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An analysis of the mobility hub concept in the Netherlands: Historical lessons for its implementation

Tibor Rongen [a,*], Taede Tillema [a], Jos Arts [a], María J. Alonso-González [b], Jan-Jelle Witte [b]

[a] Department of Economic Geography, Faculty of Spatial Sciences, University of Groningen, PO Box 800, 9700 AV Groningen, the Netherlands
[b] KiM Netherlands Institute for Transport Policy Analysis, Ministry of Infrastructure and Water Management, PO Box 20901, 2500 EX The Hague, the Netherlands

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ABSTRACT

The mobility hub concept has become increasingly popular within international research and policies, including in The Netherlands. However, judging by the (still) limited share of multimodality in the Netherlands, similar historical concepts seemed insufficient to prompting a fundamental shift from individual car use to multimodal transport. To enable planners to be better positioned to implement the mobility hub concept, we compared its value with that of related concepts that were previously implemented. Specifically, we examined historical Dutch policy documents and conducted expert and frontrunner interviews to evaluate the mobility hub as a policy concept. We first traced the evolution of the mobility hub, focusing on node and place-based concepts that have been implemented since the second half of the 20th century. We found that related concepts, such as Park and Ride (P + R) or transit-oriented development (TOD), have typically focused on improving transfers between collective and feeder transport, while interactions with land use have gained increased attention. We derived policy lessons from the implementation of these historical policy concepts. Our findings suggest that strategically chosen locations, integrated mobility systems, flanking policies, multi-level policy coherence and public–private cooperation are important considerations when implementing mobility hubs. Moreover, shared mobility, mobility as a service, vehicle electrification, and demand-responsive transit could advance the implementation of TOD, P + R, neighbourhood and rural hubs. In conclusion, the design of different types of mobility hubs should ideally be based on underlying policy objectives and adapted according to context.

1. Introduction

In recent years, the mobility hub concept has received increasing attention within international transport planning as a new feature of passenger transport systems (Geurs and Münzel, 2022). In Europe, several regions have started implementing mobility hub schemes in urban (e.g. Utrecht, Bremen, Vienna) and rural areas (e.g. Flanders, Groningen-Drenthe, Karlsruhe), which regularly link to research programmes, exemplified by recent reports of eHUBS (Bösehans et al., 2021; Coenegrachts et al., 2021), SmartHubs (Geurs and Münzel, 2022) or SMiLES (Kask et al., 2021). Moreover, for its latest trans-European transport network (TEN-T) regulation, the European Commission proposes that by 2030 "in urban nodes, in order to ensure the effective functioning of the entire network without bottlenecks, Member States shall ensure […] the development of multimodal passenger hubs to facilitate first and last mile connections" (European Commission and Directorate General for Mobility and Transport, 2021, p. 62).

For instance, in the Netherlands, the mobility hub is viewed as a panacea for solving transport-related issues, such as congestion, poor liveability and limited urban space, all of which are urgent policy issues. This view is evident in the strategic visions of municipalities and provinces, consultancy reports and conference presentations. The National Environmental Vision from 2020 acknowledges the efforts of decentral authorities to develop hubs at strategic locations where transport modes are linked within integrated transport systems, offering travellers comfortable transfers (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020). Moreover, the latest coalition agreement of the Dutch Cabinet is indicative of the centrality of this topic within contemporary politics, referring to hubs 'where travellers can easily switch to a (shared) car, (shared) bicycle, train or metro via [a] tailor-made multimodal travel advice' (Rutte et al., 2021, p. 19). However, Witte et al. (2021) have argued that despite the increased attention to hubs within academic and policy debates, the implementation of mobility hubs is at an early stage, with varying interpretations existing

* Corresponding author.
E-mail address: t.o.rongen@rug.nl (T. Rongen).

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among stakeholders.

Thus, the concept of a mobility hub remains ambiguous, with a lack of consensus on its definition. Within the recent literature, mobility hubs are described as clusters of either new, shared, or electric mobility services available at designated locations where travel demand is high, which can be integrated into conventional public transport services (Anderson et al., 2017; Bell, 2019; Bösehans et al., 2021; Coenegrachts et al., 2021; Frank et al., 2021; Miramontes et al., 2017). Although specific elaborations of the concept vary among authors, the core characteristics of mobility hubs are their provision of multimodal transfers and their frequent interactions with surrounding land uses according to their locations.

Multimodal trips typically comprise two or more legs (Van Nes, 2002), with intermediate transfers occurring primarily at hubs. Multimodal transport planning stems from the notion of bundling transport flows as a response to the adverse impacts of car usage on the environment, urbanisation patterns and congestion levels. A key vulnerability of multimodal transport relates to the connection between the trip's origin (the first mile) and destination (last mile) to the hub (Lu et al., 2021), which strongly influences public perceptions of multimodal travel (Givoni and Rietveld, 2007).

The mobility hub concept is closely related to that of *land use and transport interactions (LUTI)*, which is well-established within transport planning (see, e.g. Kelly, 1994; Mitchell and Rapkin, 1954). According to van Wee (2011), critical land use factors influencing the demand for multimodal travel are spatial density, the existence of a land-use mix, the distance between the origin and destination and the presence of hubs. Therefore, transit 'node' (and its directions, frequency and capacity) in transit-oriented development (TOD) complements human interactions within a physical 'place' and vice versa (Bertolini, 1999).

In the context of multimodal transport and LUTI, the mobility hub bears many similarities to earlier forms of transport nodes, such as TOD or Park and Ride. Despite its increased popularity in the Netherlands, little has been reflected on lessons derived from these earlier concepts. Notably, historical attempts to implement hub concepts have been limited, with multimodal trips accounting for just 4%–5% of all trips in the Netherlands (Hamersma and de Haas, 2020). Consequently, the effectiveness of historical concepts, or at least their implementation, is questionable. Comparisons of the mobility hub and related historical concepts—and their implementation—are limited within the literature. Therefore, reflections on comparable historical policy concepts, focusing on the dimensions of node and place could lead to a more nuanced and realistic view of the mobility hub concept.

We aimed to analyse the mobility hub as a policy concept by answering three questions: (1) How can the evolution of the mobility hub be traced through related historical policy concepts? (2) What historical policy lessons can inform the future implementation of mobility hubs? (3) How can innovations in the transport sector advance the mobility hub concept to achieve current policy objectives? We selected the Netherlands as our case study because it provides insights into a longstanding tradition of transport planning in a strongly urbanised delta that is subject to congestion, environmental pressure, and limited space. Moreover, as in many other countries, hubs have received increased attention within Dutch transport policy and planning (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020; Rutte et al., 2021). Our study adds to the literature on historically informed lessons for implementing mobility hubs according to established Dutch transport practices and land-use planning.

Firstly, we conducted a systematic analysis of Dutch historical policy documents to explore the broad range of hub-related concepts within these documents. Based on this selection, we conducted semi-structured expert interviews to identify central concepts and derive lessons that could inform future policy making concerning hubs. Lastly, we conducted interviews with forerunners in the contemporary discourse on mobility hubs to identify which innovations within the transport sector could advance various mobility hubs to achieve current policy objectives.

