years of disinvestment and past focus on private means of transport (McKinsey, 2015).

When analyzed and implemented in an isolated way, however, the railways suffer from the short-comings that have hindered it in the past: high public investment, reduced or inexistent revenue and less convenience that private transports, like the car, especially to cover the *first and last* mile stretch. It is, therefore, essential to analyze modern railways in an integrated manner within the concept of Smart Cities and the possibilities this concept conveys (Chaturvedi, 2015). The advances in communication technologies and the IoT now allows the railways to be part of an integrated journey experience, in which information and technology guarantee seamless, eco-friendly, hassle-free mobility and the Mobility Hubs, implemented in a mass-transit system like the railways, will function as the nodes in this smart, integrated and inter-modal future of urban transportation.

2.2 Mobility Hubs Characterization

A Mobility Hub can be characterized as a place of connectivity, where different modes of transportation, from high-speed rail to walking, come together seamlessly (Metrolinx, 2008). It is, furthermore, a place where living, shopping and enjoyment become part of the transit experience by the user.

There are several individual aspects that define and characterize Mobility Hubs and are well documented and studied in available literature:

- Optimal location;
- Key characteristics and components;
- Leadership on their development;

The optimal location of hubs in a city landscape is predominantly defined in terms of projected transportation users, but also in terms of socio-economic impact. Mobility Hubs are frequently used by city planners to revamp underprivileged areas, generating activity and investment in those areas and at the same time increasing land value (Urban Design Studio, 2016). Other variables for location include demographic characteristics, accessibility and population density (Ratti, 2017). These characteristics are well studied and modelled to enable the selection of optimized hub locations. This research, on the other hand, looks to study the expected positive impact that hubs can have on railway users and, subsequently, on revenue generation growth after its optimal location has been defined.

In terms of features, services and infrastructure that effectively constitute the hubs, the possibilities and options are vast. There are basic elements that can currently been found in the majority of Mobility Hubs: bike parking facilities, bus lay-over zones, Wi-Fi connectivity and real-time information are typical examples (218 Consultants, 2015). The association with ride-sharing services are also common, be it bike sharing services (Midgley, 2009), ride-hailing zones and car-sharing services, which all present great potential in solving the *first and last* mile issue typically associated with not using the railway. Other possible infrastructure includes EV charging facilities, retail areas and public leisure areas. When assessing the future possibilities for hubs, other types of less-obvious services can be expected to be present in Mobility Hubs, like virtual supermarkets (Arup, 2014), where commuters can order by scanning QR codes to have same day delivery, or shared workspace areas integrated with large retail areas, making hubs the actual travel destination. Similarly to location definition and selection criteria, the different configurations for hubs are well studied and characterized. This research aims to establish which of the possible configurations and features can best impact the railway operators and infrastructure owners in terms of revenue increase, either by user increase revenue as well as indirect revenue introduced by retail (SmartRail

World, 2017) (Yeates & Jones, 1998) and other service providers which would pay to be present in the hub.

The development of hubs cannot be dissociated from City Planning departments and Railway Infrastructure Managers/Operators. Investment strategies must be jointly prepared to take full advantage of the possibilities hubs introduce in a city landscape and economy (Metrolinx, 2008). The current literature commonly agrees that new stations must be analysed in terms of customer experience, social benefits, landscape impact, commercial opportunities and overall transportation planning possibilities (Arcadis, 2018). With these assumptions well established, this research will aim to quantify and demonstrate that the hubs should indeed be incorporated, with the right configuration and characteristics, in new railway infrastructure developments.

2.3 Investment and Funding

One of the main drivers for the development of an investment business case will be the potential increase in passenger satisfaction levels (Network Rail, 2017); requirements from different user groups, such as cyclists (Küster, et al., 2016) should be evaluated before any justification for change is sought.

One of the biggest advantages of Mobility Hubs is that they present a unique and previously inexistent opportunity to capture private funding to transportation networks and new railway developments. Public-private partnerships (PPPs) have in the past been used in formats that resulted in very onerous obligations to public budgets which had to compensate private losses due to poorly developed demand studies and contracts. The hubs introduce a new way to capture private investment, with the public focused on increase of users and social-economic impact of new transportation developments, and private investors targeting the commercial advantages that hubs can bring to a wide array of service providers.

It is argued that the model can even progress to purely private investment funding new public transportation developments due to the business it will generate in modern hubs (Arcadis, 2018).

