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TNO report

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Futureproof and integral hub development: the Haarlem Nieuw-Zuid case

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Managementsamenvatting

De provincie Noord-Holland signaleert dat de manier waarop mensen reizen verandert. Dit komt door technologische ontwikkelingen (nieuwe modaliteiten en mobiliteitsconcepten die van invloed zijn op de modal split en het ruimtegebruik), ander reisgedrag, de energietransitie en de manier waarop steden en regio's zich ontwikkelen en verdichten. De toenemende verstedelijking leidt tot een extra vraag naar mobiliteit, waardoor de druk op een gezonde, veilige en levendige leefomgeving toeneemt. In de strategie van de provincie Noord-Holland over OV-knooppunten (Strategie Programma OV-knooppunten 2019 - 2023) wordt beschreven dat - om de ruimte beter te benutten, reisketens te optimaliseren, een goede ruimtelijke kwaliteit te waarborgen, klimaatdoelstellingen te halen en woningbouw te faciliteren - hubs een oplossing kunnen vormen. Om een noodzakelijke transitie naar schone, veilige en slimme mobiliteit te faciliteren, kunnen hubs fungeren als impuls voor ruimtelijke efficiëntie en kwaliteits-, milieu- en gezondheidswinst.

De samenwerking tussen de provincie Noord-Holland en TNO aan de hub Haarlem Nieuw-Zuid is opgebouwd langs drie onderzoekslijnen: 1) een kwalitatieve analyse over hubs met een overzicht van hubs in het algemeen en een analyse van Haarlem Nieuw-Zuid (definities van hubs, kenmerken, typologieën, functies en elementen, gekoppelde beleidsdoelen en gebruikers van hubs), 2) een kwantitatieve analyse van scenario's voor Haarlem Nieuw-Zuid met behulp van TNO's Urban Strategy platform (groeiscenario's, hub configuratiescenario's en beleidsmaatregelen scenario's) en 3) inzichten over toekomstbestendig en integraal hubontwerp.

Het project Haarlem Nieuw-Zuid (HNZ) hangt samen met de plannen voor de herinrichting van het centraal station van Haarlem, waarvoor een verplaatsing van het busstation nodig is om de geplande gebiedsontwikkelingen mogelijk te maken. Deze nieuwe locatie voor het busstation wordt Haarlem Nieuw-Zuid. De hub is echter niet alleen bedoeld om de ontwikkelingen rond het centraal station te faciliteren. De hub Haarlem Nieuw-Zuid zal bijdragen aan effecten als duurzame bereikbaarheid van de regio Amsterdam en MRA, minder uitstoot, betere multimodale bereikbaarheid, minder verkeersincidenten , een veilig mobiliteitssysteem, beter ruimtegebruik en het verhogen van leefbaarheid. De ambitie voor de hub Haarlem Nieuw-Zuid is om te transformeren tot een hoogstedelijk milieu, dat functioneert als een toegang tot de stad en de omliggende wijken met verdichting, diverse programmering en hoge kwaliteit van de (openbare) ruimte.

TNO analyseerde verschillende scenario's voor de hub Haarlem Nieuw-Zuid met behulp van het TNO Urban Strategy platform. Urban Strategy maakt het mogelijk om voorspellende digital twins te construeren op basis waarvan het effect van verschillende beleidsmaatregelen en ruimtelijke configuraties op mobiliteit en andere indicatoren zoals luchtkwaliteit en geluid kan worden onderzocht. De in deze studie opgenomen scenario's kunnen worden onderverdeeld in drie hoofddoelstellingen: (1) inzicht in de verwachte groei in het jaar 2030 en 2040, (2) effectbeoordeling van twee ruimtelijk verschillende configuraties van mobiliteitshubs in het jaar 2030 en (3) effectbeoordeling van aanvullende beleidsmaatregelen naast een mobiliteitshub in het jaar 2030. Tabel 1 bevat een overzicht van de scenario's.

Tabel 1: Overzicht van scenario's toegepast in de kwantitatieve analyse

Doel	#	Naam	Basis scenario
Groeiscenario	1	Referentie 2020	VMA 3.5, 2020AR
	2	Projectie 2030	VMA 3.5, 2030AR
	3	Projectie 2040	VMA 3.5, 2040AR
Hubontwerp scenario's	4	Hub Noord (2030)	Projectie 2030
	5	Hub Tunnel (2030)	Projectie 2030
Additionele beleidsscenario's	6	Verhoogde OV frequentie	Hub Noord (2030)
	7	Ontmoedigen autogebruik	Hub Noord (2030)
	8	Combinatie	Hub Noord (2030)

Het gebruik van de hub Haarlem Nieuw-Zuid

Op basis van de kwantitatieve studie kan allereerst worden geconcludeerd dat het aantal reizigers dat gebruik maakt van het busstation op de locatie Haarlem Nieuw-Zuid zal groeien tot 1,5 keer zoveel in 2030, en 2 keer zoveel in 2040 - vergeleken met de referentiesituatie in 2020. De invoering van de hub Haarlem Nieuw-Zuid en de bijbehorende buslijnen heeft niet veel invloed op de modal split in de stad Haarlem - er is slechts een toename van 0,1% in de modal split van openbaar vervoergebruikers te zien. Ook de twee verschillende ruimtelijke configuraties (Noord en Tunnel) hebben geen significante invloed op het aantal gebruikers of de modal split in de stad Haarlem. Daarentegen heeft de introductie van de hub Haarlem Nieuw-Zuid wel een groot effect op de route- en lijnkeuze van het openbaar vervoer: drie keer zoveel mensen stappen op de hub over op een andere bus in vergelijking met het busstation in dezelfde situatie zonder hubontwikkeling.

Het gebruik van deelfietsen en de benodigde fietsparkeercapaciteit wordt sterk beïnvloed door de doelen en ambities van de gemeente ten aanzien van de fiets als vervoersmiddel. Als het doel is om het busverkeer door het stadscentrum te verminderen en de hub meer te gebruiken als een 'openbaar vervoer-eindpunt' waar de reis wordt voortgezet met de (gedeelde) fiets, zouden potentieel grote aantallen fietsers bereid zijn om deze optie te gebruiken. Als de fietsenstalling of het gedeelde fietsaanbod echter beperkt is, wordt verwacht dat meer mensen de (stads)bus zullen gebruiken als toegangs- of uitgangsmogelijkheid naar de hub.

Aanvullende beleidsmaatregelen kunnen ertoe bijdragen dat mensen de auto minder gebruiken ten gunste van het openbaar vervoer en de fiets. In de scenario's met aanvullend beleid is berekend wat het effect is van verbetering van het openbaar vervoer (door verhoging van de frequenties), het effect van ontmoediging van het autogebruik (door snelheidsverlagingen en verhoging van de parkeertarieven in Haarlem) en het effect van een combinatie van deze maatregelen. Elk van de scenario's heeft een positief effect op het gebruik van het openbaar vervoer en vooral op de hub Nieuw-Zuid. Het ontmoedigen van het autogebruik heeft een groter effect op het aandeel reizigers dat met het OV reist dan het verhogen van de OV-frequentie, daarbij heeft het ontmoedigen van het autogebruik ook een sterk effect op de routekeuze van autoritten door snelheidsverlagingen in het netwerk. Deze resultaten zijn uitgezet in tabel 2 en tabel 3.

Tabel 2: Ritten van en naar Haarlem per scenario

District en modaliteit			Referentie	Hogere OV frequentie	Ontmoedigen autogebruik	Combinatie
Haarlem	Auto	Vertrekken	22.314	-	-0,6%	-0,6%
		Aankomen	20.281	-	-2,1%	-2,1%
	OV	Vertrekken	10.602	-	0,3%	0,3%
		Aankomen	8.344	0,4%	2,1%	2,6%
	Fiets	Vertrekken	24.321	-	0,4%	0,4%
		Aankomen	27.403	-0,1%	0,9%	0,7%

Tabel 3: Impact van aanvullende beleidsmaatregelen op rit activiteiten van OV-reizigers

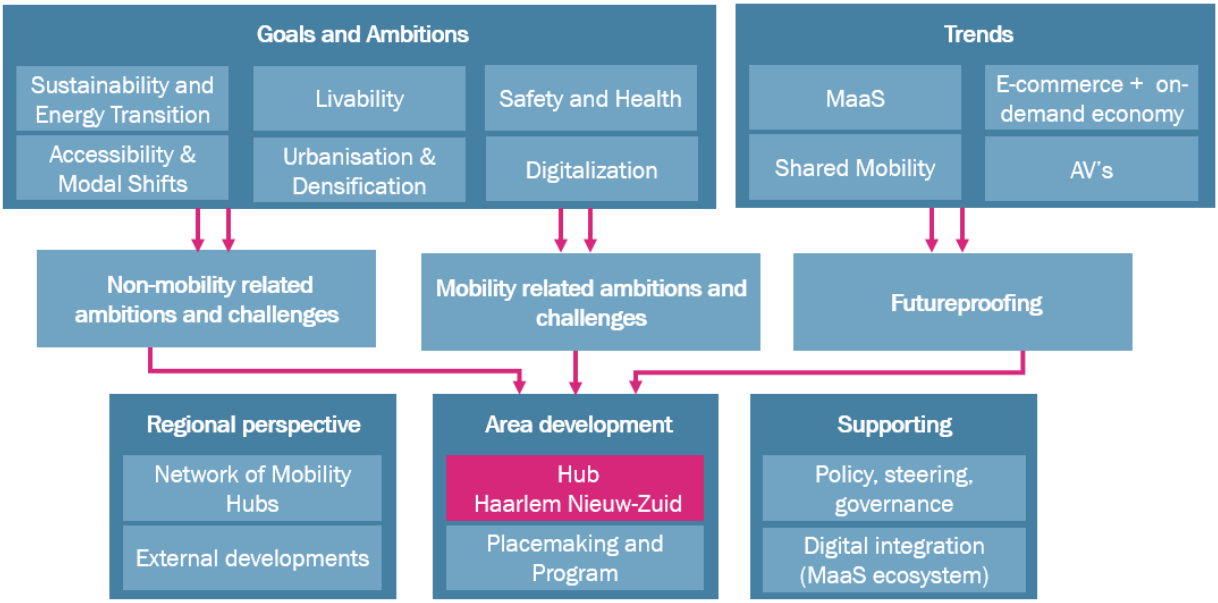
Locatie	Rit activiteit	Referentie	Hogere OV frequentie delta trips	Ontmoedigen autogebruik delta trips	Combi-natie delta
Central Station by train	Instappen	6.450	-320	-320	-380
	Uitstappen	4.480	-120	-120	-230
	Overstappen	2.350	-110	-110	-140
Central Station by bus	Instappen	80	-10	-10	0
	Uitstappen	110	-30	-30	-40
	Overstappen	1.920	-670	-670	-780
Hub Nieuw Zuid by bus	Instappen	190	10	10	10
	Uitstappen	70	-	-	-10
	Overstappen	470	900	900	1190

In een uitgebreidere modelstudie zou het interessant zijn om een netwerk van hubs te onderzoeken (bijvoorbeeld meerdere hubs die met elkaar interageren en concurreren), alsook een meer gedetailleerde studie van het gebruik van gedeelde mobiliteitssystemen, zowel op de hub als in de hele stad. Dit zou meer inzicht kunnen geven in de rol van de hub binnen het gehele mobiliteitssysteem waar nieuwe (gedeelde) vervoerswijzen en aanvullend beleid worden ingevoerd.

Ontwerpprincipes voor toekomstbestendige en integrale hubs

Observaties en inzichten op basis van de analyse op de hub en adviezen voor het verbreden van de scope van de hub Haarlem Nieuw-Zuid zijn samengevat in figuur 1. Allereerst is het belangrijk om (beleidsmatige/maatschappelijke) doelen die verder gaan dan 'alleen mobiliteit' te integreren in het hubontwerp door de scope te verbreden. Ook wordt benadrukt dat toekomstbestendigheid in het hubontwerp aan de orde moet komen; inclusief een vooruitziende blik en flexibiliteit om in te spelen op huidige en toekomstige behoeften. Vervolgens is het belangrijk om rekening te houden met de lokale integratie van de hub, met aandacht voor zowel "plaats" als "pad", en het verbinden van de hub met de gebiedsontwikkelingen. Ten slotte is regionale integratie en het ontwerpen van de hub vanuit een netwerkperspectief en het bespreken van ondersteunende voorwaarden (bv. governance, flankerend beleid) die aanwezig moeten zijn om de gewenste impact op strategische doelen en ambities te creëren, essentieel om de gewenste impact op belangrijke prestatie-indicatoren en vanuit een regionaal perspectief te bereiken. De in dit hoofdstuk gepresenteerde inzichten zijn zowel specifiek voor Haarlem Nieuw-Zuid, maar zijn

ook relevant voor andere hubontwikkelingen (elders of op andere schaal) om aantrekkelijke, toekomstbestendige en integraal ontworpen hubs te creëren.



Figuur 1: Framework voor integraal en toekomstbestendig hubontwerp gebaseerd op observaties en analyses van Haarlem Nieuw-Zuid

Gebaseerd op deze ontwerpprincipes voor toekomstbestendige en integrale hubs kan de hub Haarlem Nieuw-Zuid baat hebben bij een verbreding en het nemen van bepaalde ontwerpkeuzes en dilemma's die in deze studie zijn geïdentificeerd. Deze zijn:

- **Het adresseren van meerdere en uiteenlopende (beleids)doelen en ambities in het hub-ontwerp door de scope te verbreden voorbij mobiliteit**. Het adresseren van *alle* doelen en ambities is een uitdaging maar het is belangrijk om hier rekening mee te houden bij het ontwerpen van de hub, het bepalen van het programma en de implementatie van de hub. Dit vereist beslissingen over de scope van de hub, maar ook over het stellen van prioriteiten. Bijvoorbeeld: hoeveel ruimte laat je voor gedeelde versus private micromobiliteit? En hoeveel ruimte moet worden besteed aan het creëren van parkeervoorzieningen voor micromobiliteit versus placemaking? Deze dilemma's over integratie komen allemaal neer op vragen over hoe prioriteiten te stellen en strategische doelen te operationaliseren. Wat zijn voorkeuren? En hoe dicteren deze voorkeuren het beleid en genereren ze inkomsten?
- **Toekomstbestendigheid van de hub door adaptiviteit en flexibiliteit.** Adaptiviteit is het opnemen van/anticiperen op trends en ontwikkelingen in het ontwerp van de hub - ook al is de impact van deze trends nog niet volledig duidelijk (known unknowns). Daarnaast moet er ook enige flexibiliteit of aanpassingsvermogen in het hubontwerp zijn waardoor de hub kan veranderen en zich kan aanpassen aan toekomstige behoeften en contexten. Dit omvat zowel een analyse van de feitelijke "wheels on the ground", als beleidsdocumenten, ambities en visies over toekomstige modal split. Dit omvat zowel de micromobiliteitsopties ((e-)bikes, bakfietsen, (e)-scooters, (e)-stepjes) als gedeelde auto's en mobiliteitsdiensten zoals MaaS-

oplossingen. Ook trends in privé micromobiliteitsopties zoals e-bikes en bakfietsen (voor personen en logistiek) moeten in aanmerking worden genomen, aangezien zij a) andere randvoorwaarden nodig kunnen hebben op het gebied van oplaadinfrastructuur, ruimtelijke implicaties en veiligheid en b) verplaatsingen die momenteel met de auto of het openbaar vervoer worden gemaakt, gedeeltelijk kunnen vervangen.