The remainder of the paper is structured as follows. Section 2 discusses the methodological approach in more detail. Section 3 describes the historical evolution of mobility hub-related concepts. Section 4 presents key lessons derived from the interviewed experts' reflections on these concepts. Section 5 discusses transport innovations and the utility of existing mobility hubs, and Section 6 offers conclusions.

2. Methodology

2.1. Literature search and document analysis

We applied a two-step methodology to explore historical policy concepts related to the hub concept within Dutch national transport and land-use planning. Given the ambiguity of the definition of the hub concept, we indexed related keywords sourced from the international scientific literature to search for related concepts within Dutch historical policy documents.

We first conducted a literature search using related keywords in the Scopus database, starting with a preliminary publication sample which we selected using the query *KEY (hub) AND ABS (transport)* to locate the co-occurrence of the Scopus index keyword, 'hub' with 'transport' mentioned in paper abstracts. We listed the index keywords sourced from 691 publications located through this query and manually extracted the main keywords by excluding keywords from non-passenger transport research fields, methodology-related keywords and articles and auxiliary verbs.

Next, we performed a document analysis of policy reports using the previously obtained terms to identify relevant hub concepts in the Dutch context. The terms that were finally selected were translated into Dutch and complemented with synonyms (if necessary to the Dutch language context) to analyse strategic policy documents obtained from the Dutch ministries responsible for transport and land-use planning. We selected 1958 as the starting year because it marked an explosion in individual car ownership and investments in associated road infrastructure (Arts et al., 2016; Molnár-in 't Veld, 2019). We included documents published up to 2020, which was when the current national strategic plan on transport and spatial planning was issued (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020). The 25 documents selected enabled an analysis of the varying stances of the national government towards multimodal transport via hubs over time. We performed the query using a coding tool in the ATLAS.ti software, which automatically highlighted paragraphs in which the selected terms appeared. Finally, we analysed the highlighted text and compiled a list of historical concepts that was submitted to the experts during interviews.

2.2. Expert interviews

We conducted semi-structured expert interviews to explore historical policy lessons for implementing mobility hubs. This method was beneficial for analysing the link between historical and contemporary hub interpretations as the experts were experienced practitioners working in the field for the decades during which the concepts under study were implemented. We structured the discussions using the historical hub concepts identified during the analysis of policy documents. Six interviews were conducted with transport policy experts from the academic (Respondents H1 and H2), policy-making (Respondents H3, H4 and H5), and consultancy (Respondent H6) fields (Appendix A). The respondents were selected because of their longstanding experience (30–40 years) and close involvement in the formulation, implementation and/or evaluation of national hub policies during the period under investigation. The interviews took place via video calls conducted between November 2020 and February 2021, each lasting 45–90 min. The calls were recorded and transcribed with the respondents' consent. We coded the interview quotes according to historical policy concepts using a deductive coding procedure in the ATLAS.ti software.

During the interviews, we asked the respondents to reflect on the completeness of the draft list of historical policy concepts. Subsequently, the respondents selected policy concepts for discussion according to their expertise and the perceived relevance of these concepts to the hub concept. The discussion focused on defining each policy concept, its objectives; instruments; and experiences at national, provincial, and national levels.

2.3. Frontrunner interviews

In addition to the historical analysis, we conducted six additional interviews to explore innovations within the transport sector that could advance the mobility hub towards achieving current policy objectives. Accordingly, we interviewed six frontrunners from private consultancies (I1, I2 and I3), transport companies (I4 and I5), and an academic institution (I6), selected because of their prominence within the contemporary discourse on mobility hubs in the Netherlands (Appendix A). Because of restrictions relating to the COVID-19 pandemic, we conducted the interviews via video calls between October 2020 and February 2021. The interviews lasted 45–60 min and were recorded and analysed with the respondents' consent.

For this distinct analysis, we used interviews conducted as part of a larger research project commissioned by the Dutch Ministry of Infrastructure and Water Management. We used an open interview format that enabled respondents to explore a wide range of perspectives. For the present study, we asked respondents to discuss innovations that drive the prevailing interest in mobility hubs. Subsequently, we discussed hub types, which could evolve because of these innovations, and their distinctive characteristics.

3. Evolution of the mobility hub

The document analysis revealed terms such as 'node', 'intermodal', and 'transfer'. Our search of 25 policy documents dating from 1958 to 2020 using these terms resulted in a preliminary sample of 11 policy concepts. From this sample, the interviewees selected policy concepts that they viewed as being related to the node and/or place dimension(s) of the mobility hub for further discussion. As shown in Table 1, each respondent selected three or four concepts, resulting in a total of six relevant concepts, indicated by an X. The remainder of this section examines the evolution of the mobility hub concept in the Netherlands using the following concepts selected by respondents: P + R, ABC location policy, 'Transferia', compact city, New Key Projects, and the Sustainable Urbanisation Ladder. We discuss these concepts thematically according to their focus on nodes or places. This distinction is in line with that made by Bertolini (1999) and the expertise of different ministries relating to infrastructure planning (nodes), spatial planning (places) or both during the period under investigation.

3.1. Node-based concepts

The first node-based concept is linked to the introduction of the **Park-and-Ride** in the Multiannual Passenger Transport Plan (1976–1980). Large-scale investments in highway networks, starting from the 1960s, increased car ownership, and the fragmented distribution of residential and employment areas underpinned increased road congestion and environmental problems. These processes triggered a shift from the existing car facilitation paradigm towards a desire to foster collective transport. Policymakers assumed that parking facilities available near train stations (park-and-ride facilities) would incentivise car users to use public transport for part of their trips.

The Park-and-Ride concept was further developed through the introduction of measures that helped to make intermodal transfers more comfortable. The Second Structural Plan for Traffic and Transport (SVV-II, 1991) recognised that merely linking parking facilities to public transport at park-and-rides was insufficient for achieving the aim of halving the projected 70% growth in car use between 1986 and 2010. In the **Transferia** pilots, transport companies (e.g. national railways), car lobbyists and market actors negotiated the development of parking facilities, which, compared with the initial P + R park-and-ride scheme, aimed to improve travel comfort through, for example, dynamic traveller information systems located along highways, wayfinding (e.g. signage) and parking safety. Moreover, the SVV-II Plan reflected the realisation that parking measures implemented at the destination of a

Table 1
Timeline of documents and concepts resulting from the document analysis and expert interviews validated the relevance of these results.