It is admitted that cycling hubs, connected with metro stations have an impact on housing market prices (Transport for London, 2018); this can be considered as an opportunity to attract additional investment opportunities and generate growth. Reduced travel times can better connect city areas (Jäppinen, et al., 2013), increasing commuters' satisfaction and the value of their properties.

These assumptions will be part of this research study in the demonstration and quantification of optimized investment into Mobility Hubs, by comparing levels of satisfaction against cost, with a NPV analysis.

2.4 Theoretical Framework

Potential elements of a Mobility Hub have been defined above, following existing available information on relevant literature. This section will focus on the basis by which investment on those proposed features are potentially expected to drive a revenue increase:

- **Passenger satisfaction driving profitability increase**

  It is known that customer satisfaction enhances profitability, and that this grows over time. The length of the period that a customer is maintained is directly proportional to the expected profit the company will receive from that particular customer (as the company would benefit from reduced operational costs, referrals, price premiums, etc.) (Reichheld & Sasser, 1990). It is therefore considered that an increase in passenger satisfaction - which is expected if Mobility Hub features are implemented in a standard railway station - leads to an enhancement in investment returns.

- **Passenger increase and enhancement of retail facilities leading to an increase in sales:**

  Railway stations have been historically seen as an "ancillary" location, where retail facilities would base their business model in the pedestrian traffic generated by non-retail activities (Brown, 1991). The basis that an increase in pedestrian traffic leads to a proportional spend in the shops is therefore evidenced.

  Appropriate investment into retail facilities (expansion, renovation…) can also lead to increase in sales. This is heavily interlinked with the dependency on potential customers being attracted to the area, as described above. (Feldman, 2004). It is considered that passengers on a railway station will directly appreciate any enhancements on shops - as they ineluctably need to visit the station to travel - feedbacking their satisfaction.

- **NPV investment return**

Returns after investment will not be immediate. To determine if the cash flows throughout time are positive, and - if so - the level of profitability of an investment, a Net Present Value (NPV) analysis should be undertaken. It is assumed a NPV > 0 will justify investment, and negative NPV will discourage it (Berk & DeMarzo, 2017). This basis will be followed for this particular study. It should however be noted that other variables (reduction in CO_2, political interests etc.) could also influence the business case for an investment.

An Internal Rate of Return calculation would also complement the NPV analysis to evaluate what return rate would justify investment within a given time.

2.5 Summary

Whilst there is abundant literature on hub characterization, its many possibilities and variables, its advantages and its optimum implementation in the city landscape, it is not evident to a railway infrastructure owner and/or operator if a Mobility Hub, and especially which features of a Mobility Hub, will bring the biggest advantages to a network in terms of:

- new users increase
- revenue opportunities
- investment value

It is the intention to use the available research data (passenger usage, revenue and case studies) and studied literature in a way that can balance and correlate these variables.

The objective is to, ultimately, establish an assessment methodology and use it to analyze the investment in Mobility Hub features individually, allowing to understand its potential for generating positive impacts.

3. Methodology

This chapter outlines the methodology adopted for this research. It describes the selected approach to study the formulated problem, as well as the methods to collect the necessary data and how to analyze it.

3.1 Research Approach

To address the formulated problem, it is necessary to gather information on the expected impact of investing in a Mobility Hub in the levels of passenger increase, increase in ticket sales, increase in retail sales and subsequent total revenue enhancements.

Existing data - most of which coming from previous research and Railway Infrastructure Owners and Operators reports - is to be collected and analysed in an attempt to determine:

1) How investment in Mobility Hub features can lead to an increase in passenger numbers and subsequent ticket sales;
2) How investment can lead to an increase on the sales of the retail facilities in a Mobility Hub;
3) Which Mobility Hub features have the potential to generate the most positive impacts?

With this data it will be possible to measure the impact of Mobility Hub features and answer the question "*How long would it take to generate profits after investing in the different features of a Mobility Hub?";* similarly, by understanding which Hub services are most valued and therefore have the most positive impact, it is possible to answer the question "*Which Hub features can generate the biggest positive impact on revenue generation and user's increase?*"; and finally, based on the answers to the two previous questions, the research main question will be addressed "*Can investment in Mobility Hub features be justified and, if so, which features maximize its expected positive impact?".*

3.2 Method

Due to the constraints to collect primary data within the available research time-frame, the selected method to collect the defined necessary data is secondary research, in the form of available survey data from other researches and railway owners and operators records and reports.

The main advantage that secondary research presents to this research is a much shorter completion time to collect the data, which is a vital aspect for the available time-frame. It will also allow to collect a much larger data set for analysis, when compared to primary research.