- **De hub niet alleen ontwerpen als een pad maar ook als een plek.** Voor Haarlem Nieuw-Zuid wordt benadrukt dat het belangrijk is de hub niet alleen met het oog op efficiëntie te ontwerpen, maar ook vanuit het oogpunt van verblijfskwaliteit, een plek te hebben om te ontspannen, veilige voetgangersroutes, pleinen of programmering toe te voegen om de aantrekkelijkheid te vergroten en de ervaring van de gebruikers van de hub (of dat nu reizigers zijn of niet) te verbeteren. Daarnaast is ook de sociale veiligheid een aandachtspunt waarmee bij het ontwerp van de hub rekening moet worden gehouden. In de huidige staat van de locatie kan de sociale veiligheid verbeterd worden. Hier is het rekening houden met de sociale veiligheid met een tijdsbestek van 24 uur in gedachten van belang.
- **Aandacht voor de rol van de hub bij ontwikkelingen in het gebied.** De hub kan ook de (woningbouw)ontwikkelingen (o.a. Elan Wonen, Spaarne 1 VOF, Being Development, New Cheese Development) in het gebied faciliteren. De hub kan bijvoorbeeld het parkeren (zowel auto's als andere modaliteiten, gedeelde mobiliteitsdiensten aanbieden voor nieuwe bewoners) en de mobiliteitsbehoeften van deze nieuwe bewoners, bezoekers en forenzen op de hub ondersteunen, in plaats van deze op straat op te nemen. Dit kan betekenen dat de elementen en functies (zowel mobiliteitgerelateerd als niet-mobiliteitgerelateerd) van de hub opnieuw kunnen worden bekeken om niet alleen te voldoen aan de behoeften van de busreiziger, maar ook aan andere (mobiliteits)behoeften van (nieuwe) buurtbewoners (bijvoorbeeld door andere functies toe te voegen of de schaal van het (gedeelde) mobiliteitsaanbod te veranderen).
- **De hub ontwerpen vanuit een netwerkperspectief.** Dit betekent zowel het regionale perspectief - aansluiting op (grotere) regionale knooppunten - als kleinschaliger knooppunten in de stad Haarlem en omgeving. Daarnaast is het belangrijk om te kijken naar de randvoorwaarden (governance, beleid, etc.) om ervoor te zorgen dat de hub functioneert en wordt gebruikt op een manier die bijdraagt aan de doelstellingen van de provincie Noord-Holland en Haarlem en zowel het lokale als het regionale perspectief.
- **Maak effectief (flankerend) beleid om de gewenste effecten van de hub(s) te bereiken**. Het is belangrijk op te merken dat de fysieke uitvoering van de hub op zichzelf geen significante invloed zal hebben op de modal shift. Uit de kwantitatieve analyse blijkt dat de modal split voor de stad Haarlem slechts met 0,1% toeneemt voor het openbaar vervoer. De hub heeft echter wel invloed op de hoeveelheid reizigers die via de hub reist (invloed op routekeuze en lijnkeuze) - waardoor het centraal station ruimte krijgt om de groei op te vangen en er minder bussen door de binnenstad rijden. Wanneer de hub wordt gebruikt als middel om niet alleen (regionale) bereikbaarheidsdoelstellingen te bereiken, maar ook om het centraal station van Haarlem te faciliteren in zijn ambities om te groeien, ontstaat de behoefte aan flankerend beleid. Zoals blijkt uit de resultaten van de modelstudie kan de invoering van flankerend beleid en maatregelen om zowel het openbaar vervoer aantrekkelijker als de auto minder aantrekkelijk te maken een positief effect hebben. Opvallend is dat bij de aanpak van de verschuiving in

vervoerswijzen maatregelen om de auto minder aantrekkelijk te maken een groter effect hebben op de keuze voor het openbaar vervoer en de fiets dan maatregelen om het openbaar vervoer aantrekkelijker te maken (door de frequentie te verhogen). Het is daarom belangrijk om zowel de 'push- als de pull-kant' aan te pakken bij het ontwikkelen van flankerend beleid om het gewenste gebruik en effect van de hub Haarlem Nieuw-Zuid te waarborgen. Daarnaast, aangezien de hub meer doelen kan dienen dan alleen de mobiliteit gerelateerde ambities en doelen, kan ook rekening worden gehouden met hoe te sturen op niet-mobiliteit gerelateerde ambities en doelen. Wanneer de hub bijvoorbeeld ook rekening houdt met de mobiliteitsbehoeften (en eventueel de niet-mobiliteitsbehoeften) van de gebiedsontwikkeling in zijn omgeving, moet dit aan bod komen in het mobiliteitsplan voor deze ontwikkelingen. Ook bij de beoordeling van de aantrekkelijkheid en de waargenomen gebruikerservaring vanuit een "plaats"-perspectief kunnen er verschillende indicatoren zijn om het functioneren van de hub te monitoren (bv. sociale veiligheid, variatie in voorzieningen en winkels, groen en kwaliteit van de plaats). Bij het sturen op deze doelstellingen kunnen specifieke beleids- of ontwerpvoorwaarden belangrijk zijn om rekening mee te houden bij het ontwerpen van de hub.

Doorontwikkeling van hubs

Om de ontwerpprincipes voor toekomstbestendige en integrale hubs in de praktijk te brengen hebben we de volgende aanbevelingen voor de (verdere) ontwikkeling van hubs:

- *Richt een interactieve ontwerpcyclus in om de bijdrage aan maatschappelijke doelen te borgen*

Dit betekent het ontwerp en de ontwikkeling van een hub in de praktijk in verschillende iteraties, aangevuld met de ontwikkeling van flankerend beleid. Dit kan met een combinatie van een kwantitatieve en kwalitatieve aanpak.

- *Betrek de benodigde experts voor de ontwikkeling van de hub en het inbrengen van een toekomstbestendig perspectief*

Een multidisciplinair team kan bestaan uit experts van verschillende vakdisciplines, met een strategisch, tactisch en operationeel perspectief en met kennis van het toekomstbestendig maken van een hub. Daarnaast kan het helpen om de hub vanuit verschillende perspectieven (ruimte, sociale veiligheid, klimaat, mobiliteit, etc.) te onderzoeken of per hub expliciet te kiezen welke doelen en ambities prioriteit krijgen.

- *Beschouw het gehele netwerk van hubs*

Daarnaast bevelen we aan om verder onderzoek te doen naar het ontwikkelen van een netwerk van hubs en wat hiervan de effecten zijn. Hierbij gaat het op de samenhang van (verschillende typen) hubs inclusief de diversiteit van het aanbod van faciliteiten en modaliteiten en de interacties tussen deze hubs.

- *Benchmark en monitor de voortgang*

Aangezien de ontwikkeling van hubs voorbij de scope van OV-knooppunten in de praktijk nog pionieren betreft, wordt tot slot aanbevolen om monitoring in te richten. Monitoring ondersteunt het expliciteren van (verwachte) bijdragen aan maatschappelijke doelen en houdt relevante (externe) ontwikkelingen in de gaten (zoals de modal split) en het ondersteunt het benchmarken van de hub in vergelijking met andere hubs. Daarnaast kan een monitoringsprogramma ook ondersteunen in kennisuitwisselingen en het gezamenlijke leerproces van de betrokken stakeholders faciliteren.

Contents

1 Introduction

The Province of North-Holland signals that the way people travel is changing. This is due to technological developments (new modes and mobility concepts that affect modal split and use of space), different travel behaviour, our energy transition but also the way cities and regions develop and densify. Increased urbanisation results in additional demand for mobility which in turn creates more pressure on a healthy, save and lively place to live. In their strategy on public transport nodes (Strategie Programma OV-knooppunten 2019 – 2023), they state that - to make better use of space, to optimize travel chains, ensure good quality of space, reach climate goals and facilitate housing developments - hubs could pose a solution. To facilitate a necessary transition to clean, safe and smart mobility, hubs can function as an impulse for spatial efficiency and quality, environmental and health benefits.

1.1 Research scope

The Province of North-Holland collaborates with TNO on futureproof mobility hubs, with specific focus on the case Haarlem Nieuw-Zuid. Haarlem Nieuw-Zuid is a bus-hub in development in Haarlem that is being developed by both the Province as the municipality of Haarlem to ensure future, regional accessibility. This study is aimed to provide insights into potential effects of hubs and how they attribute to (policy) goals and ambitions. TNO will do this along three lines of research:

1. **A qualitative analysis on hubs**
   In this line of research, desk research generated insights on hubs based on literature and practice (elsewhere). This provides an overview of the most important trends and developments when it comes to hubs. This analysis covers topics such as; hubs definitions, characteristics, typologies, functions and elements, connected policy goals, and users of hubs. Then an analysis of the Haarlem Nieuw-Zuid case is done to provide a qualitative overview of its specifications. Insights from this first line of research are shown in chapter 2.
2. **A quantitative analysis on scenarios for Haarlem Nieuw-Zuid**
   This line of research focuses on the development and analysis of scenarios regarding the hub Haarlem Nieuw-Zuid. Using TNO's tool, Urban Strategy, quantitative results are generated on growth scenarios and hub design scenarios (including some flanking policies). Insights from this second line of research are shown in chapter 3.
3. **Futureproof and integral hub design principles**
   In this third and final line of research insights (both qualitative and quantitative) will be translated to practical advice and boundary conditions for futureproof and integral hub design. This contains both insights on design dilemmas as ways to increase the impact of hubs on policy goals. Insights from this final line of research are shown in chapter 4.

1.2 Research process

In the figure below, the research process for each of the lines of research is shown. In this figure activities, important external workshops (with TNO, the Province of North-Holland and municipality of Haarlem) and deliverables in reporting are shown in figure 1.1.

	1: Qualitative analysis	2: Quantitative analysis	3: Futureproof & integral hubs	Reporting
JAN	Desk Research	Model Development		
FEB	Desk Research and Analysis	Model Development		
MAR	Analysis and Reporting	Workshop: scenario input	Workshop: futureproof hubs	Deliverable Research line 1
APR		Model application (round 1)		
AUG		Workshop: modelling insights	Analysis	Reporting
SEP		Model application (round 1)	Analysis	Reporting
OCT		Reporting research line 2	Reporting research line 3	Full draft report to PNH
NOV				Finalize reporting

Figure 1.1: Research process for research lines and reporting

2 Hub trends and developments

In this chapter the results from desk research and insights on hubs based on literature and practice (elsewhere) are summarized (chapter 2.1). This provides an overview of the most important trends and developments when it comes to hubs. This analysis covers topics such as; hubs definitions, characteristics, typologies, functions and elements, connected policy goals, and users of hubs. This is followed by an analysis of the Haarlem Nieuw-Zuid case to provide a qualitative overview of its specifications (chapter 2.2.).

2.1 Hubs: an overview from literature and practice

2.1.1 Why hubs and what are they?

Before we define hubs, we first explain the developments that lead to interest in hubs. In urban areas there are several developments that have an impact on liveability, economic vitality and welfare beyond GDP (gross domestic product). These are amongst others:

- Demographic trends such as population growth and an ageing population, combined with an increasing demand for transport (for people, goods, and services). The negative impact of those movements on air pollution, safety, public space use, equity, and accessibility grows. A balance between reducing negative impact of transport and accessibility whilst maintaining or facilitating quality of life and quality of space is a challenge.
- Retail and economic trends, in particular the growth of e-commerce and on demand services (for parcels, groceries and fresh meals) and the recent phenomenon of flash deliveries from ‘dark stores’ (e.g. Gorillas, Flink, Zapp) that compete with local SME. This growth of these services has been exacerbated by the Corona lockdowns. Moreover, such new delivery services contribute to the instant gratification of individual consumers but do not necessarily lead to an overall positive contribution to the local economy. local SME, citizens and visitors (can) experience increased vehicle movements and nuisance in terms of noise, traffic safety and occupancy of sidewalks[1].
- Sustainability trends aimed at improving livability, social cohesion and health. This includes developments towards more active modes of travelling (reducing car usage), ‘greenification’ in light of climate adaption, the energy transition, car free areas and ’15-minute cities’ in which facilities – ‘’from food to work to exercise to socialising and everything in between” (Ragan, 2020) – are accessible on foot or by bike within 15 minutes.

These developments put different but increasing *claims upon scarcely available public space*. Consequently, it requires a new perspective and different design on how we organize our neighborhoods. This also affects (the impact of) transportation and accessibility.

In response to policy goals such as livability, economic vitality and welfare and above listed developments, hubs are increasingly seen as solution that can *potentially* address multiple challenges whilst being spatially efficient. However, this does not make it a quick-fix, one-size-fits-all solution. There is not *one* definition of hubs,

[1] Cities’ next headache: Ultrafast grocery delivery – POLITICO

however it often refers to combination of functions, that can be realized on a new physical location, an existing physical location but also digitally. Functions could be addressing mobility, logistics, energy or societal needs. Mobility hubs often include shared (electric) mobility such as bikes, mopeds, scooters, and cars. In addition, many definitions consider a hub to be a node in a network, which also means that it should facilitate some form of transfer or transshipment. Based on an extensive literature review in the European Smart Hubs project, the following definition is proposed: "*A mobility hub is a physical location where different shared transport options are offered at permanent, dedicated and well-visible locations and public or collective transport is available at walking distance*."[2]. In the Netherlands, the knowledge institute for mobility (KiM) defines hubs as: *"physical nodes between modes that besides their mobility function also can serve as a location for spatial developments*"[3]. A (large) Public Transport node combining different modes and offering additional services is in that sense also a hub.

These definitions do not seem reflect that hubs are presented as new, innovative and promising solutions to the complex societal challenges that urban areas face. TNO defines hubs as *a transfer - , transshipment point and/or node for various activities, services and facilities (ranging from mobility, to logistics, energy and societal functions). […] Hubs should be developed from a futureproof and integral perspective and should contribute towards societal goals (welfare beyond GDP)*[4].

In this study we broaden the scope of hub development and specifically explore the added value of a futureproof and integral perspective and a contribution to the operationalization of how a hub impacts societal goals. Futureproof refers to taking policy goals and developments that could play an important role in the future into account in hub development. Examples are MaaS (Mobility-as-a-Service), shared mobility, electric mobility, Zero Emission logistics and Autonomous Vehicles (AV's). An integral perspective refers to addressing domains beyond mobility, and a focus on hub development beyond a single location, but also include the role it plays in a larger network or system.

2.1.2 Hub Characteristics, Typologies, and Functions

Hubs could be characterized based on geographical scale (e.g. neighbourhood, international), functions and (sub)activities (e.g. shared mobility, PT, logistics, energy, societal), users and target audience (e.g. commuters, residents, SME), and governance aspects (e.g. ownership, market structure, exploitation and collaboration structures) (Janjevic & Winkenbach, 2020). Most hub visions, strategies or other exploitations scope hubs towards either mobility for people *or* goods, and the integration of the two is not very common. Most often in cities (such as the city of Rotterdam), there are separate visions or strategies on the development of mobility and logistics hubs. In the hubs vision of the city of Amsterdam both types are mentioned, but not necessarily integrated. Ideally, the integration is going beyond the transportation domain, also addressing other needs such as energy (e.g. for

[2] SmartHubs. (2021). *D2.1: A multidimensional mobility hub typology and inventory: https://www.smartmobilityhubs.eu/_files/ugd/c54b12_819c85702a6442c6bebb18538fb93516.pdf*
[3] Kennisinstituut voor Mobiliteit. (2021). *Verkenning van het concept mobiliteitshub.*
[4] Heezen et. al. (2021). *Hubs: Knooppunt van maatschappelijke opgaven*. CVS congres 2021, Utrecht. [page 2] https://repository.tno.nl/islandora/object/uuid%3A347fb6c2-d6fe-4bd9-8a94-4c4a60d1c6ed

charging, buffer capacity) and societal functions (e.g. day-care, library, coffee shop, repair shops).

When addressing the scale of hubs, there are different levels to distinguish[5,6,7]:

- Small scale neighbourhood hub (buurthubs)
- Larger scale neighbourhood hubs (wijkhubs)
- City hubs / Public Transport hubs
- Regional hubs
- Logistics hubs (ranging from smaller scale to large scale)

The typology used in Amsterdam describes the scale of the hub (amount of intended users), the location, the functions (e.g. PT, parking, shared modes), and its contribution to societal goals[8]. The Dutch Knowledge institute for Mobility (KiM) distinguishes hubs both in urban context and on city scale as well as rural context and larger scale. They distinguish between hubs for people (small scale and larger scale neighbourhood hubs, city hubs, corridor hub (connecting city and region - what Amsterdam calls a regional hub), regional hubs (in rural areas), (inter)national hubs) and goods (urban consolidation centres, regional consolidation centres, (inter)national goods hub)s[9]. The way these different hub-types are coherent and co-operate is shown in Figure 2.1.

While the transport system for people and goods is traditionally addressed separate, there is substantial potential to integrate it, especially when considering the potential efficiency gains (spatial, financial, infrastructure)[10]. This hypothesis and concept of integrating these domains towards creating multimodal and interconnected hubs for freight and passenger transport is the goal of H2020 project MOVE21 (www.move21.eu).

[5] Rijkswaterstaat. (2020). *De multimodale Hub en Rijkswaterstaat.* [page 23]
[6] Gemeente Amsterdam. (2021). *Hubsvisie Amsterdam.* [page 13 – 28]
https://amsterdam.raadsinformatie.nl/document/10972695/1/De_Hubsvisie_Amsterdam
[7] Kennisinstituut voor Mobiliteit. (2021). *Verkenning van het concept mobiliteitshub.* [page 21]
[8] Gemeente Amsterdam. (2021). *Hubsvisie Amsterdam.* [page 13 – 28]
https://amsterdam.raadsinformatie.nl/document/10972695/1/De_Hubsvisie_Amsterdam
[9] Kennisinstituut voor Mobiliteit. (2021). *Verkenning van het concept mobiliteitshub.* [page 21]
[10] From: https://move21.eu/why/

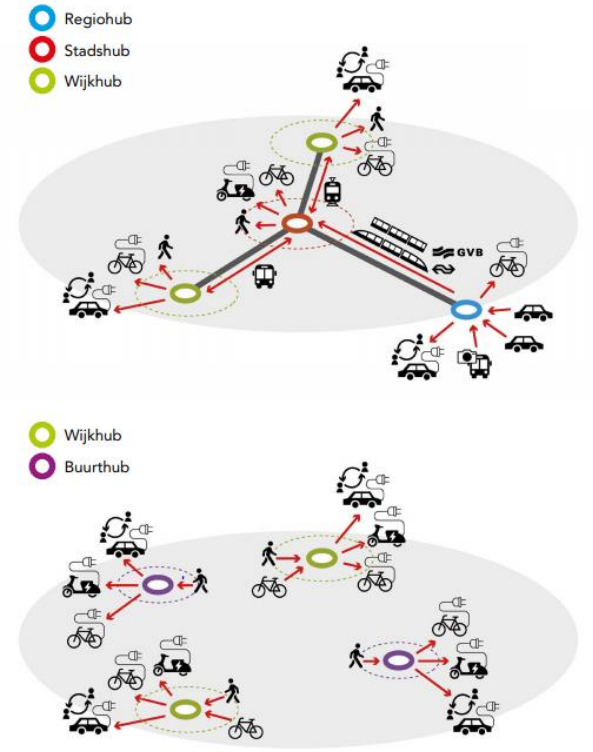


Figure 2.1: Connections between different hub types in Amsterdam[11]

2.1.3 *Hub Functions and Elements*

While primary functions of mobility hubs address transportation, there are also functions or elements supporting transportation (e.g. wayfinding, ticketing) and functions that support societal needs and placemaking (e.g. kiosk, day care). In the study of RISE and ARUP they distinguish between building blocks/elements that form 'the foundation' of a hub (mobility-related services necessary for a functioning mobility hub), and 'the supporting' elements (additional, non-mobility services to users of the hub) (see figure 2.1)[12].