Year	Document	Concept	Dimension		Respondent's discussion					
			Node	Place	H1	H2	H3	H4	H5	H6
1958	Memorandum on the Development of the West	–								
1958	State Highway Plan 1958	–								
1959	1200 Kilometre Plan	–								
1960	First Memorandum on Spatial Planning	–								
1966	Second Memorandum on Spatial Planning	Bundled deconcentration		X						
1966	Structural Plan for the Main Road Network	–								
1968	State Highway Plan	–								
1974	Third Memorandum on Spatial Planning	–								
1976	Urbanisation Memorandum	–								
1976	Multiannual Passenger Transport Plan 1976–1980	Park and Ride	X		X	X	X	X	X	
1980	Multiannual Passenger Transport Plan 1980–1984	–								
1981	Structural Plan for Traffic and Transport	–								
1983	Structural Outline for Urban Areas	–								
1984	State Highway Plan, 1984	–								
1988	Fourth Memorandum on Spatial Planning	ABC location policy		X	X			X	X	
		Urban nodes		X						
		Key projects		X						
1991	Structural Plan for Traffic and Transport	Transferia	X		X	X		X	X	
1992	Fourth Memorandum on Spatial Planning Extra (VINEX)	Compact city		X	X	X	X			X
1997	VINEX update	New Key Projects	X			X	X			X
2000	Accessibility Offensive Randstad	–								
2004	Memorandum on Space	Bundling areas		X						
2005	Memorandum on Mobility	HQ public transport	X							
2007	Growth on the Railways	–								
2012	Structural Vision Infrastructure and Spatial Planning	Sustainable Urbanisation Ladder		X						X
2019	Future Contours of Public Transport 2040	–								
2020	National Environmental Vision	Mobility hubs								

multimodal trip could incentivise an intermodal transfer from cars to public transport within the urban fringe. The aim was to enhance park-and-ride facilities and minimise the adverse effects of car traffic in urban centres. Fig. 1 illustrates the basic concept of the Transferia.

In the late 1990s, the nodal concept evolved into the concept of TOD with the introduction of the **New Key Projects** (in Dutch: 'Nieuwe Sleutelprojecten'), foregrounding high-speed rail intended to improve the international competitiveness of Dutch networked urban units. This top-down scheme designated six train stations at strategic locations as sites for significant high-density development of housing and office spaces catalysed by national-level investments in high-speed rail. The responsible ministries established agreements with municipalities for formalising the timing and coordination of government investments in infrastructure and the spatial quality of the immediate surroundings. Bundling transport flows between hubs in dense urban settings required first−/last mile solutions via public transport, cycling and walking, marking a new type of hub functionality. Fig. 2 provides an artist's impression of Utrecht Central Station, one of the six New Key Projects.

3.2. Place concepts

The first place-focused concept can be traced back to the Fourth Memorandum on Spatial Planning (1988), which marked a paradigmatic shift from a conception of hubs as transfer nodes to their conception as locations of complementary transport and land-use functions. This Memorandum introduced the **ABC location policy**, which assumed that the concentration of employment at (multimodal) accessible sites would deter car use and stimulate public transport and active modes. Moreover, this policy marked the first step towards a decentralised governance structure. Applying an approach of 'the right company in the right place', the national government established a framework for municipalities to allocate employment locations to companies differentiated according to transport-generated impacts. Three location types based on differential accessibility were introduced. A-locations with public transport accessibility were dense urban environments located near intercity stations. B-locations comprised urban fringe areas served by public transport and highway infrastructure. C-locations were located near motorway exits and were easily accessible by car.

The principle of proximity further augmented the place-focused concept in the Fourth Memorandum on Spatial Planning Extra (VINEX, 1992). The focus shifted from a restrictive framework for spatial development towards stimulating concentrated urbanisation near public transport hubs to incentivise travellers to engage in multimodal trips across a broad spectrum of origin–destination combinations. Following this principle, the **Compact city** anticipated an urbanisation strategy in which mixed and dense land-use development sought to ensure proximity to daily amenities and demands for bundled transport. The national government made agreements with municipalities to develop new residential areas linked to land cost subsidies and contributions for developing public transport connections and green space. Fig. 3 provides an illustrative example from the VINEX (1992), applying the ABC location policy and the Compact city concept to the metropolitan area of Amsterdam.

In the Memorandum on Space (2004), national control over hub development clearly shifted towards provinces and municipalities, notwithstanding recognition of the increased relevance of interurban travel patterns apparent in the New Key Projects. The decentralisation trend continued in the Structural Vision on Infrastructure and Spatial Planning (SVIR, 2012), in which the **Sustainable Urbanisation Ladder** was introduced as an instrument aimed at promoting the efficient use of limited space for new area development.

In practice, this concept amounted to a planning hierarchy supporting area development according to three requirements. Firstly, there should be sufficient demand for the development. Secondly, this development should occur within existing urban contours. Thirdly, the development site should have multimodal accessibility (SVIR, 2012). The justification provided by decentralised governments for deviating

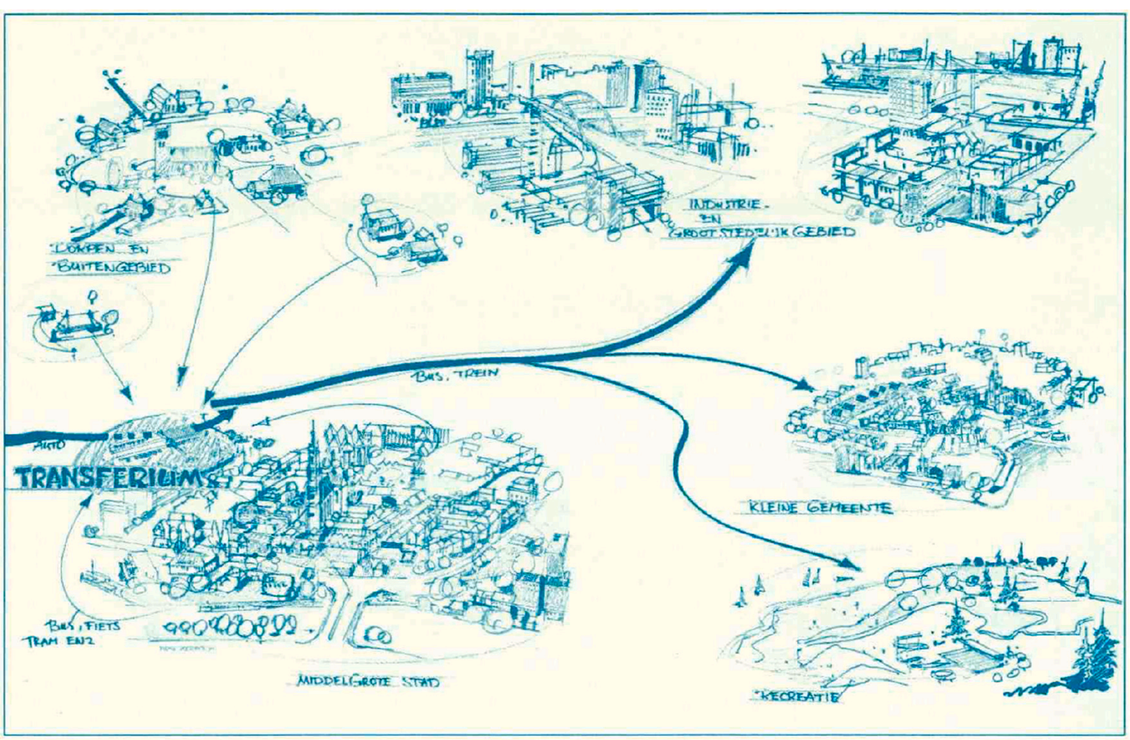

Fig. 1. An illustration of the Transferia concept prior to the pilot implementation (Rijkswaterstaat, 1993). The hub locates on the fringe of a medium-sized city connecting car infrastructure to bus and train connections to serve manifold destination types: villages and peripheral areas, industrial and metropolitan areas, small municipalities, and recreational areas.