The main disadvantage is that secondary research data may not have been gathered with the aim of a similar research objective and there may be gaps of information. To overcome this, additional interdependencies and correlations need to be sought, based on the existing data. Finally, another disadvantage of secondary research is that there is a lack of control over the quality of the data gathered and it will be necessary to evaluate how the data was previously obtained and presented, if that information is available, to establish its suitability. Trustworthy sources will be used to ensure the appropriateness of the results, with the focus on gathering institutional as well as corporate generated data.

For the purpose of this research, and based on the disadvantages described above, it will be necessary to combine different secondary data sets to enable sufficient relevant data to be gathered for this research problems. Both quantitative and qualitative data will be necessary to address the research questions and correlate variables.

The data collection methodology will be:

1) Search and identify secondary research data set(s)
2) Screen the data set(s) and establish if they are relevant to the research questions and associated variables under study
3) Evaluate the selected data set(s) by assessing what was the aim of the original study, when was the data collected, what methodology was employed and listing its limitations to the current research

4) Prepare and analyse the data set(s) that have been selected and positively evaluated for this research

The main hypothesis is that Mobility Hubs features attract more passengers and generate higher revenue than standard stations.

3.2.1 Operationalization

The complete operationalization for all identified features and the proposed variables can be found below:

Identified Independent variables

1. Investment — $C = C_I + C_M$
    a. Cost of investment — $C_I = \Sigma C_{I,x}$
        i. Shared bikes — $C_{I,sb}$
        ii. Wi-Fi — $C_{I,wf}$
        iii. Car-sharing facilities — $C_{I,cs}$
        iv. Bicycle parking — $C_{I,bp}$
        v. Car parking — $C_{I,cp}$
        vi. Retail facilities — $C_{I,rf}$
        vii. EV infrastructure — $C_{I,ev}$
    b. Cost of maintenance per year — $C_M = \Sigma C_{M,x}$
        i. Shared bikes — $C_{M,sb}$
        ii. Wi-Fi — $C_{M,wf}$
        iii. Car-sharing facilities — $C_{M,cs}$
        iv. Bicycle parking — $C_{M,bp}$
        v. Car parking — $C_{M,cp}$
        vi. Retail facilities — $C_{M,rf}$
        vii. EV infrastructure — $C_{M,ev}$

Identified Dependent variables

1. Passenger increase — $\Delta P = f(C_{I,x}, C_{M,x})$
2. Revenue increase — $\Delta R = \Delta R_P + \Delta R_S$
    a. Increase in ticket sales — $\Delta R_P = f(\Delta P)$
    b. Retail sales increase — $\Delta R_S = f(\Delta P, C_{I,rf})$

It is expected that the expected increase in retail sales depends on the cost of investment on retail facilities on two different ways, the increased number of passengers (depending on the rest of the investment in conjunction with retail) and the increase of attractiveness of the retail facilities themselves.

It is assumed that the investor directly receives benefits on retail sales increase. Although this may not happen in practice as the retails facilities may be leased, it has been considered that sales increase could lead to higher rents in a competitive market, resulting in a proportional benefit to the investor.

3.3 Analysis

A correlation between the variables - passenger increase vs. investment, etc.- will be done to determine if the hypothesis is realistic.

The revenue calculation model would be as follows:

$$\Delta R = f(C_{I,sb}, C_{I,wf}, C_{I,cs}, C_{I,bp}, C_{I,cp}, C_{I,rf}, C_{I,ev}, C_{M,sb}, C_{M,wf}, C_{M,cs}, C_{M,bp}, C_{M,cp}, C_{M,rf}, C_{M,ev})$$

By isolating each of the variable pars (initial capital investment / maintenance costs), the individual increase on revenue based on each proposed feature can be evaluated.

And an NPV calculation will be undertaken to establish whether the investment is justifiable, and to what extent:

$$NPV(t) = -C_I + \sum_{t=1}^{t} \frac{\Delta R - C_M}{(1+r)^t}$$

For the current research and due to its delimitations, previously identified in 3.2.1, the following variables have been selected for data collection and analysis:

Selected Independent Variables (Investment)

Investment $C = C_I + C_M$

a. Cost of investment $C_I = \Sigma C_{I,x}$
   i. **Shared bikes** $\mathbf{C_{I,sb}}$
   ii. **Retail facilities** $\mathbf{C_{I,rf}}$
b. Cost of maintenance per year $C_I = \Sigma C_{M,x}$

i. **Shared bikes** $C_{M,sb}$
ii. **Retail facilities** $C_{M,rf}$

Selected Dependent Variables (Revenue)

1. **Passenger increase** $\Delta P = f(C_{I,x}, C_{M,x})$
2. Revenue increase $\Delta R = \Delta R_P + \Delta R_S$
   a. **Increase in ticket sales** $\Delta R_P = f(\Delta P)$
   b. **Retail sales increase** $\Delta R_S = f(\Delta P, C_{I,rf})$

Other variables listed in 3.2.1, but not selected for study under the current research, can be studied in future research following the methods and theories applied for the selected variables.