Figure 2.2: Elements and functions of a mobility hub[9]

[11] Gemeente Amsterdam. (2021). *Hubsvisie Amsterdam.* [page 25]
[12] RISE, ARUP. (2020). *Mobility hubs of the future.* [page 11]

In the US, the San Diego region uses five categories of services and amenities in their so-called “Mobility Hub Features Catalog”. These are: Transit Amenities (PT) such as waiting areas and real-time travel information, Pedestrian amenities (such as crossings), bike amenities (e.g. bike parking, sharing), motorized services and amenities (e.g. electric bike and scooter share, on-demand rideshare, smart parking, EV-charging) and support services and amenities (e.g. package delivery, wayfinding) [13]. The city of Portland additionally considers ‘priority access’ as an important element of designing a mobility hub. Portland here prioritizes certain user groups and modes to reach their policy goals and ambitions with regards to mobility (e.g. reduced car use, sustainability, and traffic safety). This means that there should be prioritized walkways for all ages and abilities, safe bicycle and pedestrian crossings and prioritized bike and micro mobility access (e.g. separate lanes)[14].

The SmartHubs project additionally states that digital (e.g. MaaS), physical and visual (e.g. signage, branding, urban fabric) and social or democratic integration (e.g. co-creation) is essential[15]. Based on their literature review, they’ve come up with an ‘integration ladder’ for Smart Mobility Hubs that ranges from level 0 (only offering single mobility services, no physical or digital integration and no stakeholder involvement) to level 4 (a Smart Mobility Hub). This integration ladder is shown in figure 2.2. It is important to note that to achieve level 4, you must address all three different aspects of level 4 integration (physical, digital and social/democratic). The integration ladder is used to score hubs (or hub designs) to asses for each of the three integration goals how far they currently are and where they still can improve.

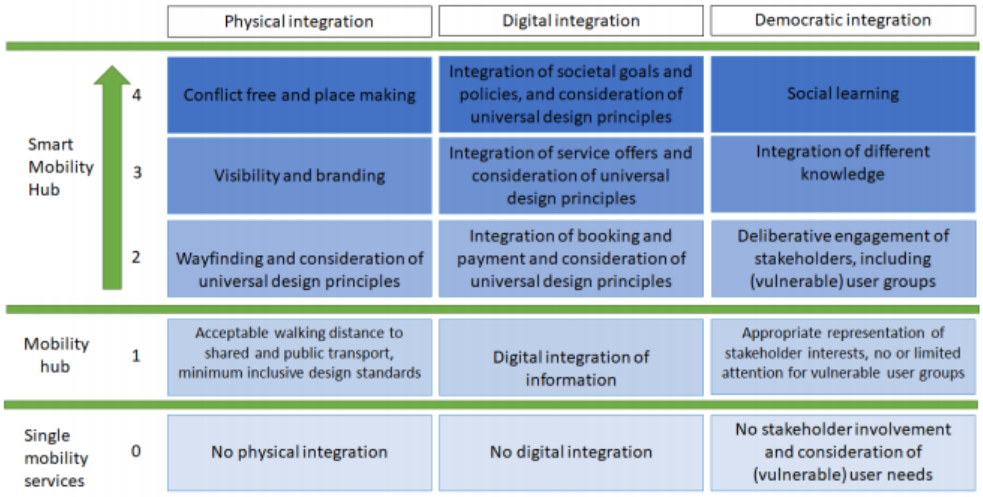


Figure 2.3: The SmartHubs Integration Ladder for Smart Mobility Hubs12

2.1.4 *Policy Goals and Expectations of Hubs*

Hubs are a popular measure not only from the potential to facilitate and improve mobility, but also for its possible attribution to policy goals and ambitions. These goals

[13] SANDAG, ICTC. (2017). *Mobility Hub Features Catalog – regional mobility hub implementation strategy.*
[14] Portland Bureau Of Transportation. (2020). *Mobility Hub Typology Study.*
[15] SmartHubs. (2022). *The SmartHubs Ladder – description of the multidimensional mobility hub typology.*

are (based on literature, strategic visions and ambitions for regions and cities, as well as practice)[16, 17, 18]:

- Accessibility: specifically focus on public transport and first- and last-mile integration. Accessibility should no longer just be about getting there but getting there in a safe, sustainable and smart way.
- Sustainability: Facilitating efficient, seamless integration of sustainable transport options.
- Liveability: This includes an improvement in environmental aspects such as emissions and noise, but also includes safety, green, place making and quality of space. Besides hubs, also measures such as car-free cities, Zero Emission Zones and '15-minute cities' are popular and can support the ambitions towards futureproof liveable cities and urban areas.
- Facilitating the 'mobility transitions', for example facilitating EV's and charging, but also facilitating a shift from ownership to use of modes.
- Facilitating densification and/or growth of urban areas in a way that is spatially efficient and ensuring the availability of required functions and services in these areas.
- Facilitating urban logistics and consolidation solutions to eliminate the negative impact of transportation of goods (such as emissions, noise, curb space occupancy, safety).
- Economic Vitality: stimulating local businesses and lively neighbourhoods
- Climate resilience measures for heat, air quality and water storage.
- Equity measures such as enhancement for underserved and commonly excluded population groups

While hubs are often described as focused on helping achieve societal, environmental and/or economic goals, there is limited research done and information available on the measured impacts of hubs and their contribution to policy goals and ambitions[19] . This is largely due to the early state of mobility hub deployments and relatively limited number of existing mobility hub pilots. There are however a lot of expectations about hubs, which makes them such a popular measure and why they are included in visions and strategies of cities and regions. As was also mentioned before, this does not mean that hubs are actually living up to the expectations (this is depending on how they are designed and implemented and if the boundary conditions (such as flanking policies) are in place). Below, some commonly mentioned expectations of hubs:

- Hubs result in less use of space / are a spatially efficient measure
- Hubs create a more attractive mobility package:
    - A travel portfolio as an alternative for car use and especially car ownership
    - Attract new and more travellers to shared mobility
    - Increase accessibility for all users
- Hubs make public transport more attractive:
    - Attract new and more passengers to use PT
    - Higher appreciation of the trip by making the hub experience pleasant

[16] Gemeente Amsterdam. (2021). *Hubsvisie Amsterdam.* https://amsterdam.raadsinformatie.nl/document/10972695/1/De_Hubsvisie_Amsterdam
[17] Provincie Noord-Holland. (2019). Strategie Programma OV-knooppunten 2019 – 2023.
[18] Provincie Noord-Holland. (2021). *Smart Mobility Provincie Noord-Holland – focus 2022 – 2025*
[19] SmartHubs. (2021). *D2.1: A multidimensional mobility hub typology and inventory: https://www.smartmobilityhubs.eu/_files/ugd/c54b12_819c85702a6442c6bebb18538fb93516.pdf*

    - Offer useful services in addition to mobility functions
    - Create first/last mile options
- Hubs make the transportation system more efficient (shared vehicles require a smaller fleet for similar amounts of trips)
- Hubs increase social welfare
    - Increased mobility and accessibility at low costs
    - Connect less-connected areas to the larger transportation network
- Hubs can stimulate or facilitate (new) (local) businesses and SME
- Hubs can increase the attractiveness of the area/city:
    - Attractive program and additional functions/services
    - Placemaking and branding
- Hubs can increase the quality of life (e.g. clean air, less noise, safety, quality of space, green)
- Hubs can become essential and active neighbourhood spaces
    - Placemaking opportunities
    - Community information
    - Community events/gathering spaces
- Hubs can stimulate and facilitate walking and cycling as a desirable, sustainable and healthy means of transportation
- Hubs can facilitate a reduction in emissions:
    - Offer sustainable modes and transportation options to passengers
    - Offer and facilitate sustainable consolidation solutions

2.1.5 Users of Hubs

There is not a lot of data available about the users of hubs. This is both due to the fact that hubs are not always past the pilot phase, uptake is still fairly limited, and use is not always monitored. Current users of hubs and shared modes are predominantly highly educated, middle-aged males that have a high income [20], although this is highly dependent on the location where a hub is deployed. Besides socio-demographic characteristics of users, also travel behaviour and mobility patterns are a predictor of the uptake of hubs in people's daily life. For instance, Public Transport users might in some cases be perceived as 'early adopters'[21], however, since the hubs and connected services and functions might be more expensive than solely PT, these users might not all be able to use (all services provided by) hubs due to its higher price point. This, of course, could be mitigated by policy measures that subsidize the use of modes associated with hubs[22]

When designing hubs, reasons for travelling (e.g. visiting, tourists, residents, commuters, leisure) can also be taken into account when scoping functions and services to scope the hub in a way that suits user needs. However, the risk is that when designing hubs for all – trying to combine multiple challenges and addressing the majority of all travellers – you can also differentiate too much and create "conflicting requirements for different user groups"[23]. Being able to adapt the hub to both changing user interests and need but also changes due to trends and

[20] Liao, Correia. (2020). *Electric carsharing and micromobility: a literature review on their usage pattern, demand, and potential impacts.*
[21] Zijlstra, et.al. (2020). *Early adopters of Mobility-as-a-Service in the Netherlands.*
[22] MOVE PGH as an example: https://move-pgh.com/affordable
[23] SmartHubs. (2021). *D2.1: A multidimensional mobility hub typology and inventory: https://www.smartmobilityhubs.eu/_files/ugd/c54b12_819c85702a6442c6bebb18538fb93516.pdf*

developments, new mobility offers (such as shared mobility and MaaS) is therefore an important design approach for futureproof hubs.

Changing user behaviour towards the adoption of new modes and travelling via hubs is a topic that is currently not very well covered. Since it is not exactly known who will use hubs and for what reasons, it is also difficult to pinpoint reasons for changing behaviour. Based on studies on the adoptions of new mobility technologies it is known that designing something that looks attractive, and is 'easy to use', does not necessarily mean that people will actually use it. There is research ongoing on the factors that increase and/or influence the acceptance for using new technologies and concepts in the mobility domain. These studies suggest that both extrinsic motivation (such as expectations about performance, the ease of use, social influences, signage and wayfinding, connected services and perceived risk), intrinsic motivations (such as sustainability, health, and the 'fun-factor') as well as demographic characteristics (age, income, education, gender, etc) are all of importance [24], [25], [18]. To change behaviour and travel patterns of users requires therefore a strong strategy and vision to attract people to use hubs – also when this requires and additional transfer (people) or transhipment (goods).

2.2 Development of the Haarlem Nieuw-Zuid hub

Based on the insights from literature and practice we provide here an analysis of the proposed hub Haarlem Nieuw-Zuid, highlighting key characteristics. This description is made based on the documents studied in table A.1, included in Appendix A. In chapter 4, based on this description, the hub is discussed according to its possible scope, design choices and decisions, and most specifically how to ensure futureproof and integral hub design.

2.2.1 Province of North-Holland and Haarlem: visions on hubs

In policy documents of the Province (PNH) hubs are presented as a possible solution that could contribute to a functioning regional mobility system. Challenges that the PNH identifies (both short and long term challenges) are:

- Urbanization and increased demand for housing
- Traffic safety
- Modal shifts
- Connections between urban and rural areas
- The energy transition
- Shared mobility
- Automatization of mobility and transport processes
- Digitalization and asset management.

Hubs are positioned as a promising solution to address (some of) these challenges, specifically concerning area developments, clean mobility, and smart and flexible use of space. PNH states that hubs are multimodal nodes with a Park+Ride and/or Park+Bike. Digitalization and smart mobility will cause a more efficient and smarter use of mobility and logistics (by using sharing systems, sharing apps, and autonomous shuttles). Hubs should therefore contribute to effects such as: less

[24] Alonso-González, et.al. (2020). *Drivers and barriers in adopting Mobility as a Service (MaaS) – A latent class cluster analysis of attitudes.*

[25] Schikofsky, et.al. (2020). *Exploring motivational mechanisms behind the intention to adopt Mobility as a Service (MaaS): Insights from Germany*

emissions, better multimodal accessibility, less traffic incidents and a safe mobility system, better use of space and effects in terms of livability.

The city of Haarlem also mentions hubs in their mobility policy as an important instrument to stimulate clean and spatially efficient mobility. Their mobility policy states the ambition to become an attractive, healthy, green and accessible city for living, working and shopping. The city is expecting a growth of 10.000 new houses which challenges these ambitions, specifically in terms of accessibility, pressure on parking spaces, and CO_2 emissions. Therefore the ambition clearly states the spatially efficient mobility solutions, where hubs can also play a part. Mode shifts are needed to succeed according to Haarlem, and they state that in 2030 90% of all short trips (2,5km or less) should be done by walking or cycling, and 60% of trips to and from Haarlem should be done using PT and bikes. This requires a different prioritization when designing the mobility system and its infrastructures (walking and biking as prioritized modes), and a reduction in speed to 30 km/h as the new norm and to reduce car traffic. Haarlem is considering hubs both on the edges of the city for logistics and people to transfer from a car to the bike, PT, transport over water, or zero emission shared cars. Haarlem also wants to realize hubs on neighborhood level where residents can choose from a range of shared modes. These hubs also include charging infrastructure for EV's, logistics points and should reduce parking on street level to allow more room for walking, cycling and quality of place.

2.2.2 Hub Haarlem Nieuw-Zuid characteristics

The project Haarlem Nieuw-Zuid (HNZ) is connected to the plans for redesigning Haarlem's central train station, which requires a relocation of the bus station to facilitate the planned area developments. This new location for the bus station will be Haarlem Nieuw-Zuid. This hub is a no-regret measure and will be an essential building block for realizing the vision in the area of Haarlem's central train station. For the Province of North-Holland the to be developed hub fits with their PT-node development program (Programma OV-knooppunten), where hubs are multimodal nodes (beyond only PT). For PNH, hubs like Haarlem Nieuw-Zuid should contribute to sustained accessibility for the Amsterdam area, MRA region and other parts of the province.

The to be developed hub Haarlem Nieuw-Zuid can play an important part in the *regional* mobility system; connecting Haarlem to the MRA, Amsterdam and other parts of the Province. It's location, just outside Haarlem's city centre, and connection to main traffic routes (N205), makes it a very suitable location. The scope of the hub is tailored to mobility – specifically PT (busses) and bikes. Logistics are not part of the core concept. The expected growth of busses in Haarlem and the region is about 50% until 2040. For car traffic there is an expected growth of 30% until 2040. Haarlem and PNH wish to accommodate this growth but limit the negative side effects of (specifically car) traffic and to address the very high traffic intensity in this area.

The location of the hub Haarlem Nieuw-Zuid is also considered an interesting area for urban development projects, where spatial quality and efficiency is very important. This location should transform into a metropolitan environment, which functions as an entry to the city and surrounding neighbourhoods with densification, diverse programming and public space of high quality. In short, the hub should feel as much as a place to inhabit and enjoy as it does part of a longer transportation path to pass through. Due to these various developments, the hub could both play a part as a

regional mobility as well as play a part in facilitating mobility related services and other functions for the (new) residents, offices, shops and small and medium-sized enterprises (SME) in this area.

2.2.3 Functions and elements of the hub Haarlem Nieuw-Zuid

In the plans for the hub Haarlem Nieuw-Zuid the mobility related services that are mentioned are:

- Bus stops
- Bike parking
- Kiss&Ride / taxi stands
- Infrastructure for pedestrians, busses, cars and cyclists (infrastructure as much as possible separated).
- Travel information
- Waiting area's / shelter
- Shared modes (specifically station-based shared bikes)

Services and functions related to mobility that are often mentioned in other studies, such as specific ambitions on car sharing, or parking cars, charging EV's, are not currently included in this project. Regional hubs are often locations that are also considered for P+R/P+B locations, however in the case of HNZ it is specifically mentioned that this is not desirable. The car is currently no part of the bus system in this region and a P+R could take up a lot of space, and does not fit with the ambition of Haarlem to stimulate residents and visitors to travel by bike and PT. There are ambitions to include charging infrastructure for busses, however not very specific.

Supporting elements and functions of the hub Haarlem Nieuw-Zuid that are mentioned are:

- Café/kiosk
- Delivery/pick-up for packages
- Ticketing
- To-go grocery store

Other ambitions that are mentioned, however not addressed specifically are local energy production/storage to support sustainable operations of the busses and the hub. This requires a lot of space, which is a trade-off to be made. Safety (traffic and social) is an important requirement when developing this hub. First of all because with the expected growth to 2040 in terms of busses, this hub will be one of the busiest bus stations in the Netherlands. This means that there will be a lot of traffic movements. When designing the hub as a metropolitan environment, with a high quality of space, this causes a challenge since this might conflict with the high number of busses that will come and go in this location (ambition is about 150 busses per hour during rush hours) – both in terms of ensuring a safe environment as well as creating an environment where people want to be. Second, social safety should be considered when designing the hub as an attractive location. In the current state of the location, social safety is lacking (bus stops are too busy and narrow, no facilities, low quality of space, incidents with verbal aggression and harassment towards personnel and travelers)[26].

2.2.4 Policy goals and expectations of the hub Haarlem Nieuw-Zuid

Haarlem created an ambition document for the area (in concept – 'Ambitiedocument Knooppunt Haarlem Nieuw-Zuid conceptversie', December 2021) which addresses

[26] Rapport 006379.20200619.R1.04: Knooppunt Haarlem Nieuw-Zuid – verkenning mogelijke locaties. 29 September 2020 – Goudappel Coffeng & Urhahn

both the hub development as other developments and visions for this area. The area should have a positive appearance, and people should be proud of this part of the city, with its own identity and branding. The area should connect to Haarlem's values such as sustainability, green and a healthy environment. The hub itself will become one of Haarlem's three big PT nodes (Haarlem central station, Haarlem Spaarnwoude and Haarlem Nieuw-Zuid). With the metropolitan appearance of this area that is inspirational, it is important that the development of the mobility hub is connected to additional program. The hub will be an important part of this area's identity. Some of the core values (and expectations about the hub and the area) are:

- a quick and safe transfer point,
- a safe space where people can move with ease,
- 'gezelligheid' – a place to have a drink or a coffee,
- a dynamic workplace with sports facilities, restaurants and child care.