Fig. 2. Utrecht Central Station was one of the New Key Projects (Moonen, 2016).

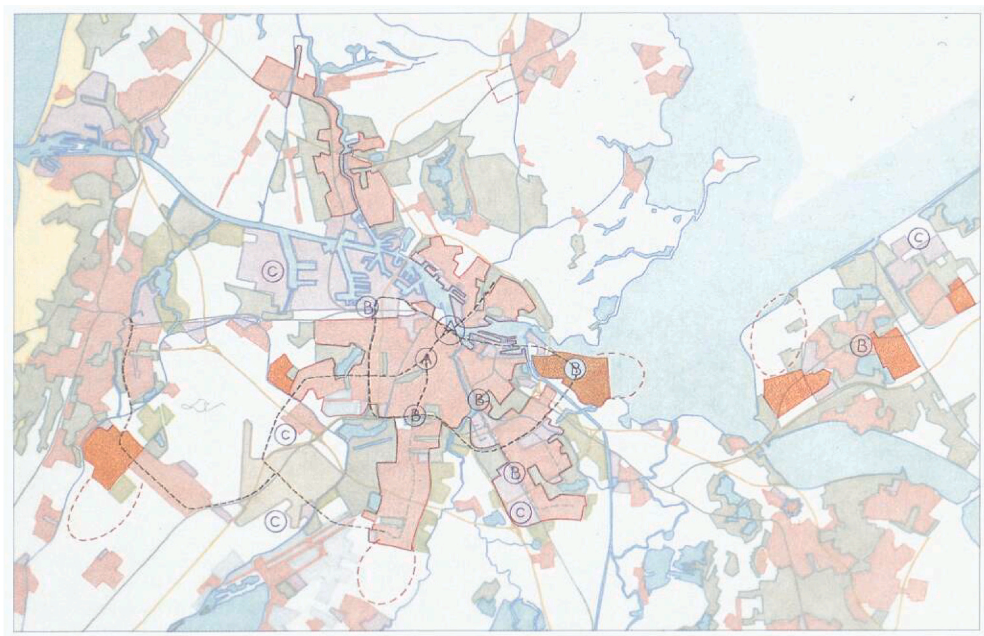

Fig. 3. Application of the ABC location policy and Compact city concepts to the Amsterdam region (Vinex, 1992). According to the Compact city concept, darker orange areas signify preferred directions for urban area development. A, B and C demarcations indicate the respective tiers of the ABC location policy. The black dotted lines identify as projected high-quality public transport lines.

from this principle became legally binding. The SVIR was the last strategic policy document released prior to the introduction in 2020 of the National Environmental Vision, which focuses on mobility hubs.

3.3. *Reflection*

The document analysis revealed that historical node concepts focused on reducing the transfer resistance between collective and individual transport modes. The place-focused concepts complemented the node concepts by managing the spatial distribution of travel demands. In short, mobility hubs started from node concepts, providing multimodal transfers between individual and collective transport, with the later addition of elements of place-focused concepts. Through node-place integration, mobility hubs enable and promote multimodality and serve as activity opportunities in their own right. Regarding their locational context, function in transport systems, and extent of spatial development, these are the **TOD hub** – the largest of which were the New Key Projects – and the **P + R hub**, rooted in the park-and-ride and Transferia concepts. Fig. 4 visualises these two hub types within a regional transport network.

3.3.1. *Transit-oriented development hubs*

A TOD hub has a train or bus station at its core. TOD hubs are located in urbanised areas and connect mixed and intensive land-use patterns to (high frequency) rail and bus rapid transit connections. The distinctive function of this hub type entails a high degree of (interurban) connectivity combined with high-density, mixed land-use patterns. The first objective of TOD hubs is to improve urban liveability by making public transport the core feature of a dense area of mixed land use, increasing the appeal of public transport over cars. A second objective is to enhance the accessibility of core economic activities, which contribute to the competitiveness of polycentric urban areas.

3.3.2. *P + R hubs*

The main components of the P + R hub are an extensive public transport station and car parking facilities. P + R hubs bundle transport flows towards central urban areas by linking car traffic with diffuse origin patterns to public transport in the urban fringe. The objectives of P + R hubs differ according to the multimodal transport options they provide and their positions relative to important destination areas. Destination-oriented P + Rs are located close to the urban fringe. They are primarily intended to improve liveability and reduce congestion associated with urban traffic. Origin-oriented P + Rs are situated at a greater distance from urban attraction poles and intend to replace cars with public transport for a substantial part of a multimodal trip. Origin-oriented P + Rs focus on alleviating congestion and reducing emissions along the main road network.

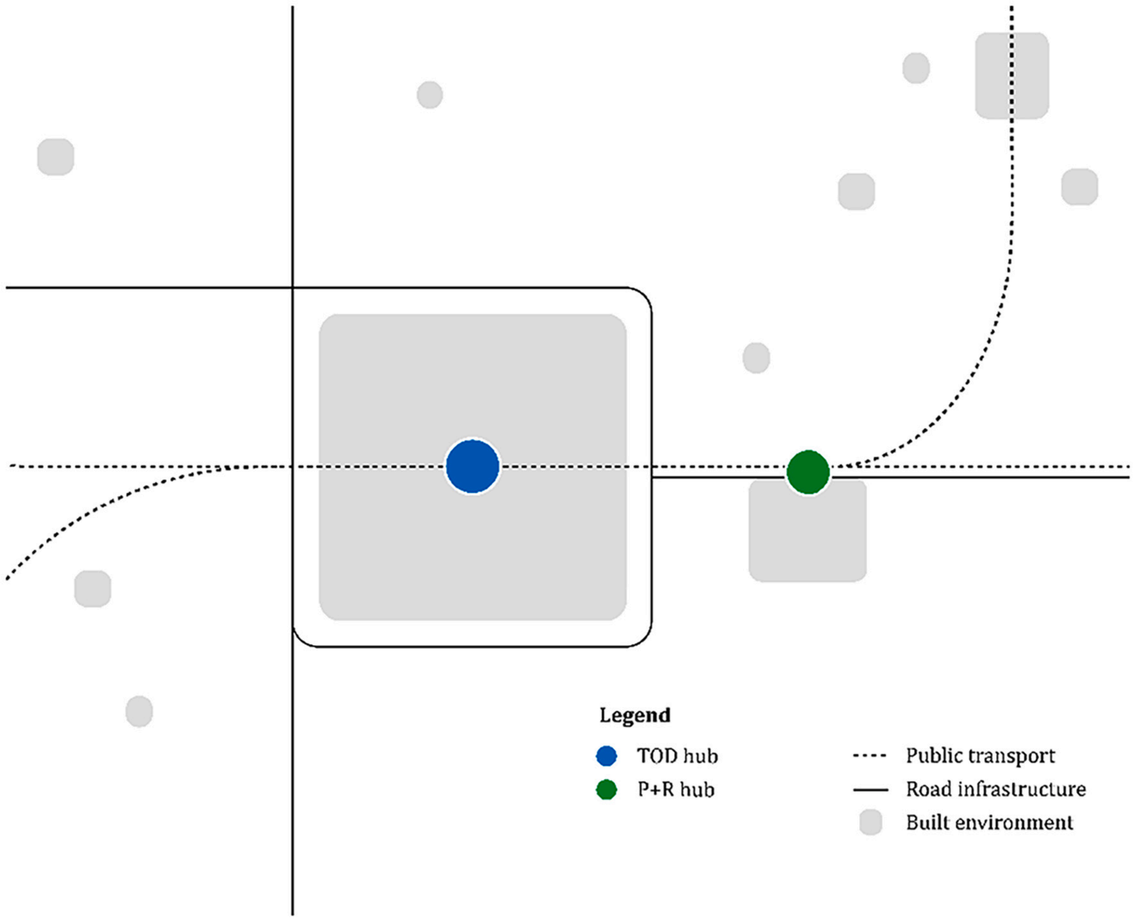

Fig. 4. Conceptual visualisation of a preliminary hub typology based on a historical analysis of Dutch transport policies. Dot size signifies approximate user volumes.