4. Data Analysis and Results

The analysis focuses on the selected features/variables (investment in retail and shared-bikes facilities, respectively); open data has been gathered from reliable sources online (such as reports from the European Union, Network Rail, the Office of Rail and Road etc.), and informed assumptions (stated where applicable) have been made where information was not available. The data was analysed using Microsoft Excel.

4.1 Data Sets

4.1.1 Retail

The data for the analysis on the investment on retail facilities has been extracted from available information taken from the British railway industry, principally Network Rail (railway infrastructure manager) and the Office of Rail and Road (rail regulator). The information has been split on financial years (starting on the 1st of April), and Control Periods (5-year funding and planning timespans). The data is based on Network Rail´s managed stations unless otherwise stated (Network Rail, 2019).

Data sources are listed below:

- Station usage (entries + exits)
  - Station usage 2017-18 data (Office of Rail and Road, 2018)
  - Station usage 2016-17 data (Office of Rail and Road, 2017)
  - Station usage 2015-16 data (Office of Rail and Road, 2016)
  - Station usage 2014-15 data (Office of Rail and Road, 2015)
  - Station usage 2013-14 data (Office of Rail and Road, 2014)
  - Station usage 2012-13 data (Office of Rail and Road, 2013)
  - Station usage 2011-12 data (Office of Rail and Road, 2012)

The information gathered is summarized in Table 1:

Table 1: Network Rail managed stations usage (entries + exits)

	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018
London Waterloo	94,127,282	95,936,542	98,442,742	99,201,604	99,148,388	99,403,096	94,355,000
London Victoria	76,163,428	77,346,676	81,356,330	85,337,996	81,151,418	75,889,396	74,955,332
London Liverpool Street	57,105,400	58,448,814	63,004,002	63,631,246	66,556,690	67,339,218	66,966,512
London Bridge	52,603,158	53,351,116	56,442,044	49,517,854	53,850,938	47,874,250	48,453,496
London Charing Cross	38,113,546	38,607,238	40,170,074	42,978,890	28,998,152	29,559,646	28,344,898
London Euston	36,520,544	38,299,206	41,911,706	42,952,298	41,677,870	44,059,402	44,745,816
London Paddington	33,709,272	34,143,220	35,093,628	35,724,684	36,536,074	35,835,970	36,578,292
London St Pancras	23,045,876	24,298,276	26,046,082	28,241,930	31,723,686	33,492,476	34,622,178
London King's Cross	27,840,484	28,454,460	29,833,456	31,346,862	33,361,696	33,816,396	33,904,758
London Cannon Street	20,222,708	20,020,054	20,689,022	22,129,604	21,242,364	22,660,250	23,446,822
Stratford	21,797,460	25,564,250	26,377,506	30,974,204	41,113,260	42,251,592	40,077,086
Bristol Temple Meads	-	-	-	10,099,526	10,711,464	11,336,806	11,350,146
Edinburgh Waverley	17,992,340	18,879,684	20,012,302	21,106,540	21,723,960	22,582,342	23,334,430
Glasgow Central	26,610,016	27,185,020	27,152,694	28,964,760	30,000,582	32,060,134	32,915,936
Leeds	25,051,436	26,200,916	27,729,632	28,847,648	29,723,734	30,942,592	31,107,672
Manchester Piccadilly	22,925,411	23,158,477	24,476,137	24,614,970	25,792,700	27,807,063	27,724,962
Reading	-	-	-	16,339,602	16,755,984	17,122,000	16,979,808
Liverpool Lime Street	13,849,827	13,166,539	14,236,806	14,870,920	15,227,344	15,613,057	16,032,460
Birmingham New Street	31,235,638	32,090,346	34,748,984	35,312,788	39,077,018	42,366,776	43,741,712
Gatwick Airport	14,759,610	15,353,056	-	-	-	-	-
Fenchurch Street	16,936,552	16,842,654	18,244,526	-	-	-	-

- Revenue per franchised passenger journey
    - Revenue per passenger kilometre and revenue per passenger journey (Office of Rail and Road, 2019)

- Revenue increment due to ticket sales increase
    - Product of total station usage by revenue per passenger journey.