Policy goals on a more regional level and city level have already been addressed in section 2.2.1. When it comes to the hub Haarlem Nieuw-Zuid, ambitions, goals and expectations include:

- PT-node as an entryway to the city and its surrounding neighbourhoods
- PT-node as a crucial component for robust development of the PT network towards 2040 (and accommodate growth of bus network)
- High quality hub, with various facilities and high quality of space.
- Ambitions regarding sustainability (local energy production, storage an charging facilities).
- Plenty of space for active modes, less barriers in infrastructure and logical crosswalks (e.g. high scores in terms of bike parking, pedestrian facilities)
- Urban squares with high quality of stay (places to meet)
- Health: reduce nuisance from noise, higher air quality, green and trees, green facades. This also addresses climate adaptation (e.g. biodiversity and heat stress).
- Priority for cycling and walking (also as stimulus for PT)
- Adding houses, offices and (societal) facilities.
- Connection: ensure a good flow of traffic and PT
- Accessibility of the region, location and surrounding neighborhoods.
- Safety: both regarding traffic safety and social safety

2.2.5 Users of the hub Haarlem Nieuw-Zuid

This Following from ambition documents and studies of Haarlem Nieuw-Zuid, this hub development focuses on different types of users, ranging from residents, commuters, visitors to the city of Haarlem, travelers for leisure activities in the area (such as visiting the beach), and facilitating people travelling to and from the airport.

When trying to address these different user types, the risk exists that it is hard to please all or to include the specific needs of each of these users. Another challenge might be the required shift in behavior of travelers to travel via the hub. Users that currently also travel by bus might not need additional convincing, however, when facilitating the aspired mode shift from cars to walking, cycling, and PT this might be a challenge that requires specific attention.

3 Quantitative analysis

This quantitative analysis aims to assess the impact of several exploratory scenarios within the city of Haarlem. The scenarios focus on (1) the projected growth in the year 2030 and 2040, (2) evaluating the impact of two spatially different mobility hubs in the year 2030 and (3) exploring the impact of additional policy measures alongside a mobility hub in the year 2030. Results are obtained through a predictive digital twin as constructed with the Urban Strategy platform.

3.1 Urban Strategy

The Urban Strategy platform developed by TNO, enables to construct predictive digital twins from which the impact of different policy measures and spatial configurations on mobility and other indicators such as air quality and noise can be explored. A predictive digital twin in an urban context can be defined as the digital representation of a physical urban environment from which, due to the inclusion of simulation models, exploratory what-if scenarios can be carried out to examine future situations of an area or city (Oirbans et al., 2022)[27].

Urban Strategy, as opposed to traditional traffic models such as the VMA, was chosen in this study because of its high computational speed and functionalities. The computational speed of Urban Strategy enables to try out a range of different exploratory 'what if' scenarios within a short period of time. Moreover, Urban Strategy offers opportunities for providing shared mobility and other new modes as main mode of transport.

The basis of the digital twin as constructed for this quantitative analysis is the traffic model ‘Verkeersmodel Amsterdam’ (VMA) version 3.5. This implies all mobility system elements (i.e. networks, zones, trip matrices, travel modes, and so on) are initially similar to VMA 3.5. The VMA is adopted instead of the often used Noord-Holland Zuid model because it includes networks for car, bike and public transport, whereas the Noord-Holland Zuid model only contains a car network and travel times for bike and public transport. It is therefore not possible to adjust the public transport network – which is necessary as part of this study. The VMA itself is a further specification on the regional model VENOM. Subsequently, the capabilities of Urban Strategy are utilized to construct exploratory scenarios for hubs and additional policy scenarios and to simulate the effects of these scenarios by re-estimating mode choice and assigning resulting trips to the network.

3.1.1 Re-estimation of mode choice

The Urban Strategy mode-choice model re-estimates the mode-choice of the original model scenario given changed conditions such as the introduction of new bus lines, increase in frequency, and increased parking tariffs[28]. The module uses population data (e.g. including information on car possession and drivers’ license) and the

[27] Oirbans, L. P., Van den Berg, A. C., & Snelder, M. (2022). *Burgerparticipatie 2.0: Het benutten van predictive Digital Twin technologie in een participatieproces*. Colloquium Vervoersplanologisch Speurwerk 2022.

[28] Snelder, M., Wilmink, I., van der Gun, J., Bergveld, H. J., Hoseini, P., & van Arem, B. (2019). *Mobility impacts of automated driving and shared mobility: Explorative model and case study of the province of north Holland*. European Journal of Transport and Infrastructure Research, 19(4).

original trips as an input. Next, a multinomial logit-model predicts for every trip what the mode choice will be in the new simulated scenario. The logit-model and accompanying utility function has been estimated using OViN and ODiN-data, the travel diary survey in the Netherlands.

3.1.2 Assignment of trips on the road network

The Urban Strategy traffic assignment model handles the assignment of trips by car, truck and bicycle on the road network. The model utilizes an all-or-nothing algorithm for trips by truck and bicycle, this means that route-choice of these modes are not influenced by congestion on individual roads or routes. The muti-user class assignment volume averaging algorithm is utilized to assign trips by car, implying route choice of car trips are influenced by intensities on a road from other car trips. The volume averaging assignment consists of 20 iterations.

3.1.3 Assignment of trips on the public transport network

The public transport assignment of the Verkeersmodel Amsterdam is used for assignment of trips by train and bus, as well as the assignment of the access and egress by means of cycling or walking. It is assumed that the bicycle as means of access and egress option will only apply if the public transport stop is at least 15 minutes, but no further than 30 minutes, from the origin or destination. The boundaries for walking consists of a minimum of 0 and a maximum of 20 minutes.

3.2 Scenarios

The scenarios can be divided in three main objectives: (1) projected growth in the year 2030 and 2040, (2) impact assessment of two spatially different mobility hubs in the year 2030[29] and (3) impact assessment of additional policy measures alongside a mobility hub in the year 2030. An overview of scenarios is provided in Table 3.1.

Table 3.1: Overview of scenarios used in the quantitative analysis

Objective	#	Name	Basis scenario
Growth scenarios	1	Reference 2020	VMA 3.5, 2020AR
	2	Projection 2030	VMA 3.5, 2030AR
	3	Projection 2040	VMA 3.5, 2040AR
Hub design scenarios	4	Hub North (2030)	Projection 2030
	5	Hub Tunnel (2030)	Projection 2030
Additional policy scenarios	6	Increased PT frequency	Hub North (2030)
	7	Discouraging car use	Hub North (2030)
	8	Combination	Hub North (2030)

3.2.1 Growth scenarios

In order to assess the projected growth in the years 2030 and 2040, a reference scenario is created from VMA 3.5, 2020AR. “AR” stands for Amsterdam Realistic, i.e. a scenario that is realistic according to the prognoses specified for Amsterdam. In the Amsterdam model there is no notion of a ‘high’ and ‘low’ growth scenario.

[29] During the project, the council of Haarlem has chosen the hub North (Noordvariant) as the chosen alternative (20220609866-1-Vaststellen-noordvariant-als-voorkeursvariant-mobiliteitshub-Haarlem-Nieuw-Zuid.pdf).

In addition, two future scenarios are created for the year 2030 and 2040 respectively from VMA 3.5, 2030AR and VMA 3.5, 2040AR. With this set, future scenarios for the years 2030 and 2040 are compared to the year 2020. The assumed growth in terms of houses and inhabitants for the municipality of Haarlem are shown in
Table 3.2. This shows a 9% growth in inhabitants for 2030, and a 18% growth in inhabitants (compared to 2020) for the year 2040.

Table 3.2: Increase in population and houses compared to model year 2020

	Houses	Inhabitants
2030	8400 (10%)	14400 (9%)
2040	18600 (24%)	29500 (18%)

3.2.2 Hub design scenarios

The hub-scenarios aim to assess the impact of two spatially different hub designs (1) Hub North and (2) Hub Tunnel for the year 2030. The reference scenario consists of VMA 3.5, 2030AR, whereas the two hub scenarios are variations. Under the assumption that both hubs are similar in function, the difference lies within the surrounding infrastructure configuration as depicted in Figure 3.1. The service road J.J. Hamelinkstraat running parallel to the main road only consists of one road link in the network, and is therefore set bidirectional completely instead of a partly one-directional road. Besides the network related spatial differences of the hubs, the corresponding bus routes in Haarlem are projected to differ from the current situation. As depicted in Figure 3.2 and Figure 3.3 in detail, this will impact the routes and stops of bus service number 80, 244, 255 and 346. Moreover, a new high speed bus route (HOV) is projected to be added to the transport system. As a result, in comparison to the base year of 2030, the frequency of busses between the central station and the hub location of Nieuw-Zuid will decrease, while the frequency between Nieuw-Zuid and Northern areas of Haarlem will increase. In comparison to 2020, the number of buses through the city centre are stable. The shown details in Figure 3.3 show the frequencies during the morning rush hour, meaning the frequencies per direction are different. This is based on information in the underlying traffic model VMA.

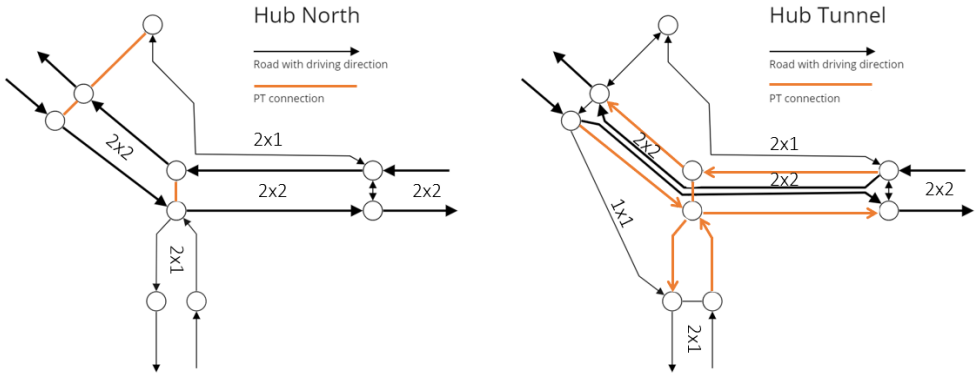


Figure 3.1: Schematic representation of the infrastructure configuration of the North and Tunnel hub variant. Orange roads are only accessible by bus lines. Numbers indicate the number of lanes available for car traffic.

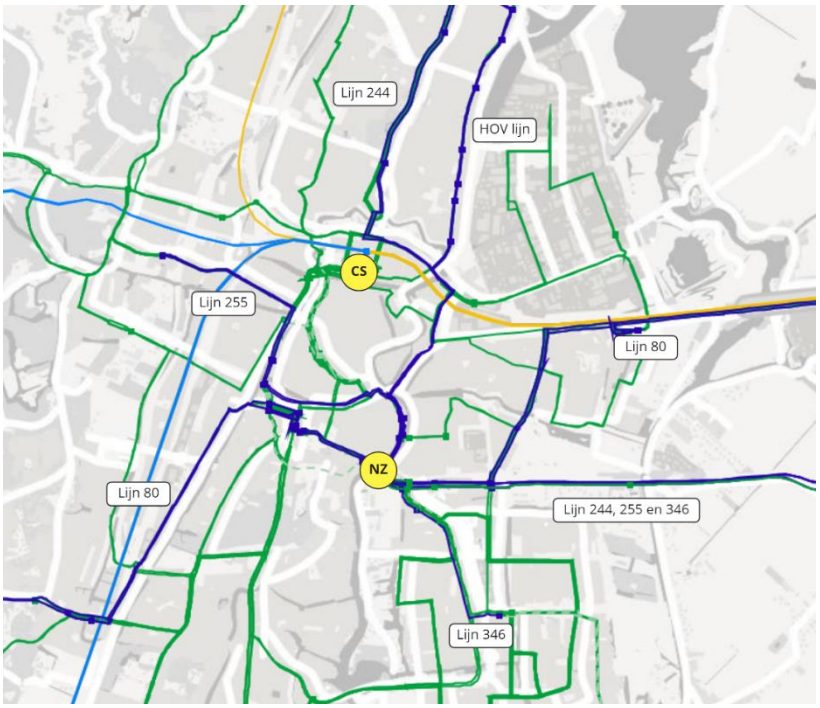


Figure 3.2: Public transport lines around Haarlem Central Station (CS) and the hub (NZ). Dark-blue coloured lines indicate newly added or changed connections.

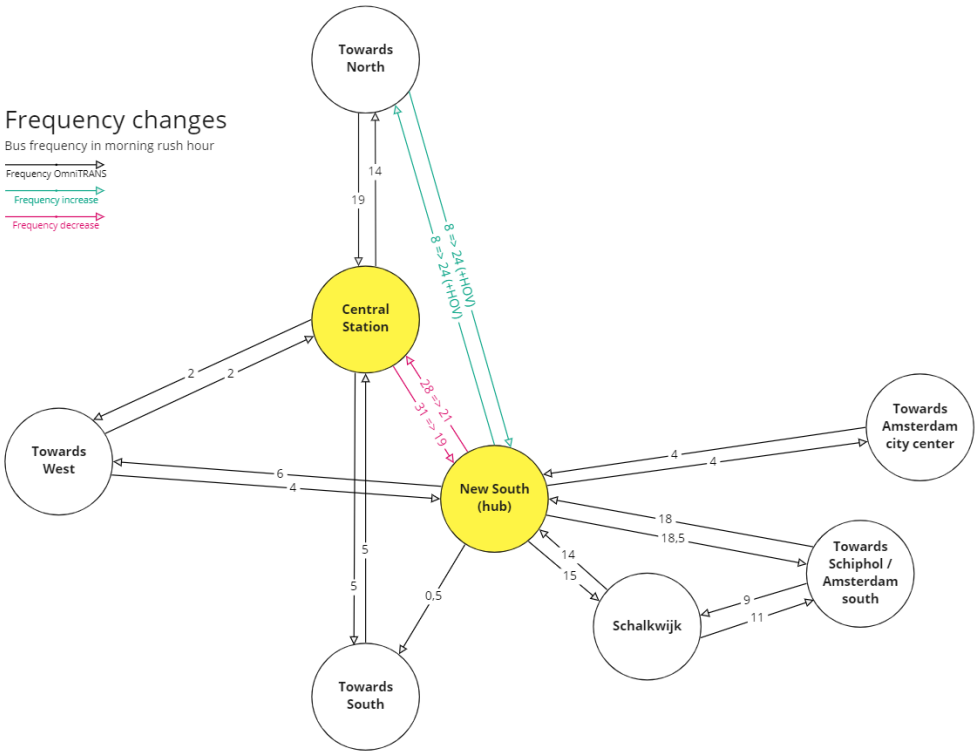


Figure 3.3: Schematic representation of frequency changes within Haarlem and surroundings in the morning rush hour. For the changed transit lines both the original and new frequencies are indicated.

3.2.3 Additional policy measure scenarios

For the impact assessment of additional policy measures alongside a mobility hub in the year 2030 variations are made to the Hub North (2030) scenario as described in Section 3.2.2. The variations include additional policy measures consisting of (1) increasing public transport frequency, (2) discouraging car use by reducing speeds, increasing parking tariffs and reducing parking capacities, and (3) a combination of both increasing public transport frequency and discouraging car usage. Both the increased public transport frequencies (as depicted in Table 3.3) as the location for potential speed reductions and increased parking tariffs (respectively depicted in Figure 3.4 and Figure 3.5) are provided by the municipality of Haarlem. The parking tariffs are increased by €8 for each parking session (for its entire duration). For an average parking duration of 3 hours, this entails an increase of about €2,50 per hour, i.e. leading to a total tariff alike the city centre of Amsterdam. Additionally, the parking capacity of the newly built living areas close to the hub are being drastically reduced in scenario 2 and 3. This has been modelled by altering the speed of the feederlink corresponding to the BPR-function as described in the paper of Van der Tuin et al. (2021).[30]

Table 3.3 Overview of increased frequencies during the morning rush hour (2-hour period).

Bus	Direction	Reference frequency	Increased frequency
80	East-West connection	4	6
300	Hoofdorp/Schiphol	11	17
346	BRT towards Amsterdam	8	24
385	New HOV line towards North	4	8

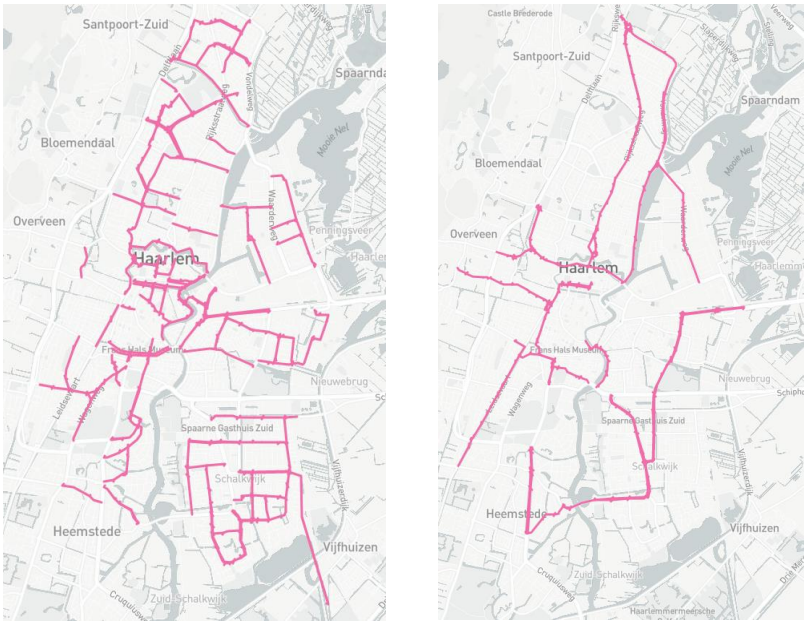


Figure 3.4: Roads set to a speed limit of 30 km/h (left) and 50 km/h (right) in the additional policy scenario.