4. Historical lessons for implementation

To explore pertinent historical policy lessons for implementing mobility hubs, we asked the expert interviewees to reflect on the node and place-based concepts described in the previous section and on the general policy discourse on mobility hubs. We analysed the interview transcripts using an inductive coding procedure based on the above policy concepts. Accordingly, we categorised the main lessons into five clusters: strategic location choice, integrated mobility systems, flanking policies, multi-level policy coherence and stakeholder collaboration. This section examines these policy lessons using illustrative quotes from the expert interviews.

4.1. Strategic location choice

The strategic location of a mobility hub relative to important destination areas appeared to provide a comparative advantage by providing travellers with options for multimodal transfers. For example, one interviewee argued that if the P + R location is too close to the destination area, the traveller will be tempted to continue using their car:

The [P + R at the Amsterdam] ArenA was not a great success [because of the travel time] to get there, and finally reach the centre of Amsterdam. Some people said: ‘In that time, I can go directly by car from Hilversum to Amsterdam’. (Respondent H1).

Evidently, multimodal transport at the regional scale becomes an increasingly viable option with an increase in the distance between the hub and target destination. Respondent H2 explained: ‘With the origin-oriented [P+R], there is much more mixing of the different modalities at a regional scale’.

The interviews revealed that policy objectives can vary according to the location of the mobility hub. Frank et al. (2021) developed a decision-making support tool for locating mobility hubs linked to municipal policy objectives in the rural area of Heinsberg, Germany. They too found that mobility hubs can improve accessibility, but optimal locations may vary for trips made for specific purposes. Compared with destination-oriented P + R hubs, origin-oriented P + Rs have a limited impact on reducing the number of cars entering urban areas (Zijlstra et al., 2015). However, as they are intended to bundle transport flows for a more significant segment of a trip, they potentially have a more significant impact on congestion levels and environmental pollution at the regional scale (Mingardo, 2013).

4.2. Integrated mobility systems

Mobility hubs can attract a larger share of the travel demand when designed as part of an integrated mobility system. The reluctance of travellers to perform intermodal transfers can be minimised by establishing these systems in competition with unimodal car transport. As Respondent H3 explained: ‘The door-to-door trip is powerful. Hence, we seek competing alternatives in terms of convenience, time and cost’.

Transfers made at a hub increase the uncertainty of travel time, leading to higher generalised transport costs: ‘As a traveller, the uncertainty increases with every transfer on a journey’ (Respondent H4).

Moreover, multimodal transport is fragmented, consisting of different modes, transfer points and service providers. This fragmentation impedes the evaluation of individual service attributes influencing travel demand. Respondents mentioned travel demand attributes related to socio-demographic characteristics (e.g. age and education level), personal values (e.g. environmental consciousness and the image of public transport), freedom of choice (e.g. possession of a driver's licence and travel budget), habitual behaviour (e.g. inveterate car drivers) and the perception of alternative modes.

Improving the recognisability of the P + R facility helps to manage travellers' expectations towards hub services and meet their needs: 'The signal value, […] signs with similar design styles, lettering and names play a role in recognising the concept' (Respondent H5).

The distance between transport modes offered at a hub also affects the transfer burden. TOD hubs entail considerable transfer times between modes, which is a significant drawback contributing to the transfer burden: 'Look at the large concentrations of bicycle parking around the main rail network. One spends five minutes before reaching the entrance gate [of the station] from the bicycle [parking area]' (Respondent H4).

In addition to physical barriers, there are institutional barriers impeding transfers between different transport providers that must be removed to achieve seamless transfers. A successful example is the introduction of the OV bike by the Dutch National Railways. This bicycle-sharing scheme provides docked bicycles as a last-mile solution at most train stations, bus and metro stops and P + R facilities. Respondent H3 observed: 'The OV bike is easy for the traveller because it is cheap, ready within three seconds, and parking facilities are close to station exits'.

These insights into travellers' preferences relating to integrated systems are not routinely incorporated into policies. Respondent H4 expressed this point clearly, while reflecting on the National Environmental Vision:

All sorts of assumptions are made [in the National Environmental Vision]. 'You have to offer nice public facilities [at hubs] because then it will be easier to switch from one [type of] transport to another. But nothing is said about [the question], "what does the public think about this?"

It can be concluded that users' experiences with multimodal travel can benefit from physical and institutional integration of mobility systems.

4.3. *Flanking policies*

The extent to which a mobility hub contributes to its envisioned policy objectives, such as reducing transport poverty, depends on the integration of the P + R concept with flanking policies, such as parking restrictions. According to Respondent H2*,* policies are not always aligned, resulting in adverse effects*:* 'The transport sector hardly meets its climate [change] objectives because all kinds of policy objectives [are in] conflict, such as the lack of a car-discouraging policy that should complement public transport investments'.

Respondent H1 further argued that the P + R concept encourages travellers to complete the entire journey by car if the destination has sufficient, price-competitive parking capacity: '[…] as long as sufficient parking space is available [at the hub], people are not tempted to take the car and drive straight to the city. So parking is a crucial point'.

Apart from parking measures, a road-pricing scheme targeting specific times, places or vehicles could have been implemented as a flanking policy relating to the P + R concept. Respondent H1 explained: 'The roads from the urban fringe […] have a high toll rate [due to traffic intensity], incentivising travellers to park at a P+R [facility] and continue [their journey] by public transport'.

Such restrictive flanking policies do, however, require collaboration between neighbouring authorities. For example, most transport flows via P + Rs occur at a regional scale. Therefore, Respondent H5 contended that policy packages in which municipalities coordinated the management of the desired state of traffic were important for the success of the P + R concept. This expert noted: '[the P+R concept] was elaborated at different administrative levels: in the municipality where it is located, and [at the destination] where the municipality provided a parking policy'.

The core flanking policy for hub concepts relates to integration with the place elements of the hub. The TOD hub exemplifies a conceptual shift from a hub as a functional transfer node to the hub itself as an attractive destination area. As Respondent H6 noted: 'The quality of the New Key Projects has changed how we think about stations, which used to be [considered] utilitarian places that only involved transportation'.

The interviews indicated that the effectiveness of hub concepts depends on the presence of flanking policies. For example, a rural mobility hub can offer an inclusive and sustainable transport service to residents travelling to nearby cities, but it is unlikely to stop independent car use. Hypothetically, removing parking facilities in the city would likely induce a modal shift to public transport use in the absence of alternatives.