- Maintenance costs (Property)
    - Network Rail expenditure in 2016/17 (Network Rail, 2017)
    - Network Rail expenditure in 2015/16 (Network Rail, 2016)
    - Network Rail expenditure in 2014/15 (Network Rail, 2015)
    - Network Rail expenditure in 2013/14 (Network Rail, 2014)

- Property enhancements cost
    - Network Rail Strategic Business Plan - Property income forecast review (Cushman & Wakefield, 2018)

- Property income (managed stations)
    - Network Rail Strategic Business Plan - Property income forecast review (Cushman & Wakefield, 2018)
    - Assessment of robustness of property income forecasts of NR in the Strategic Business Plan (DTZ, 2013)

Summarized data on which the analysis will be based is shown on Table 2:

Table 2: Retail-related available data (Network Rail)

	Control Period 4			Control Period 5				
	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019
Station usage (entries + exits)	650,609,988	667,346,544	685,967,673	712,193,927	724,373,322	732,012,461	729,637,316	-
Revenue per franchised passenger journey	£4.95	£5.13	£5.17	£5.32	£5.37	£5.46	£5.66	£5.83
Revenue increment due to ticket sales increase[1]	-	£85,858,528	£96,271,236	£139,523,671	£65,403,353	£41,709,701	-£13,443,322	-
Property maintenance costs	-	-	£10,000,000	£12,000,000	£9,000,000	£8,000,000	-	-
Property enhancements cost[2]	-	-	-	£83,200,000	£83,200,000	£83,200,000	£83,200,000	£83,200,000
Property income	£125,740,000	£125,740,000	£125,740,000	£139,947,500	£155,464,500	£165,218,000	£171,039,000	£176,856,500

4.1.2 Shared Bikes

For the Shared Bikes feature analysis, the presented data has been gathered from available reports and feasibility studies, both from EU and US cities, for Bike Schemes implementation, as well as studies from the European Commission – Directorate for Mobility and Transport regarding Ticket Pricing data in the EU and Evaluation Reports for Bike/Train Pilot Schemes under assessment in the EU.

Data sources and resulting gathered information are listed below.

[1] Profit is generally taken by railway franchise operators, and not by the infrastructure manager; it has however been included in the calculation as the aim of the study is to analyse the revenue generation, independent from the beneficiary.

[2] Split proportionately throughout the five years of the Control Period.

- New Users Increase
  - “Bike+Train+Bike Evaluation Report Summary - The Pilot Project step by step – Final Summary December 2016” and “D4_4_BiTiBi Global Evaluation”, reflecting the key performance indicators of bike+train scheme pilots implementation, between September 2014 and September 2016, in Belgium, Italy and the UK:

Table 3: BiTiBi new users data due to bike-share scheme between 2014 – 2016

	Nº of new BiTiBi scheme journeys per year	Percentage of new users that are new to using the train due to bike-share scheme	Number of bikes installed	New BiTiBi users in the three countries
Belgium	98,454	32%	1300	11.032
Italy	24,503	20%	608	
UK	30,123	48%	650	

The online surveys that generated the above data established the percentage of new users that were not previously using the train and started using it during the period under analysis due to the Bike+Rail scheme, allowing to calculate a weighted average of new train user’s percentage increase due to the Bike+Rail scheme implementation.

The weighted average between countries, considering the implementation of the scheme (by number of new trips generated) and the percentage of users that are new to using the train, returned that 33% of new bike+train scheme users will be new train users. Applying this percentage to the number of new users that joined the scheme in the three countries between 2014 and 2016, we establish that 3.641 of these 11.032 new users would be also new to using the train.

For the purpose of this research, it will be assumed that these new train users were evenly distributed over the period of 2-years under analysis, which means that 1821 new train users joined on each year. It will, furthermore, be assumed that each of the new 1821 users makes at least 1 return trip/week, adding 189.384 new single trips to the network for the period of 1 year.

Finally, by dividing the number of new single trips generated in one year by the average number of bikes installed in the different countries (852), we can make the assumption that each bike installed in a bike share scheme has the potential to generate 222 new train journeys per year. This assumption will be used for the purpose of forecasting train ticketing revenue increase due to bike share feature.