[30] Van der Tuin, M., de Romph, E., Pieters, M. (2021) Grip op parkeercapaciteiten - modelaanpak en data-analyse. Bijdrage aan het Colloquium Vervoersplanologisch Speurwerk 25-26 november 2021, Utrecht.

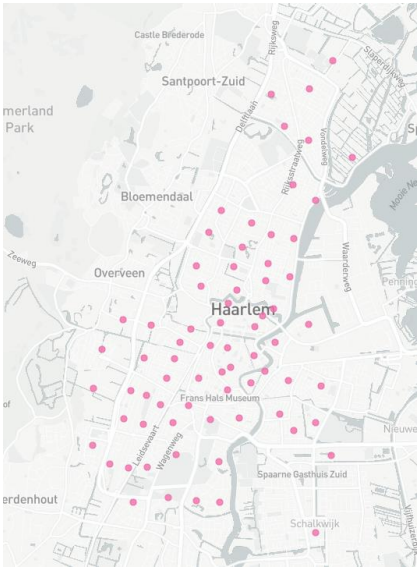


Figure 3.5: Zones in the traffic model where parking tariffs are increased.

3.3 Results

This chapter describes the impact of the growth scenarios for 2030 and 2040 in terms of number of trips and modal split, the impact of two spatially different mobility hub designs in the year 2030 on modal split and route choice and the impact of additional policy measures alongside a mobility hub in the year 2030 on mode choice. Additionally, results are provided for shared bike usage and needed bike parking capacity at the hub. The provided results entail the number of trips within the morning rush hour (7 to 9 AM). Results are split into trips per district, e.g. Noord, Centrum, Schalkwijk, Zuidwest and Oost as shown in
Figure 3.6.

Figure 3.6: Districts (stadsdelen) in Haarlem[31]

3.3.1 Results of growth scenarios

This section describes the projected growth in the year 2030 and 2040 compared to the year 2020. The scenarios do not include the hub and corresponding public transport line changes, and thereby merely reflect the change in travelers and mode choice caused by an increase in population.

As presented in Table 3.4, the projected growth revolves around trips by bike and car. For 2030, an average growth of the number of trips within Haarlem of 5-10% is predicted. The largest growth can be seen in arriving trips (during the morning rush hour), showing that on average more people will have Haarlem as their destination (e.g. work, eduction). For 2040, a growth of 10 to 20% is shown.

The highest growth is expected within the districts Centrum, Oost and Schalkwijk, all predominantly on arriving trips by bike and car. The least growth is projected on trips by public transport, regardless of district. It is expected that this is the result of the living area of population: in Haarlem a lot of houses are being built, especially around Schalkwijk. The inhabitants are expected to cause an increase in bike trips. The trips in Noord even show a limited increase in public transport than other districts. This is caused by the lack of introducing the new HOV lines (which will be considered later on as part of the hub studies itself). On the other hand, more inhabitants are expected to live in the surrounding areas of Haarlem such as IJmuiden and Zandvoort due to large redevelopments of these areas, while still travelling to Haarlem for work purposes. These places currently have fewer public transport connections available compared to the Haarlem intercity train station – leading to an increase in car usage toward Haarlem.

Table 3.4: Projected growth of trips in the morning peak in the year 2030 and 2040 compared to 2020.

District	Mode		Reference trips 2020	Delta trips 2030 [%]	Delta trips 2040 [%]
Entire VMA	Car	Total	2.747.410	5,2%	10,2%
	PT	Total	2.467.210	0,4%	0,9%
	Bike	Total	580.770	8,7%	15,2%
Haarlem	Car	Departing	19.240	5,1%	10,4%
		Arriving	19.930	9,8%	18,4%
	PT	Departing	27.430	4,2%	8,8%
		Arriving	23.960	5,4%	11,1%
	Bike	Departing	7.700	7,8%	16,4%
		Arriving	9.340	10,4%	21,3%
Centrum	Car	Departing	2.400	2,8%	5,5%
		Arriving	1.700	15,7%	28,8%
	PT	Departing	3.610	5,1%	11,1%
		Arriving	2.160	14,4%	28,8%
	Bike	Departing	1.260	4,7%	12,0%
		Arriving	980	16,3%	33,6%
Noord	Car	Departing	4.390	3,6%	7,4%

[31] Data (and according shapefiles) of districts taken from Open Data op de Kaart, Haarlem. https://kaart.haarlem.nl/app/map/18

		Arriving	6.590	5,6%	10,2%
	PT	Departing	7.730	0,9%	2,1%
		Arriving	8.390	0,3%	0,3%
	Bike	Departing	1.860	8,4%	16,4%
		Arriving	3.350	5,8%	12,4%
Oost	Car	Departing	4.750	5,5%	11,4%
		Arriving	2.890	15,5%	29,2%
	PT	Departing	3.300	6,6%	13,9%
		Arriving	3.270	14,0%	28,0%
	Bike	Departing	960	4,4%	11,3%
		Arriving	1.340	15,7%	32,3%
Schalkwijk	Car	Departing	3.840	9,6%	19,2%
		Arriving	4.170	12,2%	23,2%
	PT	Departing	4.470	9,0%	18,5%
		Arriving	4.810	9,8%	19,9%
	Bike	Departing	930	12,1%	25,2%
		Arriving	1.720	14,2%	27,7%
Zuidwest	Car	Departing	4.580	8,1%	15,1%
		Arriving	3.850	3,6%	7,1%
	PT	Departing	5.330	1,5%	3,5%
		Arriving	4.470	3,4%	6,7%
	Bike	Departing	1.940	8,2%	17,0%
		Arriving	930	8,6%	17,2%

Table 3.5 represents the projected growth at the location of the central station by both train and bus and the location of Nieuw-Zuid by bus in the year 2030 and 2040 compared to 2020. Note that the Nieuw-Zuid hub is not considered in the simulation runs: it is assumed to be the same bus stops (i.e., the current bus stops at Schipholweg and Europaweg) as currently exists. These results project an increase of travelers that will board, disembark and transfer to trains at central station in 2030 and 2040. Moreover, this is also projected for transfers at central station to busses. At the location of Nieuw-Zuid this consists primarily of travelers boarding and transferring. It can be seen that overall at the hub Nieuw-Zuid location this entails a growth of 1.5 times as much people boarding at the hub in 2030, and a 2 times growth in 2040. As a reference, the earlier performed study[32] estimated a growth of about 2.5 times compared to 2020 (without using model results), but that also includes the growth due to frequency changes after introduction of the hub.

Table 3.5: Projected growth of travellers boarding, disembarking and transferring on the location of Central Station and Hub Nieuw-Zuid in the year 2030 and 2040 compared to 2020.

Location	Trip activity	Reference trips 2020	Delta trips 2030	Delta trips 2040
Central Station by train	Boarding	5.350	360	800
	Disembarking	3.620	250	510
	Transfer	2.160	40	250
Central Station by bus	Boarding	50	20	30
	Disembarking	80	-	-
	Transfer	1.060	40	150

[32] OV-knooppunten van de toekomst, een integraal handelingsperspectief (2020). Goudappel Coffeng b.v.

Hub Niew Zuid by bus	Boarding	120	60	110
	Disembarking	50	-	-
	Transfer	350	50	90

3.3.2 Results of hub design scenarios

This section describes the impact of two spatially different hub configurations in the year 2030 compared to a reference scenario, without a hub, within the same year. As presented in Table 3.6 no significant modal split differences in terms of number of trips can be determined when comparing both hub designs (Hub North and Hub Tunnel) with the reference scenario. This implies that, within the model, the creation of a hub has marginal impact on mode choice. Moreover, no differences can be determined between both spatial designs of the hub, which is in line with the expectations because on a city- or regional scale, the minor differences between the two spatial configurations are not expected to have any difference in modal split.

Table 3.6: Impact of hub design to mode choice of departing trips.

District	Mode	Reference trips 2030	Hub North delta trips [%]	Hub Tunnel delta trips [%]
Entire VMA	Car	526.700	-	-
	PT	269.300	0,1%	0,1%
	Bike	321.300	-0,1%	-0,1%
Haarlem	Car	22.300	-	-
	PT	10.800	-	-
	Bike	24.200	-	-
Centrum	Car	2.000	-	-
	PT	1.100	-	-
	Bike	2.500	-	-
Noord	Car	7.100	-	-
	PT	3.700	0,2%	0,2%
	Bike	8.000	-0,1%	-0,1%
Oost	Car	3.500	-	-
	PT	1.700	0,4%	0,4%
	Bike	3.400	-0,2%	-0,2%
Schalkwijk	Car	4.700	-	-
	PT	2.100	-0,1%	-0,1%
	Bike	5.100	0,1%	0,1%
Zuidwest	Car	5.000	-	-
	PT	2.200	-0,5%	-0,5%
	Bike	5.200	0,2%	0,2%

In contrast to the mode choice, route choice within the model shows to be impacted by creation of the hub. Most notably within regards to the number of travelers from and to central station and the hub location. As depicted in Table 3.7 the number of travelers boarding, disembarking or transferring at the Central Station of Haarlem is reduced due the creation of a hub at New Zuid. Especially the number of travelers boarding a train or transferring to a bus is impacted when the hub is realized.

Interestingly, the number of people boarding and disembarking at the hub location of New Zuid is relatively unaffected, in contrast to the number of travelers transferring at the hub location which largely increases due to the hub. Please note that the increase of inhabitants around the hub is already included in the reference scenario.

The effect shown is mainly caused by changes in route- and line choice, and not in additional public transport travellers (as already shown in Table 3.6). Similarly to the impact to mode choice, no differences can be determined between both spatial designs of the hub with regards to the impact on public transport route choice. Figure 3.7 displays the public transport intensities of Hub North in 2030, compared to the base projection of 2030 (without a hub).

Table 3.7: Impact of hub design to trip activity of public transport travellers

Location	Trip activity	Reference trips 2030	Hub North delta trips	Hub Tunnel delta trips
Central Station by train	Boarding	6.550	-320	-320
	Disembarking	4.480	-120	-120
	Transfer	2.350	-110	-110
Central Station by bus	Boarding	80	-10	-10
	Disembarking	110	-30	-30
	Transfer	1.920	-670	-670
Hub Niew Zuid by bus	Boarding	190	10	10
	Disembarking	70	-	-
	Transfer	470	900	900

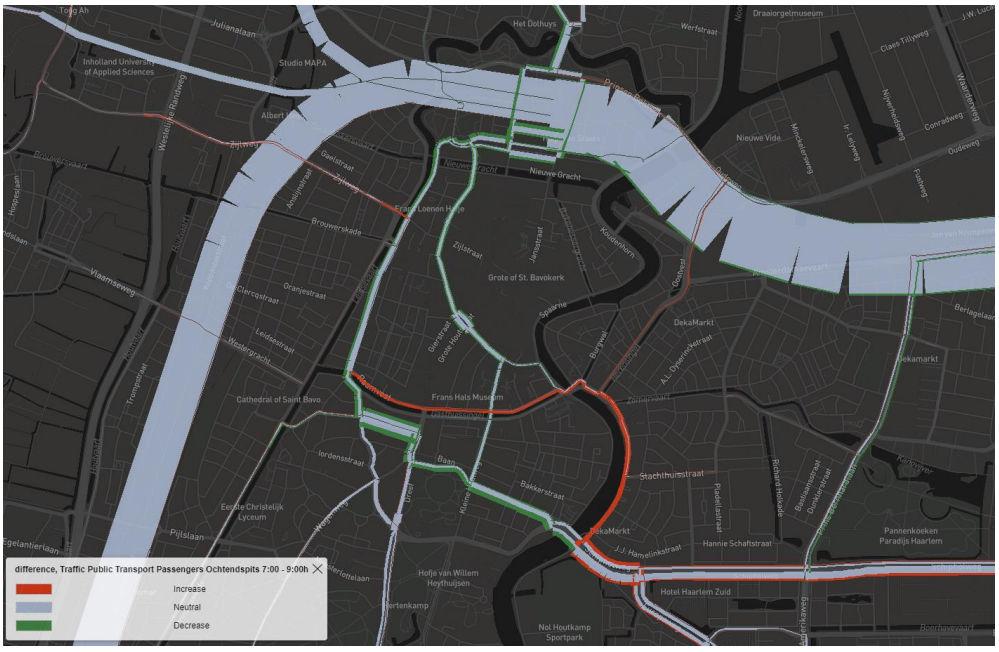


Figure 3.7: Difference plot of public transport intensities for Hub North in the year 2030 compared to the base year 2030 (without hub), impact of hub Tunnel on public transport intensities is equal.

As depicted in Figure 3.8, a slight deviation in car traffic intensities can be observed on the roads surrounding the hub location. This might indicate the emergence of potentially undesired cut-through traffic. However, travel times do not significantly increase and therefore this will not have any effect on mode choice.

It can be concluded that the introduction of the hub mainly influences the public transport line choice of people (e.g., transferring at the hub instead of the central

station), whereas only a small amount of people will switch to public transport. The two different spatial configurations have very limited effect on the number of travelers within the model runs. However, it does have effect on other aspects such as safety and spatial embedding as explained in Chapter 2.

Figure 3.8: Difference plot of traffic intensities between Hub North (left) and Hub Tunnel (right) compared to the reference 2030 scenario, based on the infrastructure configurations as presented in Figure 3.1 and Figure 3.3. Red indicates an increase in the number of cars, green a decrease. For example, more people use the Slachthuisstraat, a possibly undesired effect.

3.3.3 Impact assessment of additional policy measures alongside a mobility hub

The scenarios as presented in this section explore the impact of additional policy measures such as the increase of public transport frequency and the discouragement of car use in addition to the realization of Hub North to both mode and route choice as described in Chapter 3.2.3.

The impact of the additional policy measures on mode choice (i.e. modal split), are presented in Table 3.8. From this results it can be observed that merely increasing the frequency of public transport does not affect car shares but results in a modal shift between public transport and bike. The direction of this modal shift differs between districts in Haarlem. For example, none of the departing trips in the city center (Centrum) is affected in this scenario while in Schalkwijk a clear shift from bike (-0,1% to -0,2%) to public transport (+0,5%) can be observed in both departing and arriving trips. The district of Oost on the other hand shows a similar modal shift as Schalkwijk in terms of arriving trips (-0,2% bike and +0,5% public transport) while the departing trips shows the opposite (+0,3% bike and -0,5% public transport). Of course, this is mainly influenced by the position of the hub with respect to both districts: the hub is located between Oost and Schalkwijk.

When merely discouraging car use by means of speed reductions and parking tariff increase and a decrease of parking capacity at the new living areas around the hub, a modal shift can be observed from cars towards predominantly public transport and to some degree also bike. The magnitude of this effect differs between districts, most likely due to deviations in the level of service for public transport and predominantly affect arriving trips. For example, in this scenario the modal shift from arriving trips by car towards public transport is most notable in the districts of Centrum (-3,0% car to +2,6% PT), Zuidwest (-2,9% car to +1,5% PT) and Oost (-2,5% car to 4,9% PT).

When in combination to discouraging car use also the public transport frequency is increased, the general modal shift as observed in the prior scenario is relatively similar; a shift from car towards public transport and bike. Interestingly, by adding the increased public transport frequencies in the combined scenario almost all districts

show an increase in the trips by public transport while the increase of trips by bike is in some cases reduced. For example, when combining the discouragement of car use to the combination scenario, arriving trips by car in the district Centrum trips slightly increase (from -3,0% to -2,9%), arriving trips by public transport further increases (from +2,6% to +3,5%) but arriving trips by bikes slightly decreases (from +1,1% to +0,8%). This implies that in some cases the impact of the discouraging car use measures is slightly reduced when also increasing the public transport frequency.

Table 3.8: Trips from and to districts per scenario

District and mode			Reference	Increase PT frequency	Discourage car use	Combination
Haarlem	Car	Departing	22.314	-	-0,6%	-0,6%
		Arriving	20.281	-	-2,1%	-2,1%
	PT	Departing	10.602	-	0,3%	0,3%
		Arriving	8.344	0,4%	2,1%	2,6%
	Bike	Departing	24.321	-	0,4%	0,4%
		Arriving	27.403	-0,1%	0,9%	0,7%
Centrum	Car	Departing	1.976	-	-0,1%	-0,1%
		Arriving	2.507	-	-3,0%	-2,9%
	PT	Departing	1.143	-	-	-
		Arriving	1.277	0,8%	2,6%	3,5%
	Bike	Departing	2.463	-	0,1%	0,1%
		Arriving	3.653	-0,3%	1,1%	0,8%
Noord	Car	Departing	7.134	-	-0,7%	-0,7%
		Arriving	4.666	-	-1,9%	-2,0%
	PT	Departing	3.629	0,3%	0,3%	0,6%
		Arriving	1.998	0,7%	1,7%	2,5%
	Bike	Departing	8.030	-0,1%	0,5%	0,3%
		Arriving	7.415	-0,2%	0,8%	0,6%
Oost	Car	Departing	3.496	-	-1,4%	-1,4%
		Arriving	4.816	-	-2,5%	-2,5%
	PT	Departing	1.665	-0,5%	0,6%	0,2%
		Arriving	1.081	0,5%	4,9%	5,7%
	Bike	Departing	3.400	0,3%	1,1%	1,3%
		Arriving	3.406	-0,2%	1,6%	1,3%
Schalkwijk	Car	Departing	4.713	-	-0,3%	-0,3%
		Arriving	4.103	-	-0,5%	-0,5%
	PT	Departing	2.005	0,5%	0,2%	0,7%
		Arriving	1.149	0,5%	0,8%	1,3%
	Bike	Departing	5.166	-0,2%	0,2%	-
		Arriving	4.734	-0,1%	0,2%	0,1%
Zuidwest	Car	Departing	4.994	-	-0,5%	-0,5%
		Arriving	4.189	-	-2,9%	-2,9%
	PT	Departing	2.160	-0,5%	0,2%	-0,3%
		Arriving	2.840	-	1,5%	1,5%
	Bike	Departing	5.261	0,2%	0,4%	0,6%
		Arriving	8.196	-	1,0%	1,0%

It can be concluded that the introduction of policy measures on discouraging car usage or improving the public transport system lead to a significant shift to more public transport usage and less car usage. When only the car is discouraged, this

leads to both an increase in public transport and bike usage. However, if this is combined by increasing public transport frequencies, more people switch to public transport from car transportation (instead of switching partly to bike trips). Moreover, discouraging cars has a greater impact on public transport usage than only improving the public transport system. A combination of both policy measures is best advised for establishing a higher share of public transport.