4.4. *Multi-level policy coherence*

Apart from the need to integrate the hub concept within a package of flanking policies, policy coherence among authorities at varying levels can enhance hub effectiveness. Experiences with implementing place-focused concepts have shown that local economic interests sometimes conflict with the national desire to limit car use. According to Respondent H1, the effectiveness of the concept was often restricted due to private land ownership issues, the obligation to adhere to existing urban plans, and municipalities' tolerance of flexible parking capacity, resulting in conducive conditions for car use. Moreover, this respondent noted: "municipalities were often tolerant of the maximum number of parking spaces under pressure from market parties. Companies simply said: 'That is all well and good, but we want more parking spaces'".

Conflicting policy interests also affected the implementation of nodal concepts, as the supply of parking spaces in public spaces conflicted with public transport subsidies.

The implementation of place-focused concepts has sometimes facilitated car-oriented rather than transit-oriented development. Respondent H2 noted that most travel occurs between diverse suburban locations: 'Most travellers do not [just] travel between Utrecht Central Station and Arnhem Central Station but [also] between Utrecht-Overvecht and between Arnhem-South'.

The above quote implies that place-focused hub concepts encourage car-dependent travel patterns if the concerned areas lack adequate public transport facilities.

Despite these adverse intended consequences, the distribution of tasks between the central government and municipalities is considered appropriate for achieving policy objectives within a predefined time frame. Respondent H6 defended a proactive and centralised place-focused hub approach: 'The [national] government should retake the lead, as in the era of the compact city. […] [It should] play an active role in spatial planning and sustainability issues that transcend the municipal or provincial scale'.

The desire of some respondents for a centralised approach seems to be related to their general pessimism regarding the effects of decentralising transport policies that began in the 1990s. They argued that central coordination between municipalities is essential for achieving policy goals at higher scales.

The government's task is to keep track of long-term development of the environment, including limiting urban sprawl, which encourages car use, a known cause of environmental problems. 'Alternatives should be supplied, and people should be obliged to handle this carefully, even if it does not seem necessary locally' [Respondent H6].

Historical experiences indicate that coherent policy schemes implemented by authorities at multiple levels could foster hub development, as they are part of transport flows that extend beyond localities. The integration of scheduled public transport with demand-responsive transit (DRT) services at hubs poses challenges. In the Netherlands, municipalities manage DRT services for people with special needs, whereas the regional transport authority manages low-demand times and areas. Veeneman and Mulley (2018), who conducted a case study in Amsterdam, concluded that integrating both services within a broader public transport concession supported by collaborating municipalities is the way forward.

4.5. Cooperation between the public and private sectors

Cooperation between public and private parties is essential for organising transport and land-use resources at a hub. Moreover, encouraging the use of hubs requires the cooperation of the different parties involved in the trip chain. As Respondent H3 argued: 'The weakest trip leg attracts [a] policy focus, but the sum of [the] legs determines the travel resistance that needs to be minimised'.

This integrated trip chain approach offers transport providers a potential business model partially supported by public financing. The integration of the national railways with OV bikes is an example of a scheme that receives public funds covering the first implementation phase. As Respondent H3 noted: 'If you consider the business model [of the OV bike] over the entire journey, it is a cost-effective measure. […] [Users] were only renting the bicycle but they were also well-paying train passengers'.

Land-use planning at hubs enables governments to engage private investors. Because of their strategic locations, hubs are of commercial interest, as revealed by node concepts. Respondent H6 noted: 'There are parties that value the quality of the transport and its surroundings, leading them to choose these locations for their offices'.

The Transferia pilots associated with the P + R scheme provide another example of mutual public–private benefits. The P + R scheme offered the Dutch National Railways novel passenger potential, while simultaneously solving congestion problems for those favouring automobile use. However, this concept also relies on public funds, which some respondents have criticised on the grounds of inefficiency. They argued that the P + R concept enhances the appeal of cars, which, in turn, prompts road transport demands. Given that P + R hubs involve substantial investments, an emerging lesson is that the significance of associated physical infrastructure for achieving policy objectives requires critical evaluation, as pointed out by Respondent H1: 'Improving travel convenience is not necessarily found in massive constructions. Practical and simple solutions may be adequate to establish a modal shift'.

Private cooperation in developing an integrated transport system is important both in historical and contemporary contexts, as competing interests could impede cooperation. Respondent H1 further noted: 'One of the complexities [of MaaS implementation] is the willingness [of the transport sector] to organise customer service, information and ticketing collectively'.

Collaboration between public and private parties is essential for organising service supplies at a hub and delivering an integrated travel product to users. In their study on shared mobility hub business models in the North-Western European eHUBS project, (Coenegrachts et al., 2021) conclude that adverse effects may occur, as integration could entail substitution rather than complementarity, possibly eroding publicly-funded transport services. Furthermore, the interview findings suggest that a positive financial return becomes more realistic as area density increases. Thus, the development of mobility hubs can be challenging in areas with low and dispersed demand.

4.6. Reflection

The expert interviews revealed five historical lessons for implementing mobility hubs. Strategic location choice, mobility systems integration, and flanking policies are technical measures emphasising the effectiveness of attracting ridership through mobility hubs. Understanding the practical implementation through governance structures is often overlooked but requires appropriate policy instruments to reach transport and land-use integrated objectives (Marsden and Reardon, 2017; van Geet et al., 2021). Therefore, one could argue that the multilevel policy coherence and public-private cooperation form an institutional threshold to successfully adopt technical measures into hub policies.

5. Innovations for mobility hubs

So far, our analysis has shown that from the 1960s onwards, Dutch policies attempted to promote multimodal transport favouring individual car use using concepts similar to mobility hubs. Evidently, estimating the utility of mobility hubs in improving regional transport systems is a complex task. However, judging by the current 4%–5% share of multimodal transport in the Netherlands, historical node and place-based concepts did not result in a fundamental shift from individual car use to multimodal transport. Regional differences are evident, as levels of car dependence are significantly higher in rural areas because of greater commuting distances to the sites of daily activities and insufficient public transport compared with conditions in urban areas (Zijlstra et al., 2022).

Four policy objectives in the Dutch Environmental Vision have prompted renewed attention to mobility hubs: environment, economic competitiveness, urban and rural liveability (BZK, 2020). Due to limited space and resource conflicts in densely populated urban areas, the urban environment is under pressure. In such circumstances, a private, carcentric transport system may be unsustainable, given harmful emissions, congestion and safety problems. The provision of sufficient transport alternatives for sustaining inclusive access to sites of daily activities in peripheral regions remains challenging. The disappearance of public transport is likely to foster car dependency, leading to reduced accessibility for captive groups.

To explore how the mobility hub could address prevailing policy objectives from BZK (2020), we first asked respondents to discuss the innovations that drive the current interest in mobility hubs, the respective hub types that may evolve from them, and their distinctive characteristics. We subsequently identified four key innovations also discussed in the literature: shared mobility, mobility as a service, vehicle electrification and DRT. These innovations further exploit the potential of P + R and TOD hubs and are indicative of the emergence of two new hub types: neighbourhood and rural hubs.