- Number of train journeys
  - Station usage 2011-2018 data (Office of Rail and Road, 2011 to 2018)

    For the purpose of establishing an expected number of train journeys in the network, the station usage data was analyzed. The number of recorded entries was averaged and assumed that 75% of those entries were for train travelling purposes.

- Train journey cost
  - "Study on the prices and quality of rail passenger services" train ticket pricing summary in the EU:

    The "Rail fare per kilometer" values listed in the study for each EU country will be averaged for obtaining an EU reference value and applied to a standard 10km suburban journey, enabling revenue increase/decrease comparisons based on expected user increase.

- Bike share Capital Costs, O&M Costs and Revenue
  - "Brighton & Hove Bike Share Business Case and Business Plan" capital, operating and maintenance costs per bike and forecasted revenue:

Table 4: Bike Share Capital Costs Comparison in different cities

	Country	Number of Bikes	Capital Costs per Bike
London	UK	7,000	£2,400
Barcelona	Spain	4,100	£1,900
Montreal	Canada	3,800	£2,400
New York City	USA	4,200	£2,900
Denver	USA	450	£2,600
Minneapolis	USA	1,380	£2,700
Madison	USA	230	£3,000
Average	-	-	£2,440
Average (small schemes)	-	-	£2,700

Capital costs including bike stations, bikes, IT system costs, control centre and installation. The average small scheme figure/bike will be used. There is a Bike Replacement cost every ten years equivalent to 30% of the capital cost/bike.

Annual Operating and Maintenance cost for a scheme with 430 bikes is £700,000 with a total annual revenue forecast of £800,500.

The values will be adjusted to the research scenario, assuming 10 bikes per station and a network size of 20 stations (according to the station usage data). This data will be averaged with the city of Baton Rouge Bike Share Implementation Plan data for obtaining the analysis data-set.

- "City of Baton Rouge Bike Share Implementation Plan" capital, operating and maintenance costs per bike and forecasted revenue:

Table 5: Bike Share Business Implementation Plan – Baton Rouge

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Number of Bikes	-	510	-	310	-	-	820
System Start-up (Pre-launch)	$320,000	-	-	-	-	-	$320,000
Total Capital & Start-up costs	$320,000	$2,750,000	-	$1,780,000	-	-	$4,850,000
Total O&M costs	-	$810,000	$870,000	$1,370,000	$1,360,000	$1,400,000	$5,810,000
Total User Revenues	-	$310,000	$320,000	$560,000	$580,000	$660,000	$2,430,000

The values will be adjusted to the research scenario, assuming 10 bikes per station and a network size of 20 stations (according to the station usage data). This data will be averaged with the Brighton & Hove Bike Share Business case data for obtaining the analysis data-set.

Based on the different data sources and assumptions described above, the summarized data on which the Bike-share feature analysis will be based is shown on Table 6:

Table 6: Bike Share Analysis compiled data

	Calculated/derived value	Yearly (Y/N)	Reference data
Capital cost per bike	4.265€	N	Calculated from Steer Davies Gleave (2014). *Brighton & Hove Bike Share Business Case and Business Plan* and City of Baton Rouge (2016). *Bike Share Business and Implementation Plan*
Ops & Maintenance cost/bike/year	35.637,25€	Y	Calculated from Steer Davies Gleave (2014). *Brighton & Hove Bike Share Business Case and Business Plan* and City of Baton Rouge (2016). *Bike Share Business and Implementation Plan*
Expected revenue/bike/year	15.196,08€	Y	Calculated from Steer Davies Gleave (2014). *Brighton & Hove Bike Share Business Case and Business Plan* and City of Baton Rouge (2016). *Bike Share Business and Implementation Plan*
10y bike replacement capital cost/bike	1.279€	N	Calculated from Steer Davies Gleave (2014). *Brighton & Hove Bike Share Business Case*
Train journey cost	1,4€	Y	Obtained Steer Davies Gleave (2016). *Study on the prices and quality of rail passenger services*
Average number of train journeys/year	13,926,537	Y	Calculated from *Station usage 2011-2018 data (Office of Rail and Road, 2011 to 2018)*
Expected increase in train journeys due to bike share, per bike installed	222	N	Calculated from Assessoria d'Infraestructures i Mobilitat sl ; Blue-mobility; Poliedra; Merseyrail, (2016). *D4_4_BiTiBi Global Evaluation Report* and *Evaluation Report Summary – The Pilot projects step by step – Final results September 2016*

4.2 Analysis and Results

4.2.1 Retail

An investment equal to that one done in CP5 (£416,000,000) has been considered, with the application of the inflation in the United Kingdom between 2013 and 2018 (12.58%, (Bank of England, n.d.)), totaling £468,320,000.