Table 3.9: Impact of additional policy measures to trip activity of public transport travellers

Location	Trip activity	Reference	Increase PT frequency delta trips	Discourage car usage delta trips	Combi-nation delta
Central Station by train	Boarding	6.450	-320	-320	-380
	Disembarking	4.480	-120	-120	-230
	Transfer	2.350	-110	-110	-140
Central Station by bus	Boarding	80	-10	-10	0
	Disembarking	110	-30	-30	-40
	Transfer	1.920	-670	-670	-780
Hub Nieuw Zuid by bus	Boarding	190	10	10	10
	Disembarking	70	-	-	-10
	Transfer	470	900	900	1190

Apart from the modal split, also the route choice for car trips is significantly impacted in Haarlem when simulating the discouraging car measures as shown in Figure 3.9. The main reason for these differences in route choice by car are most likely the speed reduction to 50 and 30 km/h as displayed in Figure 3.4 (chapter 3.3.3).

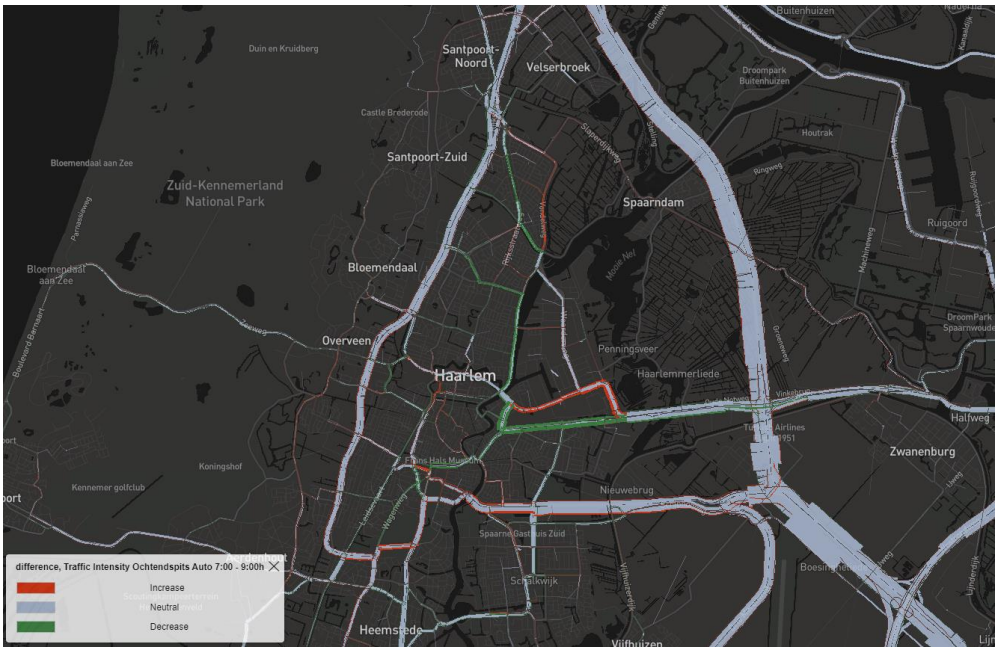


Figure 3.9: Difference plot of car intensities for Hub North with additional discouraging car measures in the year 2030 compared to the base year of 2030 Hub North.

3.3.4 *Shared bike usage*

In the performed simulation runs it was only possible to access or egress the hub location by two means of transport: walk and cycling. However, it is expected that the usage of shared bike will also have a prominent role in the future mobility system. Although the model does not predict the amount of shared bike usage, this section does give an estimate on the potential shared bike users.

The potential number of shared bikes being used at the hub depends on the shared system: station-based (e.g. OV-Fiets) or free-floating (e.g. like the Felyx scooters). Additionally, the policy in the remainder of the city influences the shared bike usage: is it encouraged or discouraged? For example, do you want to encourage using a (shared) bike to travel toward the city center, or is it perfectly fine if people use the bus? Due to the relation of policy choices, it is difficult to estimate the number of shared bikes utilized at the hub Nieuw-Zuid.

However, it is possible to distinguish the travelers that have a high potential of using a shared bike, given their origin and destination. To be specific, this concerns travelers having a destination within 3 km distance of the hub, who choose to transfer at Haarlem Nieuw-Zuid to another bus to reach their destination. For the 2030 hub scenario, there are +/- 380 travelers that show this travel pattern. Including additional policy measures discouraging car usage and improving the public transport system, this adds up to +/- 500 potential shared bike users at maximum.

Of course, not everyone would shift to a shared bike but will keep using a bus connection instead. As a reference, we can investigate the currently used number of OV-fietsen used at the central train station, and compare this to the amount of travelers at the Haarlem Nieuw-Zuid hub. Currently, 335 OV-fietsen are located[33] at the central train station. According to the model runs of 2030, approximately twice as much travelers (compared to hub Haarlem Nieuw-Zuid) transfer at the central train station to a bus connection having a destination nearby. If an equal portion of people is willing to use a shared OV-fiets as on the central train station, this would mean that approximately half of the amount of OV-fietsen as located on the train station would be a possible indication for the hub, i.e. 170 shared bikes. However, this does not consider any policy changes (e.g. promotion of shared bike usage) or any other policies regarding shared vehicles within the city center of Haarlem.

3.3.5 *Bike capacity*

The municipality of Haarlem is interested in how many bike parking locations are possibly needed at the hub Haarlem Nieuw-Zuid. The model results show that by 2030 (with a hub), at least 400 people would like to access the hub using their bicycle during the morning peak. However, the model has been calibrated on the current situation of bike parking availability and attractiveness around the hub Haarlem Nieuw-Zuid. In this current situation, too little bike parking capacity is available as can be seen in Figure 3.10. At a typical working day, 313 bikes were counted, whereas only bike parking racks for 232 bikes are located at the area[34]. This indicates that currently too less bike parking capacity is available, making it unattractive to travel by bike toward the bus station, in both current situation as well as in the calibrated model.

[33] Retrieved from https://ovfietsbeschikbaar.nl/locatie/hlm002 at 28-09-2022.
[34] OV-knooppunten van de toekomst, een integraal handelingsperspectief (2020). Goudappel Coffeng b.v.

Figure 3.10: Current bike parking situation around the busstation to be replaced by the hub Haarlem Nieuw-Zuid[34]

In the model results it can be observed that a large number of people transferring at the hub in the morning peak period are coming from the near surrounding of the hub but travel by bus. These travelers have a high potential to cycle toward the hub if the bike parking infrastructure is improved. Around 550 travelers within the model depart from a zone within cycling distance of the Hub but arrive there by bus. Potentially (some of) these travelers can be nudged to arrive by bicycle if the supporting services (e.g. infrastructure and bike parking) allow for this. Around 380 travelers continues to travel by bus from the hub towards a destination within Haarlem. These travelers could be considered potential shared-bike-users. When accounting for these two groups of cyclists this would lead to a need for +/- 1000 bike parking spots in 2030.

For 2040, a projected growth of twice as much travelers compared to 2020 is estimated (see Section 3.3.1). This would imply about 1500 to 2000 required bike parking spots at the hub.

It should be noted that the exact number of parked bikes is highly influenced by the adoption of the shared bike system (see Section 0), as well as the shared usage of the bike parking for facilities and living areas nearby. Additionally, the model does not make any distinction between a scooter and a bike. It might be expected that a portion of the bike parking is thereby needed for scooters or other odd-sized bikes.

3.4 Conclusions

The quantitative analysis on the usage of the hub using a transport model has been performed using the Urban Strategy models and the Verkeersmodel Amsterdam as a basis. First of all, it can be concluded that the number of travelers using the bus station at the location of Haarlem Nieuw-Zuid will grow to 1.5 times as much by 2030, and 2 times as much by 2040 – compared to the reference situation in 2020.

The introduction of the hub Haarlem Nieuw-Zuid and corresponding bus lines does not have much influence on the modal split in the city of Haarlem – only a 0,1% increase in modal split of public transport users can be seen. Likewise, the two different spatial configurations (Noord and Tunnel) does not have any significant impact on the number of users or the modal split within the city of Haarlem. On the other hand, the introduction of the hub Haarlem Nieuw-Zuid does have a large effect on the public transport route and line choice: three times as many people will transfer to another bus at the hub compared to the bus station in the same situation without a hub. These travelers mainly previously transferred to the bus at the central train station. Hence, less bus travel in the vicinity of the central train station opens up space and opportunity for redevelopment in the central station area and reduces the amount of busses driving through the city center of Haarlem.

Additional policy measures can help encourage people to use their car less in favor of using public transport and bike. In the additional scenarios it has been computed what the effect is of improving the public transport system (by increasing frequencies), the effect of discouraging car usage by increasing parking tariffs in Haarlem, and the combined effect. Each of the scenarios has a positive effect on the usage of public transport and especially the hub. The number of transfers at the hub increase significantly if more people switch to public transport. Discouraging car usage has a larger effect than increasing of public transport frequencies. However, combined they provide an even larger effect.

The usage of shared bikes and bike parking capacity is highly influenced by the municipality’s goals and ambitions regarding the bike travel mode. If the goal is to reduce bus traffic through the city center and use the hub more as an ‘public transport-endpoint’ where your journey is continued by (shared) bike, potentially large numbers of cyclists would be willing to use this option. However, if bike parking or shared bike offering is limited, it is expected that more people will use the (city) bus as access or egress mode toward the hub.

In an extended model study it would be interesting to also investigate a network of hubs at different geographical scales (e.g., multiple hubs interacting and competing with each other), as well as a more detailed study on the usage of shared mobility systems – both at the hub and within the entire city. This would give a better insight in the role of the hub within the entire mobility system where new (shared) modes and additional policies are being introduced.

4 Futureproof and integral hub design and implementation

This chapter focuses on the spatial and societal embedding of hubs to make the hub Haarlem Nieuw-Zuid futureproof and to also include an integral perspective in designing and implementing the hub beyond 'just' a bus stop. Based on the insights from the hub trends and developments analysis, as well as the quantitative analysis using Urban Strategy, several design dilemmas are highlighted and advice on how to design futureproof and integral hubs is given.

4.1 Integral and futureproof hub design

Observations and insights based on the analysis on the hub and advice for broadening the scope of the hub Haarlem Nieuw-Zuid are summarized in Figure 4.1. The chapter will explain the elements represented in the figure. First the chapter will go into the integration of goals beyond 'just mobility' in hub design by broadening the scope (paragraph 4.1.1 and 4.1.3). It will also highlight the need to address futureproofing in hub design; including foresight and flexibility to address current and future needs (4.1.2 and 4.1.3.). Next the chapter will go into the local integration of the hub, considering 'place' as well as 'path', and connecting the hub the area developments (paragraph 4.2). Finally the chapter will discuss regional integration and designing the hub from a network perspective and discuss supporting conditions (e.g. governance, flanking policies) that need to be in place to create the desired impact on strategic goals and ambitions (paragraph 4.3). The insights presented in this chapter are both specific to Haarlem Nieuw-Zuid, but are also relevant for other hub developments (elsewhere or at different scale) to create attractive, futureproof and integral designed hubs.

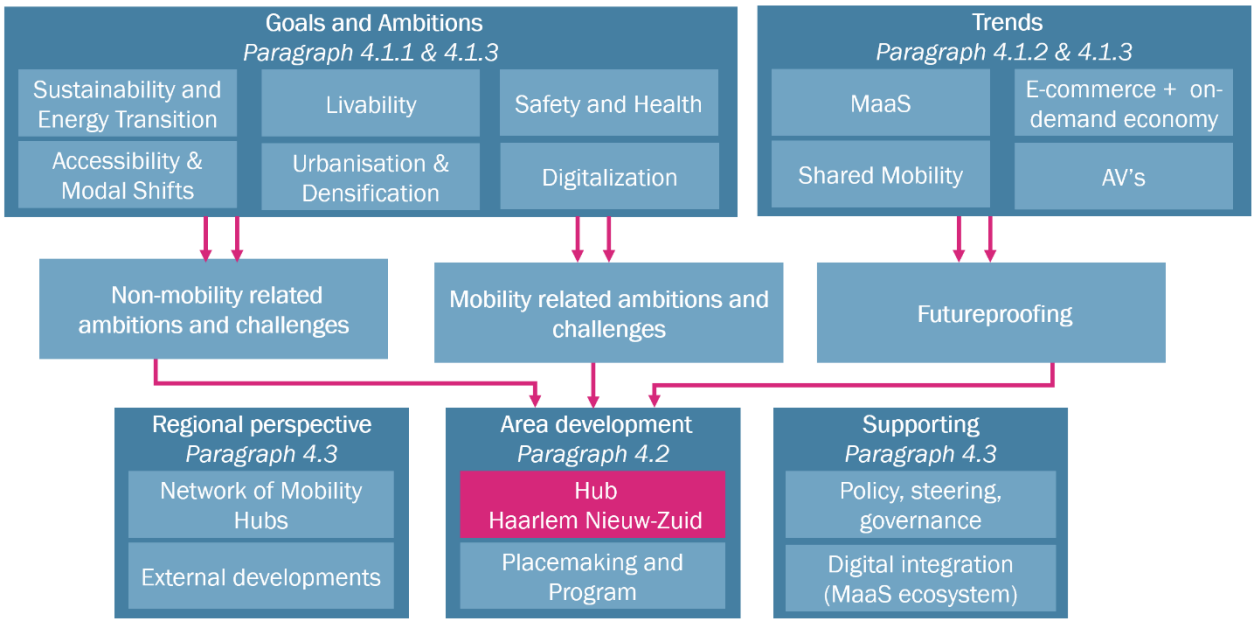


Figure 4.1: Framework towards integral and futureproof hub design based on observation and analysis of Haarlem Nieuw-Zuid

4.1.1 *Integrating strategic level goals and ambitions in hub design*

With even the best intentions and careful planning, a gap can often exists between strategic level thinking and operational level decisions and projects. Decision-making on a strategic level occurs in a highly complex context that is influenced by several aspects; 1) a scope for decision making based on policy goals and ambitions (e.g. 15-minute cities, Zero Emission), 2) trends and transitions that will impact the city and/or region (e.g. energy transition, population growth, e-commerce), and 3) shocks and unexpected impacts that are highly uncertain (e.g. COVID-19, disrupting innovations). Within this context, decisions and policies are made, goals are set and translated to the operational level. At the operational level these sometimes 'vague' ambitions such as a livable, healthy and sustainable cities, are operationalized to specific measures and projects in practice – for example a hub. The risk is that when translating these strategic level goals to a project or a measure in practice, the connection to the strategic goals, e.g. via which mechanisms the projects can have an impact on the goals is lost. This is called the tactical gap and is illustrated in Figure 4.2.

Bridging this tactical gap for hubs requires, amongst others, monitoring and evaluation on a broader set of KPI's to determine and steer on impact on the intended policy goals, design principles that address different domains and allow for a wider problem definition, access to relevant data and information, flexibility and adaptiveness when it comes to measures, methodologies and ways of working, and (political) willingness to execute.

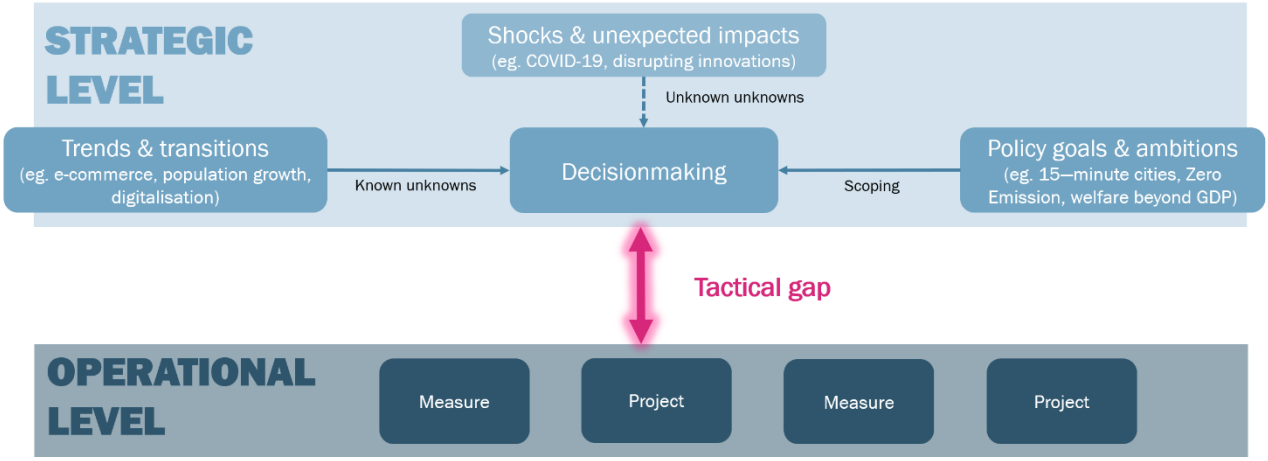


Figure 4.2: The tactical gap between strategy and operation

The hub Haarlem Nieuw-Zuid is an operationalization of several goals and ambitions of the City of Haarlem and Province North-Holland – most specifically addressing accessibility and modal shifts. An elaborate description of the goals and ambitions relevant for hub developments can be found in paragraph 2.2.1. For both the Province as the Municipality, hubs are a promising solution (however not a magic solution that fixes all) to challenges or instrument to achieve goals related to sustainability and the energy transition, increase livability (also by allowing smart and flexible use of space and enabling more space for walking cycling and higher quality of space), safety, health (less emissions, more green, facilitating active modes), accessibility and modal shifts, urbanization and densifications (role in area (re)developments and space efficiency), and digitalization. These goals cover both mobility and non-mobility related challenges and ambitions. However, when operationalizing strategic

ambitions and goals, in practice the scope often becomes narrower and focusses on specific mobility related goals and ambitions instead of the goals on strategic level – the tactical gap. However challenging, **for integral** and successful hub design that leverages all potential project benefits, it is important to occasionally revisit this wider array of goals and find ways to integrate them into the design process.