5.1. Shared mobility

Two interviewees (I3 and I4) indicated that shared mobility provides additional transport modes to hubs, thereby increasing flexibility and potentially conserving public funds for fixed public transport. Interviewee I1 added that a shift from vehicle ownership to shared use ultimately reduces road congestion, carbon emissions and parking demand and improves the liveability of public spaces. This view endorses that of Shaheen and Chan (2016), whose seminal work indicates that shared modes of transport (e.g. [electric] bicycles, scooters, or cars) enhance the appeal of multimodal trips, which provide travellers with flexibility during the first−/last-mile segments of their trips. Finally, Interviewees I2 and I6 suggested that shared mobility providers could benefit from the hub structure through the provision of designated spaces for parking their vehicles or of dedicated pick-up and drop-off locations. Jorritsma et al. (2021) found that supporting infrastructure in the Netherlands, which may include hubs, can encourage shared mobility.

5.2. Mobility as a service

Mobility as a Service (MaaS) digitally integrates searching, booking and paying processes into existing transport services (Jittrapirom et al., 2017). Three interviewees (I2, I3 and I4) stated that MaaS enables digital integration of multimodal transport offered at the hub. Hence, it could reduce users' 'transfer penalty' at the hub by lowering the associated mental burden (Kenyon and Lyons, 2003; Tang et al., 2011).

Alonso-Gonzalez et al. (2020) showed that multimodal travellers, as potential hub users, have the highest MaaS adoption potential. In conclusion, MaaS facilitates more seamless transfers and decreases trip planning uncertainty for travellers between the transport modes at the mobility hub, depending on the level of integration (Sochor et al., 2018). Vice versa, hubs can enhance the travel options offered at MaaS apps by facilitating operators to run their transport service from the hub.

5.3. Vehicle electrification

Vehicle electrification promotes the transition from fossil fuels to renewable fuels and is a core aspect of policies aimed at reducing transport emissions, as pointed out by interviewee I3. Previous research has shown that the presence of charging infrastructure is crucial for electric vehicle adoption (Morton et al., 2018; Sierzchula et al., 2014). Interviewee I6 argued that mobility hubs could be strategically located to enable connection to the electricity grid for charging infrastructure required for electric buses and cars, e-bikes and e-scooters. From a cost-saving perspective, compared with uncoordinated and dispersed structures, grid connections concentrated at hubs save costs (Csiszár et al., 2019). Interviewee I5 presented an argument for energy generation at hubs through, for example, solar panels and efficient use of this energy: 'a station without escalators needs less power than it can produce. [Through giving energy surplus] back to the environment. […] buses or the village centre around the station [can be supplied]'.

5.4. Demand-responsive transit

Interviewee I3 suggested that DRT operators could use the mobility hub as a designated pick-up and drop-off point for their services. As has been widely reported in the literature, DRT services could replace bus lines with low ridership, especially in areas where the transport demand is low and dispersed (Lakatos et al., 2020; Wang et al., 2015). Hubs can concentrate the demand for DRT services at recognisable waiting locations to provide stop-to-stop operations and increase the quality and efficiency of services. Previous research indicates that the willingness of individuals to share rides hinges on trade-offs of time and cost (Alonso-González et al., 2021). Mobility hubs are the locations where this trade-off is reduced through seamless transfers.

5.5. Reflection

The mobility hub can have different locations and functions within regional mobility systems. This configuration can support the policy objectives of the National Environmental Vision related to the environment, economic competitiveness and urban and rural liveability (BZK, 2020). The innovations of shared mobility MaaS, vehicle electrification and DRT strengthen the potential of mobility hubs to contribute to these objectives. As indicated by the interviewees, along with the TOD and P + R hub, these innovations open the way for the design of new hub types, which are not necessarily limited to the neighbourhood and rural hubs. Fig. 5 presents a conceptual map of additions to the typology discussed in Section 3.3.

5.5.1. Neighbourhood hubs

The neighbourhood hub concentrates shared transport modes at strategic locations within high-density and mixed-use urban neighbourhoods, often as part of urban redevelopment projects. These hubs are smaller than the P + R and TOD hubs, given smaller catchment areas. The most important objectives relating to this hub type are enhanced

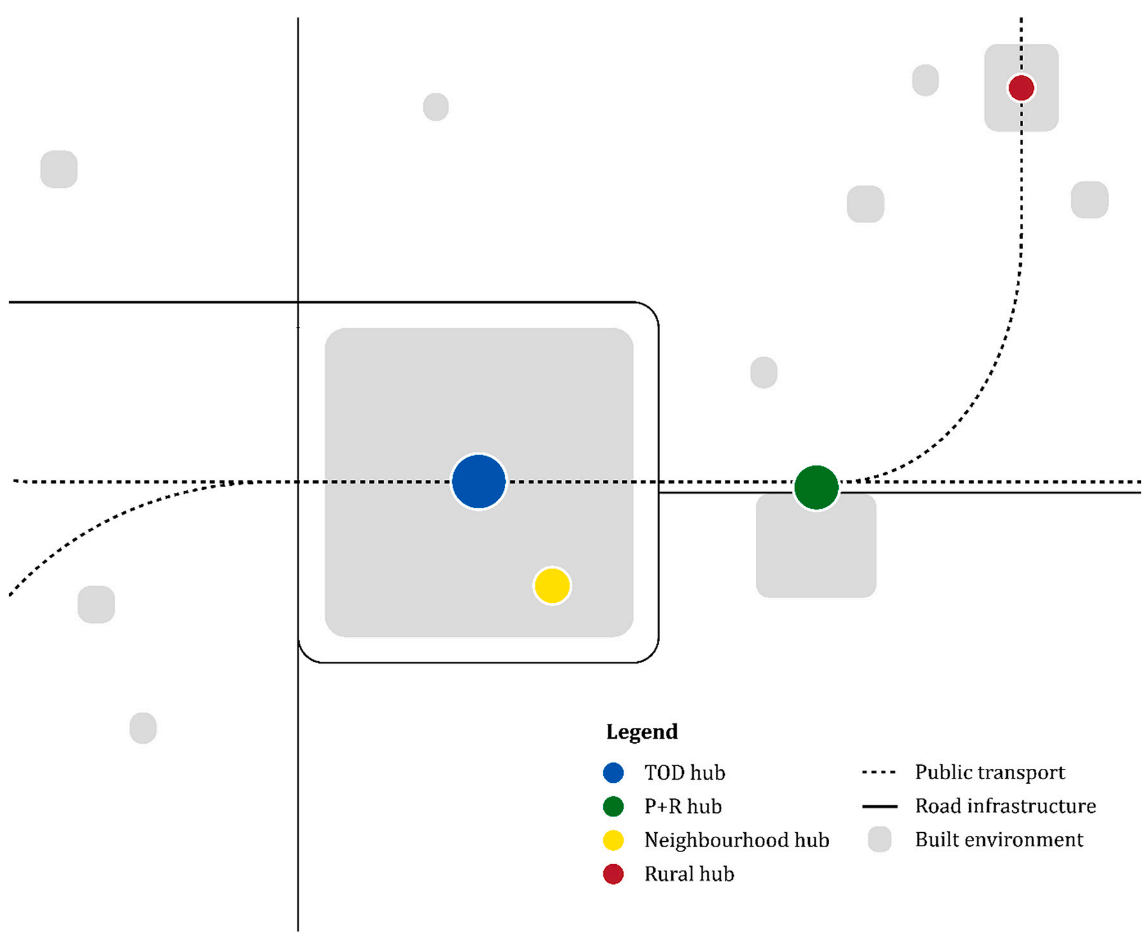

Fig. 5. Conceptual visualisation of the hub typology within existing Dutch policy and planning.

liveability and sustainability. Minimal parking standards at these hubs incentivise residents to commit to distant parking or to abandon car ownership in favour of cleaner and shared mobility alternatives with limited spatial and carbon footprints, to the benefit of residents. The smaller scale of neighbourhood hubs means that they do not always include a public transport stop, unlike P + R and TOD hubs. Instead, they provide shared modes that could be used for unimodal trips or as a first-mile solution en route to a more extensive public transport station. Doing so, neighbourhood hubs provide flexible transport options for citizens not owning a car to facilitate medium- to long-distance trips.