Assuming a rate of return of 5% and a 10-year period of return (to be named Control Periods 6 and 7 for consistency with the data in 4.1.1), an NPV analysis of an investment of the above value has been undertaken.

The running costs and the average property income increase have been estimated from the information available (see section 4.1.1), as the average of the figures available.

$$NPV(t) = -C_I + \sum_{t=1}^{t} \frac{\Delta R - C_M}{(1+r)^t}$$

Table 7: Net Present Value analysis (Retail)

			IN		OUT		Cash flow	Net present value
			Property income	Tickets revenue	Enhancement (investment)	Maintenance (running costs)		
			ΔR		C_I	C_M		
Year 0	**2018/2019**	0	£10,223,300	£58,298,351	-£468,320,000	-£9,750,000	-£409,548,349	-£409,548,349
Control Period 6	**2019/2020**	1	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£353,575,349
	2020/2021	2	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£300,267,729
	2021/2022	3	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£249,498,567
	2022/2023	4	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£201,146,985
	2023/2024	5	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£155,097,859
Control Period 7	**2024/2025**	6	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£111,241,548
	2025/2026	7	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£69,473,633
	2026/2027	8	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	-£29,694,667
	2027/2028	9	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	£8,190,063
	2028/2029	10	£10,223,300	£58,298,351	£0	-£9,750,000	£58,771,651	£44,270,759

This ascertains that such investment starts producing positive returns at the ninth year after the initial capitalization.

To determine the compound return rate which would define the boundary between losses and profit after those 10 years, an IRR (Internal Rate of Return) analysis based on the NPV is performed.

$$0 = NPV = -C_I + \sum_{t=1}^{t} \frac{\Delta R - C_M}{(1+r)^t}$$

The results are as below:

Table 8: Internal Rate of Return analysis (Retail)

Return rate	NPV
4.00%	£67,142,384
5.00%	£44,270,758
6.00%	£23,016,115
7.00%	£3,239,132
7.17%	£0
8.00%	-£15,185,789

The internal return rate would be 7.17%.

4.2.2 Shared Bikes

Based on the data presented in 4.1.2, an NPV assessment scenario was prepared in order the impact of having the Shared Bikes feature available in the stations could be analyzed.

The assessment scenario is described below:

- Period of analysis – 10y
- Network size – 20 stations
- Bike Share Units – 10 (per station)

The applicable data to be used for the NPV calculations can be found in Table 6.

Net Present Value for Standard Stations

Table 9: Net Present Value analysis for ticket revenue only

		IN					
		Tickets revenue	Bike Share revenue	Capital cost Bike Share	Ops & Maintenance Bike Share (running costs)	Cash flow	Net present value
Discount rate:	5%	ΔR		C_I	C_M		
2018/2019	0	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	19 497 151,80 €
2019/2020	1	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	18 568 716,00 €
2020/2021	2	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	17 684 491,43 €
2021/2022	3	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	16 842 372,79 €
2022/2023	4	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	16 040 355,04 €
2023/2024	5	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	15 276 528,61 €
2024/2025	6	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	14 549 074,86 €
2025/2026	7	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	13 856 261,77 €
2026/2027	8	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	13 196 439,79 €
2027/2028	9	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	12 568 037,89 €
2028/2029	10	19 497 151,80 €	0,00 €	0,00 €	0,00 €	19 497 151,80 €	11 969 559,90 €
							170 048 989,87 €

Net Present Value for Hub Stations with Bike Share

Table 10: Net Present Value analysis implementing Bike Share feature

		IN					
		Tickets revenue	Bike Share revenue	Capital cost Bike Share	Ops & Maintenance Bike Share (running costs)	Cash flow	Net present value
Discount rate:	5%	ΔR		C_I	C_M		
2018/2019	0	19 497 151,80 €	0,00 €	-852 992,16 €	0,00 €	18 644 159,64 €	18 644 159,64 €
2019/2020	1	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	18 575 821,82 €
2020/2021	2	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	17 691 258,87 €
2021/2022	3	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	16 848 817,97 €
2022/2023	4	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	16 046 493,31 €
2023/2024	5	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	15 282 374,58 €
2024/2025	6	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	14 554 642,46 €
2025/2026	7	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	13 861 564,25 €
2026/2027	8	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	13 201 489,76 €
2027/2028	9	19 559 311,80 €	276 368,27 €	0,00 €	-331 067,16 €	19 504 612,91 €	12 572 847,39 €
2028/2029	10	19 559 311,80 €	276 368,27 €	-255 897,65 €	-331 067,16 €	19 248 715,26 €	11 817 041,41 €
							169 096 511,46 €