4.1.2 Futureproofing hub design

The hub Haarlem Nieuw-Zuid is created not just to solve mobility and non-mobility related issues of today, but ideally also addresses the issues of tomorrow and many years to come. In designing the hub the scope is mostly focused at facilitating a growth in travelers for the years to come and in doing that hopefully also enable a mode shift that Haarlem strives towards in its mobility policy. However, trends and developments such as shared and autonomous modes are not specifically included and/or prioritized in the scope of the hub.

Figure 4.3: Scooter parking zone (Rotterdam central station)

For hubs, important trends to include are MaaS (Mobility-as-a-Service), E-commerce and the on-demand economy, shared mobility (bikes, kick-scooters, sit-scooters, cars, etc.) and autonomous vehicles (AV's). These trends in the mobility domain are based on filling the gaps in the transportation system of today and should help in fulfilling mobility demands without the need of owning a car and facilitating a shift to more sustainable modes. MaaS is a platform where (ideally) people can find, book and pay for their trips, using new and old mobility services such as public transportation, microtransit, ride hailing, ride-share, and shared modes. The MaaS platform enables a unified, simple and seamless experience for the user by integrating different modes and the required digital infrastructures. Whereas MaaS mostly focuses on digital integration of mobility, it can have a determinative role in

shaping design and use of the mobility system (in terms of what modes are available, used and favored). This way, MaaS also has consequences for spatial use. Including these trends – or at least anticipate the possibility of future integration – in the hub design allows for futureproof design and avoids blind spots. It is advised to assess potential futures and trends and then consider, based on policy ambitions and goals, what trends are desirable to facilitate, to steer, influence or explicitly exclude. This way, decision making about these trends is a conscious effort and it reduces the risk of being surprised by new modes, concepts, or trends when they arise.

4.1.3 Design dilemmas and choices for integral and futureproof hub design

4.1.3.1 Integral hub design – priorities and trade-offs

As was mentioned in chapter 2.2.1 and 2.2.3, there is a wide array of goals and ambitions for Haarlem and the Province in general as well as for the hub Haarlem Nieuw-Zuid. Some of them are mobility specific, some are “mobility-adjacent” (not directly on the topic of mobility however mobility plays a role in achieving the goal or achieving this goal is affecting mobility as well) and some are non-mobility ambitions and goals. This integral perspective needs to be taken into account when designing the hub, determining program and implementing the hub. This also means addressing certain design dilemmas and choices.

The city of Haarlem and the Province of North-Holland stress the importance of prioritizing active modes. The STOMP principle[35] (Stappen, Trappen, OV, MaaS, Privéauto) for the prioritization of modes is increasingly used and can serve as a design principle. However, prioritizing one mode versus the other can have consequences. For example; prioritizing active modes versus public transport might also be a trade-off between health and efficiency. Also; when creating a strategy where shared modes play a large(r) part of fulfilling local and regional mobility needs it might also mean that the public transportation system will need to be reconsidered and/or redesigned. Additionally; income from public transport trips versus shared mode trips versus private-owned bike trips is in different places ((semi-)public versus private versus no income). And finally; there are spatial implications following from the strategic design choices of the mobility system and the hub. For example; how much space do you allow for shared versus private micro mobility? And how much space should be spent on creating parking facilities for micro mobility versus placemaking? These dilemma’s on integration all trickle down to questions on how to prioritize and operationalize strategic goals. What are preferences? And how do these preferences dictate policies and generate income?

4.1.3.2 Futureproof hub design – foresight and flexibility

When addressing futureproof hubs design both foresight and flexibility are needed. Foresight is about including trends and developments into the design of the hub – even though the impact of these trends is not fully clear yet (known unknowns). Additionally, there should also be some flexibility or adaptivity in the hub design that allows the hub to change and adapt to future needs and contexts. Examples are parking space that is initially used for normal bikes but can in the future also be used for other shared modes. Another example is the type of amenities offered at the hub – user needs can change over time (e.g. shift from more practical needs to luxury

[35] https://www.crow.nl/downloads/pdf/mobiliteit/toepassen-stomp.aspx

shopping). This flexibility is especially important when addressing 'unknown-unknowns' such as disruptive innovations – the things that could not be anticipated (fully) beforehand.

For the hub Haarlem Nieuw-Zuid, considering what new mobility is currently out there, and what is ideally out there when the hub is operational should be considered. This both considers an analysis of the actual 'wheels on the ground', as well as policy documents, ambitions and visions on future modal splits. This includes both the micro mobility options ((e-)bikes, cargo bikes, (e)-mopeds (scooters), (e)-scooters (stepjes – not legal (yet) in the Netherlands, however when the hub becomes operational the context in the Netherlands might have changed) and shared cars, but also mobility services such as MaaS-solutions. Not just shared mobility options should be considered, also trends in private micro mobility options are of importance. For instance; electric bike's that might require charging facilities, and cargo bikes (both for logistic purposes or people mobility) that are expected to keep growing[36] and potentially partially replacing cars[37].

Considering the role and use of each of these modes, both private and shared modes, is important when designing the hub. It is recommended to include shared mobility from the start of the design process. Shared mobility has the opportunity to offer travelers additional options and if implemented well, can reduce the total spatial footprint and environmental impact of mobility. When taking shared mobility into account, governments can choose how active they want to promote the use of more sustainable modes than car-travel using policy measures to stimulate the preferred modes and/or policies to discourage less sustainable modes. An example of a government that is actively stimulating and facilitating shared modes is the city of Utrecht. In the Merwedekanaalzone Utrecht chooses for a very low parking norm and facilitating shared mobility[38] in their new development. This leads to design choices on what do you want to accommodate and facilitate or even stimulate? For instance; shared modes could reduce the total footprint of parking facilities by reducing the amount of parking facilities for private modes and instead solve mobility needs using walking, public transport and shared modes.

[36] https://www.tweewieler.nl/42462/verkoop-cargobikes-in-europa-53-groei-verwacht
[37] https://mtsprout.nl/groei/startup-van-de-week/deelbakfiets-baqme-maakt-auto-overbodig
[38] https://issuu.com/goudappelgroep/docs/mobiliteitsvisie_merwedekanaalzone

Figure 4.4: Kiss & Ride zone (Rotterdam central station)

A more specific design dilemma that the hub Haarlem Nieuw-Zuid faces, with regards to futureproofing is about whether or not to facilitate taxi's and/or a kiss & ride (K&R) zone at the hub – and when choosing to accommodate this, how much space to allocate. Important design choices and dilemmas to consider are; function of taxis and Kiss & Ride, phasing (need and use now versus later), fixed or flexible use, and safety.

- First of all; the function of taxis and K&R. When designing the hub and assessing supporting mobility services and space-allocations, one should consider whether or not facilitating taxis and K&R is desirable and how it ideally is used/what role it fulfills. Since the goal of the hub and Haarlem and the Provinces policy ambitions is to increase accessibility for the region as well as mode shifts (from car to active modes and public transport). This doesn't necessarily includes taxis and K&R (private car trips). However, these trips might be first- and last-mile trips to and from the hub – and thereby contributing to the goals of accessibility and mode shifts and increasing the attractiveness of the hub. It requires further analysis whether or not facilitating taxis and a K&R will have this desired effect, or what boundary conditions should be in place to achieve this effect.
- Second; when spatially implementing a zone for taxis and K&R, it is important to consider the need for this space over a longer period of time. When needs change, either the need increases or decreases, phasing the development of this zone could offer some flexibility and could avoid over-dimensioning the space allocated for the zone. For instance; when needs are expected to grow, start with a smaller K&R and/or taxi-zone and include some greenery that could later be transformed to a larger zone.
- Third; choose fixed or flexible use of space. Fixed taxi-stands take up space that cannot be used for different purposes. This forces the less official taxis – the uber-like services – to find other spots around the hub. Flexible use zones might be spatially more efficient since it can combine different types of pick-up and drop-off activities. Since the hub Haarlem Nieuw-Zuid is mainly a bus hub, a point of attention is that official taxis *can* drive on bus-

lanes, whereas others *can't*. This might influence choosing a location for a mixed-use zone.
- Finally; safety. Not facilitating a taxi-zone or K&R, does not necessarily mean that there will be no pick-up and drop-off traffic. This might mean that the surrounding streets will be used to serve this end, with some possible consequences on safety, and traffic in surrounding streets.

4.2 Local integration of the hub

One topic of discussion when developing hubs is focusing on path versus place. Path refers to the role of the hub as a facility that assists with the optimization of routes, modal shifts, and multimodal trips. In this role, the hubs primary purpose is to connect as many people as easily, quick and as seamlessly as possible from point A to point B. However, the hub is also a location, a place, designed not to come and go as quickly as possible but to actually stay there. When designing a hub as a place, other aspects than passenger volume, frequency and efficiency become important. For instance, placemaking, greenery, spatial quality and supporting services and facilities are critical to address.

An observation to be made is that the hub Haarlem Nieuw-Zuid is currently mostly designed from the perspective of facilitating the bus stop, facilitating a growth in travelers and making this an attractive node to travel to, from and through (therefore also paying attention to public space and facilities). This should also stimulate the mode shift that Haarlem aspires in its mobility policy. These ambitions mostly relate to the function of the hub in a regional public transportation system – the hub as a 'Path'. However, there are opportunities for the hub to address local needs as a 'Place', not only a 'Path'. This has to do with two main things: 1) developing the hub as a path *and* place and focus on the experience of travelers and users of the hub, and 2) the connection of the hub to its local surroundings and future developments.

4.2.1 Design the hub from the perspective of 'place' and not just 'path'

When developing the hub as a place instead of a path, different criteria become of higher importance. In the Netherlands each year the perceived attractiveness and user-experience of their stations is monitored with the so-called 'stationsbelevingsmonitor' (SBM). In the most recent study (2021), Rotterdam Centraal was the most highly appreciated larger station in the Netherlands (scoring an 8.0). The lowest scoring station, coincidentally, also was in Rotterdam – Rotterdam Zuid (scoring a 5,8)[39]. Comparing these two stations, leaving the location itself aside, it stands out that there are barely any 'place-related' facilities available at Rotterdam Zuid[40]. This station is mostly developed from a 'path' perspective. Another issue with this station is the fact that social security is insufficient, making it an unattractive place to stay. Rotterdam Central station was officially re-opened with their new design in 2014. In this design there was specific attention to this component of social security, and local integration[41]. Additionally, the station houses a wide variety of services and facilities that are both path- and place-related[42], ranging from

[39] https://www.prorail.nl/siteassets/homepage/series/lijstjes/stationsbelevingsmonitor-2021.pdf
[40] https://www.ns.nl/stationsinformatie/rtz/rotterdam-zuid
[41] https://www.architectuur.nl/nieuws/gedaanteverandering-rotterdam-centraal-station/#:~:text=Op%2013%20maart%20wordt%20het,Schooten%20Architecten%20en%20West%208.
[42] https://www.ns.nl/stationsinformatie/rtd/rotterdam-centraal

comfortable waiting areas, dry-cleaning services, to shops and food-to-go concepts. This way, the station is not only used by travelers who use it as a transport hub, but also for people living nearby (e.g. as parcel pick-up spot, a drugstore or a spot to meet for a cup of coffee).

Figure 4.5: Newly designed Rotterdam Central station with attention to social security and local integration

For Haarlem Nieuw-Zuid, it stresses the importance of designing the hub not just for efficiency, but also from the perspective of quality of stay, having a place to linger around, have safe pedestrian routes, plazas or add programming to increase the attractiveness and improve the experience of users of the hub (whether they are travelers or not). For the case of Haarlem Nieuw-Zuid, social security is also a point of attention that should be taken into account when designing the hub. In the current state of the location, social safety is lacking (bus stops are too busy and narrow, no facilities, low quality of space, incidents with verbal aggression and harassment towards personnel and travelers)[43]. The social safety should be taken into account using a 24-hour timeframe in mind. It is not only when the hub is in use as a transportation hub (when the busses are operational), but also when shops close, and there is no bus-service. Measures that could be considered are clear sight lines (no dark or shielded corners), eyes on the street, having shops and services in the plinth of the buildings surrounding the hub, and offer sufficient lighting.

[43] Rapport 006379.20200619.R1.04: Knooppunt Haarlem Nieuw-Zuid – verkenning mogelijke locaties. 29 September 2020 – Goudappel Coffeng & Urhahn

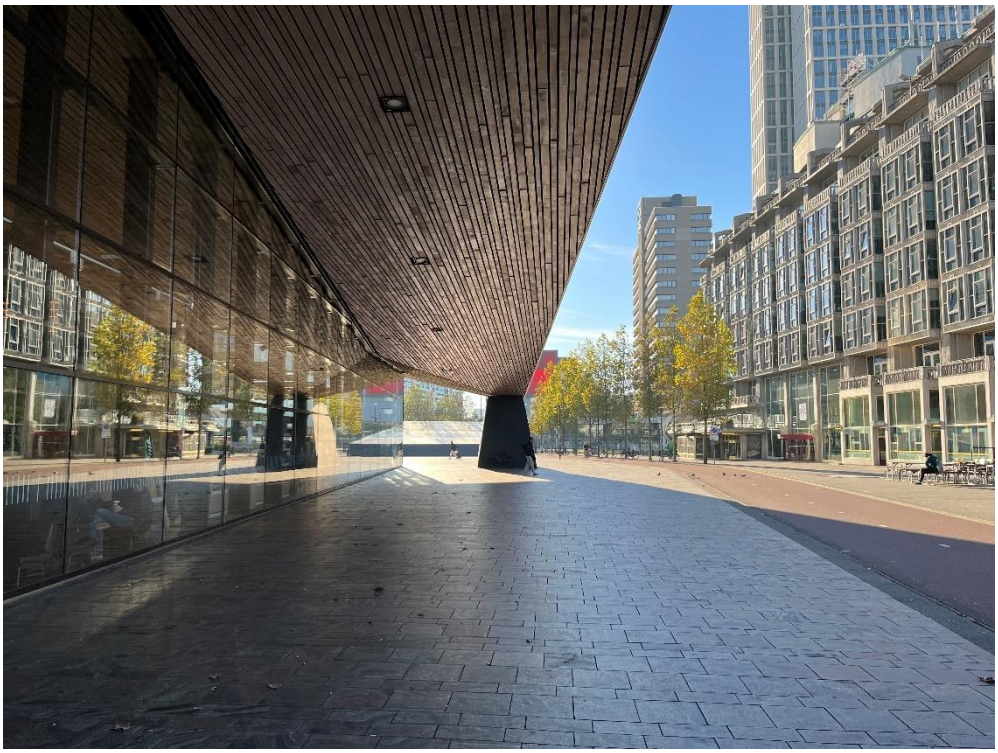


Figure 4.6: Clear sight lines (Rotterdam central station)

4.2.2 *Connecting the hub to local surroundings and future developments*

Choices made about the mobility (eco)system will influence its use of public space and the other way around. Therefore, thinking about the way mobility policy and trends are shaping or influencing public space, and thinking about the way the design of public space influences mobility behavior is important. This way, the hub Haarlem Nieuw-Zuid can be more than 'just a mobility hub', but could also solve local challenges by not just designing the hub for regional accessibility but also local mobility needs. For example, the hub can also facilitate the (residential) developments (a.o. Elan Wonen, Spaarne 1 VOF, Being Development, New Cheese Development) in the area. The hub could for instance include parking (both cars and other modes, offer shared mobility services for new residents) and support the mobility needs of these new residents, visitors and commuters on the hub, instead of having to include these on the street. This might mean that the elements and functions (both mobility related and non-mobility related – see paragraph 2.1.3) of the hub should be reconsidered to fit not just the bus traveler's needs, but also other (mobility) needs for (new) local residents (for example by adding other functions or changing scale of (shared) mobility offering). It is adviced to find synergies between the residential developments and hub development. For instance, if parking facilities at the hub (for bikes and potentially also other modes) are scaled to facilitate also the parking needs of the residential developments, this creates room for the residential developments to do other things with the space they would otherwise had to spend on parking facilities. This is spatially more efficient and creates a higher quality of space. This way, the hub is an important part of the area development and potentially, just like the Merwekanaalzone of Utrecht, facilitate a lower parking norm and higher quality of place (more space for greenery, less traffic, etc.) in the to-be-developed area. Besides the mobility functions for these developments, the hub can also

consider non-mobility functions that can serve both the local area as the traveler (as was mentioned in 4.2.1 with the example of Rotterdam Centraal station).

4.2.3 Design dilemmas and choices

There are some design dilemma's to consider when thinking about both place and path and local integration of the hub. First of all; design perspectives on regional accessibility will create different 'ideal' solutions and outcomes than perspectives that focus on local integration and local mobility needs. Addressing these two different perspectives might be difficult however important. Mandate and ownership for these two different perspectives are not necessarily with the same stakeholder. The Province of North-Holland's mandate and ownership mostly focuses on the regional accessibility and futureproof accessibility. North-Holland also strives to quality of space, however the and ownership mandate is mostly covered by the city. The city of Haarlem also needs to consider identity and place of this area. It is important to occasionally be aware of these two different perspectives and discuss how to bring both of them into the design.