5.5.2. Rural hubs

Rural hubs are regional nodes in rural contexts linking regional train or bus rapid transit services to DRT and shared modes. For public transport companies, these hubs offer a potentially more cost-efficient alternative to a fine-grained linear system with complete geographical coverage in areas with limited and dispersed travel demand. For travellers, bundling transport flows leads to more frequent and faster public transport services, which travellers value higher than direct connections despite longer first and last-mile transport and additional transfers (Bakker, 2018). Rural hubs also offer potential liveability gains, meeting a second policy objective, as the hub-generated traffic can strengthen the viability of (public) facilities in areas experiencing a demographic decline. Vice versa, integrated existing facilities with the hub improves travel comfort against limited cost. Distinctive features of these hubs are their locations in low density areas, the integration of transport policies with liveability policies, and the DRT integration.

6. Conclusion and discussion

We examined historical policy documents and conducted expert interviews to analyse the mobility hub as a policy concept. We aimed to address three research questions: (1) How can the evolution of the mobility hub be traced through related historical policy concepts? (2) What historical policy lessons from these concepts can inform the future implementation of mobility hubs? (3) How can innovations in the transport sector advance the mobility hub to achieve current policy objectives?

Our document analysis and expert interviews revealed six historical policy concepts applied within Dutch national transport and land-use planning, with close parallels to node and place dimensions of mobility hubs. Node-related concepts focus on reducing resistance to transfers between collective and individual transport modes, whereas place-related concepts complement nodal concepts by managing the spatial distribution of travel demand. Overall, implementation of these concepts has been aimed at promoting efficient use of scarce space, economic competitiveness, reducing the adverse effects of individual car traffic and achieving cost-efficiency through bundled transport flows. Our findings show that the TOD and P + R hubs are the predominant historical types combining interacting node and place characteristics.

We identified five lessons from historical concepts related to the mobility hub. First, the location of a mobility hub relative to important traveller destinations determines the relative advantage to opt for a multimodal transfer. Therefore, policy objectives can vary for different hub types. Secondly, mobility hubs can attract a share of the travel demand if designed as part of an integrated mobility system to improve user experience and reduce the transfer burden. Given the early developmental stage of some hub types, insights into the key service attributes can assist policymakers to incentivise travellers to use hubs. Thirdly, flanking policies are an important determinant of the effectiveness of mobility hubs in relation to policy objectives. Fourthly, policy coherence relating to mobility hubs is required across different levels of authority to move beyond small-scale and short-term interests that may adversely affect higher-scale objectives. Lastly, cooperation between public and private parties is key to organising transport and land-use supplies at a hub.

The lessons from the expert interviews and the characteristics of the Dutch context may influence the high expectations of transport innovations for supporting hub policies in urban and rural contexts. The impacts may be context-specific and country-specific, requiring careful international transferability interpretation. To illustrate the Dutch context, we raised the issue that historical attempts to implement hub concepts only led to 4–5% multimodal trips (Hamersma and de Haas, 2020). For example, the traditional role of the bicycle in the Netherlands is critical for unimodal trips and as a feeder to public transport (Jonkeren et al., 2021). Given this bicycle-oriented tradition, authorities are hesitant to facilitate micromobility as a first- and last-mile solution as these may substitute bicycle trips. For unimodal trips, this is already the case with the e-bike (de Haas et al., 2022). However, several recent international studies show that these electric modes can provide first-last-mile solutions to public transport hubs (e.g. Baek et al., 2021; Chicco and Diana, 2022). This illustrates that mobility hubs are only instrumental in reaching context-specific objectives, which might differ elsewhere.

We further found that the configuration of a mobility hub should ideally stem from its underlying policy objectives, with form following function. Urban and rural liveability have gained prominence within the transport policy discourse in the Netherlands and elsewhere. To assess how the mobility hub can address these challenges, we explored ways in which four innovations from the transport sector identified during expert interviews, namely shared mobility, MaaS, vehicle electrification and DRT integration, could provide opportunities for advancing the mobility hub concept. We also outlined the features of two hub types, neighbourhood and rural hubs, emerging from these innovations.

The mobility hub, as postulated in various policy and research reports internationally, is not a new concept. Our analysis from the Netherlands shows that longstanding hub types such as the TOD and P + R hub are firmly rooted in historical land-use transport coordinated concepts, from which this paper drew several lessons for implementation. However, due to the urgency to address environmental and liveability issues in urban and rural areas, there are high expectations of shared mobility, MaaS, vehicle electrification and DRT for unlocking the potential of mobility hubs to stimulate multimodality. The extent to which these innovations will gain mass adoption among specific users and in specific spatial contexts remains uncertain, and with that, the use of mobility hubs. For instance, shared mobility and MaaS are currently mainly used in urban environments by young and highly educated people (Durand et al., 2018). Future adoption and research must show whether transport innovations are facilitators of multimodal transport via hubs.

This longitudinal study has illustrated the development of various mobility hubs throughout Dutch planning history. Our findings can equip planners with preliminary guiding inputs for implementing a promising policy concept, while building on its historical roots by projecting historical lessons and the potential impacts of transport innovations on different mobility hub types. They suggest several research directions for the implementation of mobility hubs. Firstly, future research can illuminate public–private cooperation for developing mobility hubs in low density areas where returns on investments are insecure. Secondly, insights into the effects of flanking policies targeting different elements and levels of regional transport systems can strengthen stakeholders' support to engage in hub implementation.

CRediT authorship contribution statement

Tibor Rongen: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Visualization. **Taede Tillema:** Conceptualization, Supervision, Funding acquisition. **Jos Arts:** Conceptualization, Supervision, Funding acquisition. **María J. Alonso-González:** Investigation. **Jan-Jelle Witte:** Investigation.

Declaration of Competing Interest

The authors declare no competing interests.

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Appendix A. Respondents' backgrounds

Interview round	Code	Background
Expert interviews	H1	University employee
	H2	University employee
	H3	Provincial employee
	H4	Ministry employee
	H5	Ministry employee
	H6	Consultant
Frontrunner interviews	I1	Consultant
	I2	Consultant
	I3	Consultant
	I4	Shared mobility provider
	I5	Railway company employee
	I6	University employee

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