For the defined scenario and based on the available data, the impact of the Bike Share feature in the station network NPV is negative when compared to ticket revenue only. The NPV is positive for the years without capital cost investment in the bike share feature, but based on the assumption that it will be necessary to partially renovate the installed bikes every 10 years, the overall NPV of installing this Hub feature is negative.

The negative impact over the 10-year analysis period could, however, be argued as negligible (< 0,6%) and it will be further analyzed and discussed in section 5.

5. Discussion

It has been proven that investment into Mobility Hub retail facilities have a solid potential to generate returns.

The average of property income increase has been identified as £10,223,300 per year, with an additional average revenue due to ticket sales of £58,298,351 for the case studied. This would be a return of 16.47% per year.

These results should however be taken with caution, as it would be a long-term investment (circa 10 years), and the public would expect additional intermediate investments as public infrastructure is heavily influenced by political wishes (Gomes Gonçalves, et al., 2017). Furthermore, the public/private split of the benefits may not be proportionate, as being the case in the British railways, where profitable railway franchisees run on an infrastructure subsidized with public money (Bowman, 2015).

In relation to the implementation of Bike Share services, the return in terms of NPV might be initially assessed as negligible, although negative, with approximately 0,56% negative impact over a period of 10 years for the scenario analyzed.

It must be, however, taken into consideration that:

- The proposed scenario for analysis is conservative in terms of expected revenue directly from the Bike Share services. It considers a negative return for the scheme itself, not considering the additional revenue generated in train journeys, based on the average values from gathered data. The Bike Share service business plan can be adjusted to seek a positive return.
- The proposed scenario does not consider year-on-year growth from the Bike Share service, only the one-time user increase due to implementing the feature. It can be argued that the service will continue to bring new users to the network every year, although this would have to be further studied.

It can be concluded that the investment in Hub features can be justified individually for each feature, and for the studied variables it can be concluded that investing in the Retail feature has the potential to generate a substantial positive revenue return throughout the studied period, while investing in the Bike Share feature generates a negative-to-negligible impact on revenue.

The decision to invest in such Hub features, with a negative impact on NPV, would require further study on potential socio-economical impacts that can justify the investment decision.

It can be furthermore concluded that the NPV analysis, supported and integrated with previous data preparation in terms of users increase, revenue generation and investment costs, can be used as a methodology to perform the assessment of individual Hub features investment potential.

6. Conclusions

This research intended to address the gap identified in current research on Mobility Hubs, where the features that actually compose the Hub and its expected impact in the required Hub investment have not been addressed. A proposed methodology based on Net Present Value analysis, developed from expected revenue and expected cost extracted from research data was implemented. The data-gathering process for this study had to be adapted as outlined in Section 1.3.

It has been concluded based on the analysis performed and according to the results discussed that individual Hub features will have very different investment configurations and expected results and should therefore, be subject to individual analysis as outlined in this thesis during the decision-making process of Mobility Hubs investment.

The proposed assessment method, based on NPV analysis, can be considered appropriate when performed over the relevant gathered data, correlating expected revenue increase and associated costs with hub features. This method will, nonetheless, require primary research data gathering for studying a wider array of Hub features, namely to allow the analysis to determine the expected increase in the number of railway users (and associated revenue) directly attributable to different Hub features.

Further research topics and gaps were also identified in the process and duly included in this thesis for future researchers benefit.

7. Further research

The following opportunities for further research have been identified:

- Additional features can be analysed following the same approach (see sections 3.2.1 and 3.3); potentially primary- data gathering will be required to identify capital and operational costs and potential increase in revenue due to expected passenger/new users increase.
- Incentives related to CO_2 emissions reduction could be a basis for attracting third-party development funding (such as those from the European Union, where applicable), and the proposed analysis could be modified accordingly.
- CO_2 emissions reduction can also be analyzed in terms of secondary Hub benefits by expected increase of population health – pollution reduction and healthier bike/train lifestyle when compared to private car
- The hubs could also have a positive economic impact on the urban region by becoming the core of the local transportation systems, which opens a possibility of undertaking research to quantify the magnitude of this impact, for example, in real estate.

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