Second, an additional challenge is the fact that when the hub no longer solely considers mobility, but also non-mobility functions and connection to local needs and developments, there are more departments and organizations that need to be involved, ideally from the start. For instance, urban planners, parking department, shared mobility and public transport policy, energy[44] and retail representatives. This makes the design process more complex however it is important to also include local mobility needs and non-mobility functions early on in the design process since they might shape the way the hub is designed significantly (and it is hard to afterwards integrate these aspects into the design – when there is less flexibility).

4.3 Regional integration and supporting conditions for the hub

4.3.1 Regional integration of the hub

Apart from the local integration of the hub it is important to consider the regional integration. This regional perspective in terms of the regional function of the bus station is explicitly mentioned in the ambition documents as shown in paragraph 2.2 – ensuring sustained, long-term accessibility for the area. It is however also important to consider the network perspective of hubs, the connection to other regional hubs, but also smaller scale hubs in the city of Haarlem and surroundings. Additionally it is important to consider external developments from a perspective of welfare beyond GDP ('brede welvaart'). This includes an analysis on who (which groups) benefit from the hub and who do not (or even are hindered). The analysis can concern target groups and how effects are distributed among them, neighborhoods around the hub, and time periods (see futureproofing) to make sure the hub is not only including this location here and this point of time now, but also potential effects and impacts elsewhere and later.

4.3.2 Supporting conditions for the hub

Additionally it is key to consider the supporting conditions to ensure the hub functions and is used in a way that it adds to the goals set by the Province of North-Holland and Haarlem and both the local and regional perspectives. As was mentioned in paragraph 2.1.3 the SmartHubs project created an integration ladder for 'Smart

[44] This was recently also stressed by the CROW: CROW Nieuws - integrale hubs cobineren mobiliteit, energie en ruimte

Mobility Hubs' with different levels of integration on physical, democratic/social and digital integration. When assessing the levels of integration on these three different categories it can be concluded that for the hub Haarlem Nieuw-Zuid to be a 'Smart Mobility Hub' there should be (more or explicit) attention to place making, digital integration with societal goals and policy and the MaaS ecosystem, and the engagement of (local) stakeholders. Some of these points should be addressed not just for the hub Haarlem Nieuw-Zuid, but require strategic choices and discussions at city-level or regional-level.

Another important supporting condition is the creation of flanking policies that ensure the desired effects and impacts of the hub to societal, local and regional goals. For instance, when trying to address these different user types, the risk exists that it is hard to please all or to include the specific needs of each of these users. Another challenge might be the required shift in behavior of travelers to travel via the hub. Users that currently also travel by bus might not need additional convincing, however, when facilitating the aspired mode shift from cars to walking, cycling, and PT this might be a challenge that requires specific attention. Additionally, current bus-travelers that might have to make an additional interchange at the hub could experience some resistance compared to the 'old' situation and require some specific attention. Measures and flanking policies that are included in the modelling are increased public transport frequencies (making public transport more attractive) and discouraging car use (operationalized in the modelling by speed reductions and increased parking costs to make the car less attractive).

It is important to note that the physical implementation of the hub will in itself not significantly affect mode shifts. The quantitative analysis (chapter 3) shows that there is only a 0,1% increase for public transport in the modal split for the city of Haarlem. The hub however does influence the amount of travelers traveling via the hub (impacting route choice and line choice) – giving room to the central train station to accommodate growth and reducing busses driving through the city center.
When using the hub as a means to achieve not just (regional) accessibility goals and facilitating the Haarlem central train station in its ambitions to grow, the need for flanking policies arise. As is shown in the results of the modeling (paragraph 3.3.3) the implementation of flanking policies and measures concerning both making public transportation more attractive and cars less attractive can have a positive impact. Interesting to note is that when addressing mode shifts, measures on reducing the attractiveness of cars have a bigger impact towards choosing public transportation and biking as modes, than measures focused on making the public transport more attractive (by increasing frequencies). A similar effect was shown in a different TNO study for the municipality of Rotterdam concerning shared cars. Reducing climate impact for transportation was the most important indicator in this study, and it showed that measures that make sustainable modes (in this case shared cars) more attractive generated less positive results than making cars less attractive[45]. It is therefore important to address both the 'push and pull' side when developing flanking policies to ensure the desired use and impact of the hub Haarlem Nieuw-Zuid.

4.3.3 Design dilemmas and choices for regional integration and supporting conditions

When considering flanking policies to support and facilitate the hub also some specific design dilemmas and choices are to be made. As was shown in the

[45] Report R11434 – Deelmobiliteit en Klimaat – TNO, juli 2022

quantitative analysis in chapter 3, when focusing on making public transportation more attractive, this does potentially not only influence the modal shift for cars, but also for bikes. Choosing whether or not it is a 'problem' or acceptable impact that more people take public transportation than the bike than before needs to be discussed and addressed accordingly.

Another topic that requires some further attention is policies and goals concerning bikes and shared modes. When considering shared micro mobility, the role they play at the hub and in the city is influenced by 1) the business model of the concepts (station-based versus free-floating)[46], and 2) the policies in the city with regards to shared micro mobility. The city (together with the province) should consider questions like; is shared micro mobility encouraged or discouraged? What are boundary conditions for desired use of these modes? Is it considered as a desirable first- and last-mile mode or is access and egress to the hub by bus preferred?

The quantitative analysis showed that for current aggress and egress to the bus stop at Haarlem Nieuw-Zuid, a lot of people that live in close proximity to Haarlem Nieuw-Zuid will take the bus when the bike would be a feasible alternative considering the proximity of the hub to their origin or destination. This can be partially explained by the lack of attractive bike facilities as well as sufficient capacity for bike parking. If bikes are a desired first- and last-mile mode, attractiveness and capacity should be considered in policy and design choices at the hub (and other parts of the city). Also, as was mentioned before, the variety in modes should also be considered when thinking about designing bike-facilities since some of them have different needs when it comes to charging infrastructure, security and/or space (e.g. e-bikes and cargo-bikes).Including different modes and options potentially enlarges the attractiveness of the hub and the catchment area. These policy- and design-choices need to be considered when further developing the hub.

Finally, since the hub can serve more goals than just the mobility-related ambitions and goals, it should also be taken into account how to steer on non-mobility related ambitions and goals. For instance, when the hub should also consider the mobility (and possibly non-mobility) needs for the area development in its surroundings, this should be addressed in the mobility plan for these developments. Also, when assessing the attractiveness and perceived user experience from a 'place'-perspective, there might be different indicators to monitor when assessing the functioning of the hub (e.g. social safety, variety in facilities and shops, greenery and quality of place). When steering towards these goals, specific policy or design conditions might be important to take into account when designing the hub.

[46] Station-based versus free-floating concepts have different spatial consequences and business-models which also translates to different use. For instance, having a fixed parking spot versus not is different in terms of charging infrastructure, the flexibility of use (only for a shared mode or for all modes) and if shared mobility is spatially distributed (free-floating) or consolidated at specific locations (station-based)[46].

5 Conclusions and recommendations

The collaboration between the Province of North-Holland and TNO on the hub Haarlem Nieuw-Zuid followed three main lines of research: 1) a qualitative analysis on hubs giving an overview on hubs in general as well as an analysis of Haarlem Nieuw-Zuid (hubs definitions, characteristics, typologies, functions and elements, connected policy goals, and users of hubs); 2) A quantitative analysis on scenarios for Haarlem Nieuw-Zuid using TNO's Urban Strategy platform (growth scenarios, hub configurations scenarios and policy measures scenarios); and 3) insights on futureproof and integral hub design.

TNO analysed different scenarios for the hub Haarlem Nieuw-Zuid using the TNO Urban Strategy platform. Urban Strategy enables to construct predictive digital twins from which the impact of different policy measures and spatial configurations on mobility and other indicators such as air quality and noise can be explored. The scenarios included in this study can be divided in three main objectives: (1) insight in the projected growth in the year 2030 and 2040, (2) impact assessment of two spatially different configurations of mobility hubs in the year 2030 and (3) impact assessment of additional policy measures alongside a mobility hub in the year 2030.

The usage of the hub Haarlem Nieuw-Zuid
Based on the quantitative study, first of all, it can be concluded that the number of travelers using the bus station at the location of Haarlem Nieuw-Zuid will grow to 1.5 times as much by 2030, and 2 times as much by 2040 – compared to the reference situation in 2020. The introduction of the hub Haarlem Nieuw-Zuid and corresponding bus lines does not have much influence on the modal split in the city of Haarlem – only a 0,1% increase in modal split of public transport users can be seen. Likewise, the two different spatial configurations (Noord and Tunnel) does not have any significant impact on the number of users or the modal split within the city of Haarlem. On the other hand, the introduction of the hub Haarlem Nieuw-Zuid does have a large effect on the public transport route and line choices: three times as many people will transfer to another bus at the hub compared to the bus station in the same situation without a hub.

The usage of shared bikes and the required bike parking capacity is highly influenced by the municipality's goals and ambitions regarding the bike travel mode. If the goal is to reduce bus traffic through the city center and use the hub more as an 'public transport-endpoint' where your journey is continued by (shared) bike, potentially large numbers of cyclists would be willing to use this option. However, if bike parking or shared bike offering is limited, it is expected that more people will use the (city) bus as access or egress mode toward the hub.

Additional policy measures can help encourage people to use their car less in favor of using public transport and bike. In the additional scenarios it has been computed what the effect is of improving the public transport system (by increasing frequencies), the effect of discouraging car usage by increasing parking tariffs in Haarlem, and the combined effect. Each of the scenarios has a positive effect on the usage of public transport and especially the hub. Discouraging car usage has a larger effect than increasing of public transport frequencies. However, combined they provide an even larger effect.

In an extended model study it would be interesting to also investigate a network of hubs (e.g., multiple hubs interacting and competing with each other), as well as a more detailed study on the usage of shared mobility systems – both at the hub and within the entire city. This would give a better insight in the role of the hub within the entire mobility system where new (shared) modes and additional policies are being introduced.

Design principles for futureproof and integral hubs

When considering design principles for futureproof and integral hubs, the Haarlem Nieuw-Zuid hub can benefit by broadening the scope and taking into account certain design choices and dilemmas identified in this study. These are:

- **Addressing multiple and diverse (policy) goals and ambitions in hub design by broadening the scope beyond mobility**. Addressing them all is challenging however important to occasionally take into account when designing the hub, determining program and implementing the hub. This requires making decisions about scope but also about prioritization. For example; how much space do you allow for shared versus private micro mobility? And how much space should be spent on creating parking facilities for micro mobility versus placemaking? These dilemma's on integration all trickle down to questions on how to prioritize and operationalize strategic goals. What are preferences? And how do these preferences dictate policies and generate income?
- **Futureproofing the hub by including foresight and flexibility**. Foresight is about including trends and developments into the design of the hub – even though the impact of these trends is not fully clear yet (known unknowns). Additionally, there should also be some flexibility or adaptivity in the hub design that allows the hub to change and adapt to future needs and contexts. This both considers an analysis of the actual 'wheels on the ground', as well as policy documents, ambitions and visions on future modal splits. This includes both the micro mobility options ((e-)bikes, cargo bikes, (e)-mopeds (scooters), (e)-scooters (stepjes)) shared cars, and mobility services such as MaaS-solutions. Additionally, trends in private micro mobility options such as e-bikes and cargo-bikes (for people and logistics) should be included since they a) might have different needs in terms of charging infrastructure, spatial implications and security and b) might partially replace trips that are currently made by car of public transportation.
- **Designing the hub not just as a *path* but also as a *place***. For Haarlem Nieuw-Zuid, it stresses the importance of designing the hub not just for efficiency, but also from the perspective of quality of stay, having a place to linger around, have safe pedestrian routes, plazas or add programming to increase the attractiveness and improve the experience of users of the hub (whether they are travelers or not). Additionally, social security is also a point of attention that should be taken into account when designing the hub. In the current state of the location, social safety can be improved (bus stops are too busy and narrow, no facilities, low quality of space). The social safety should be taken into account using a 24-hour timeframe in mind.
- **Considering the role of the hub in developments in the area**. The hub can also facilitate the (residential) developments (a.o. Elan Wonen, Spaarne 1 VOF, Being Development, New Cheese Development) in the area. The hub could for instance include parking (both cars and other modes, offer shared

mobility services for new residents) and support the mobility needs of these new residents, visitors and commuters on the hub, instead of having to include these on the street. This might mean that the elements and functions (both mobility related and non-mobility related) of the hub should be reconsidered to fit not just the bus traveler's needs, but also other (mobility) needs for (new) local residents (for example by adding other functions or changing scale of (shared) mobility offering).

- **Designing the hub from a network perspective.** This means both considering the regional perspective – connecting to (larger) regional hubs – as well as smaller scale hubs in the city of Haarlem and surroundings. Additionally it is key to consider the supporting conditions (governance, policy, etc.) to ensure the hub functions and is used in a way that it adds to the goals set by the Province of North-Holland and Haarlem and both the local and regional perspectives.
- **Create effective (flanking) policies for achieving the desired effects of the hub(s).** It is important to note that the physical implementation of the hub will in itself not significantly affect mode shifts. The quantitative analysis (chapter 3) shows that there is only a 0,1% increase for public transport in the modal split for the city of Haarlem. The hub however does influence the amount of travelers traveling via the hub (impacting route choice and line choice) – giving room to the central train station to accommodate growth and reducing busses driving through the city center. When using the hub as a means to achieve not just (regional) accessibility goals and facilitating the Haarlem central train station in its ambitions to grow, the need for flanking policies arise. As is shown in the results of the modeling (paragraph 3.3.3) the implementation of flanking policies and measures concerning both making public transportation more attractive and cars less attractive can have a positive impact. Interesting to note is that when addressing mode shifts, measures on reducing the attractiveness of cars have a bigger impact towards choosing public transportation and biking as modes, than measures focused on making the public transport more attractive (by increasing frequencies). It is therefore important to address both the 'push and pull' side when developing flanking policies to ensure the desired use and impact of the hub Haarlem Nieuw-Zuid. Additionally, since the hub can serve more goals than just the mobility-related ambitions and goals, it should also be taken into account how to steer on non-mobility related ambitions and goals. For instance, when the hub should also consider the mobility (and possibly non-mobility) needs for the area development in its surroundings, this should be addressed in the mobility plan for these developments. Also, when assessing the attractiveness and perceived user experience from a 'place'-perspective, there might be different indicators to monitor when assessing the functioning of the hub (e.g. social safety, variety in facilities and shops, greenery and quality of place). When steering towards these goals, specific policy or design conditions might be important to take into account when designing the hub.

Next steps in hub development

To apply the design principles for future-proofed and integrated hubs into practice we have the following recommendations for the (further) developments of hubs:

- Use an iterative design approach to ensure the contribution of hubs to societal goals

This implies an iterative design and development approach to hub along with the development of needed flanking policy. A combined qualitative and quantitative approach can support this iterative design cycle. Topics for this design process are the concretization of the various hub goals and ambitions, the linking of the hub to area development, and the deployment of (a package of) policy measures to stimulate the use of the hub and steer on the desired modality in the region.

- Include required hub/future proofing expertise in the hub development

We see the establishment of a multidisciplinary team as an important precondition for establishing and maintaining an integral perspective during the development of a hub. This includes experts from various professional disciplines as well as the involvement of people who bring a strategic, tactical and operational perspective (to close the identified tactical gap between strategy and operations). Future-proofing experts should also be added to this process. In addition, it may help to examine the hub from different perspectives (urban development, social inclusions, climate, mobility, etc.) or to explicitly choose for each hub which goals and ambitions will be prioritized.

- Consider the entire hub network

In addition, we recommend further research into the development of a network of hubs and what the effects of this will be. This involves studying the cohesion of (different types of) hubs including hubs with a diversity of facilities and modalities offered and the interactions between these hubs.

- Benchmark and monitor progress

Finally, since the development of hubs beyond the scope of public transport hubs is still being pioneered, it is recommended to set up a monitoring program. Monitoring supports making (expected) contributions to social goals explicit and keeps track of relevant (external) developments (such as the modal split) and it support benchmarking the hub in comparison to other hubs. In addition, a monitoring program can also support knowledge exchange and facilitate the joint learning process of the stakeholders involved.

6 Signature

The Hague, 21 November 2022 TNO

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Appendix A: Studied documents from Haarlem and the Province of North-Holland

Table A.1: Studied documents for analysis on hub Haarlem Nieuw-Zuid

Document	**Author/Stakeholder**
Focus Koers Smart Mobility 2022-2025	PNH
Strategie Programma OV-knoooppunten 2019-2023	PNH
Mobiliteitsbeleid gemeente Haarlem	Haarlem
Uitvoeringsagenda Mobiliteitsbeleid	Haarlem
Bijlage A: vraagspecificatie uitvraag vervolgonderzoek OV-knooppunt Haarlem Nieuw-Zuid	Haarlem + PNH
Knooppunt HLM NW ZD – Modellen studie	SWECO
Knooppunt Haarlem Nieuw-Zuid report 210722 vertrouwelijk	SWECO
OV knooppunt Haarlem Nieuw-Zuid Verkeerskundige achtergrond	SWECO
OV-knooppunten van de toekomst – een integraal handelingsperspectief	Goudappel Coffeng
Toelichting verkeerskundige aspecten variant met korte tunnel	SWECO
Rapportage integrale visie stationsgebied Haarlem – oplossingsrichtingen voor toekomstige mobiliteit	APPM, Urhahn, Goudappel Coffeng
Notitie Lijnnetsessie Busstation Haarlem Zuid-Oost	Goudappel Coffeng
Knooppunt Haarlem Nieuw-Zuid – verkenning mogelijke locaties	Goudappel Coffeng
Knooppunt Haarlem Nieuw-Zuid Ruimtelijke studies	SWECO
Handelingsperspectief Haarlem Nieuw-Zuid	Goudappel Coffeng
Ambitiedocument Knooppunt Haarlem Nieuw-Zuid conceptversie december 2021	SITE