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Publication date
2022

Document Version
Final published version

Citation (APA)
Toet, A., van Kuijk, J. I., & Santema, S. (2022). *Transforming Airport Hubs into Future-Proof Multimodal Transport Hubs*. Paper presented at Relating Systems Thinking and Design (RSD11) Symposium, Brighton, United Kingdom. https://docs.google.com/document/d/1dIFoJpGGmj4TwHmm6f6_O07k2T1GUXhR-8dnpvKgJIQ/edit

Relating Systems Thinking and Design
2022 Symposium
University of Brighton, Brighton, UK,
October 13-16, 2022

Transforming Airport Hubs into Future-Proof Multimodal Transport Hubs

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Developments in sustainability and digitisation outline a future of mobility, with multimodal transport becoming the new normal. Travel modalities will no longer be the focal point of mobility, but passenger experiences and the services that provide these will. In a mobility landscape, the passenger experience is key, and multi-leg trips are the norm. Multimodal Transport Hubs are essential players as they can facilitate high-quality intermodal transfers for passengers. However, this advanced application of Multimodal Transport Hubs does not yet exist in practice.

By employing a scoping review, this research approaches the transformation from an airport hub into a Multimodal Transport Hub, as airport hubs physically unite several transport infrastructures but only offer transfers with high-quality services within air traffic and not to, from and between other modalities.

Because airport hubs have features such as a complex stakeholder landscape, long development times, reliance on independent transport operators and uncertainty about the added value of integrating new travel modalities, modality innovation at airport hubs can be perceived as a systemic design challenge. This research identified a lack of theoretical knowledge regarding harnessing and integrating alternative modalities at airport hubs to transform them into fully integrated Multimodal Transport Hubs.

Keywords: mobility, transport, multimodal, hubs, airport hubs, innovation

RSD: Sociotechnical Systems

Introduction

The complex systems of transport and mobility are developing fast, and two important trends are more sustainable forms of mobility and increasing digitisation (Ceder, 2021; Lyons, 2018). First, society's increasing demand for sustainable solutions is significant for the mobility industry. For example, fossil fuels are replaced directly by biofuels and indirectly by electric, hydrogen, and solar technologies. Second, the advent of digitisation, powered by Information and Communication Technologies (ICT), sweetens the mobility system by making passenger travel faster, cheaper, safer, and more efficient (Ceder, 2021). These trends result in new modalities often characterised by CO2 neutrality, autonomy, sharing and connection (Nikitas et al., 2020; Docherty et al., 2018; Sprei, 2018; Kane & Whitehead, 2017).

Transport modality innovations based on new technologies are subject to long feasibility timelines. It often also involves the construction of entire (eco)systems, including infrastructure and new stakeholders, making implementation more difficult because significant investments and complex development and construction processes are involved. Examples are illustrated by the improbability of a shortly, full-scale launch of autonomous vehicles and the hyperloop concept (Nikitas et al., 2017). In other respects, the technological feasibility of electric vertical take-off and landing aircraft (eVTOLS) has been partially validated. However, many potential barriers must be overcome before full-scale implementation can be reached (Cohen et al., 2021). We conclude that assessing new and alternative travel modalities and selecting the appropriate ones is challenging due to a complex stakeholder landscape, with long innovation timelines, in the context of a complex mobility system undergoing continuous and significant changes.

The developments in the mobility industry are more drastic than just incremental innovations because they give the use and application of mobility a new meaning in some cases. One of the principal systemic changes currently affecting the mobility system is the Mobility-as-a-Service (MaaS) concept, which proposes a future mobility system that offers a subscription where passengers can book a personalised service in which a range of travel modalities are bundled (Canale et al., 2019; Hensher, 2017). Under the MaaS proposition, “transport will be increasingly organised around the ‘service’ of mobility rather than the ‘medium’ (modality) to be used” (Canale et al., 2019, p.7). In other words, the passenger’s experience and service are put centre stage instead of the mode of transport.

In addition, transitions to a future mobility system are characterised by other features that bring about more than just improvements to the system. Namely, the infusion of the mobility system with passenger information via ICT (Lenz & Heinrichs, 2017; Docherty et al., 2018) and the adaption of transport schedules to travellers' needs creating the option to choose from multiple trips (Porter et al., 2015). These features reinforce the importance of multimodal future travel journeys emphasising greater passenger convenience and comprehensiveness (Docherty et al., 2018). Multimodal transportation is "an organic combination of two or more modes of transport. It captures and integrates the advantages of various modes of transportation and is an advanced mode of transportation" (Huang & Mu, 2018, p. 256).

The mobility industry can be perceived as a high-order system that consists of multiple subsystems based on different transport modalities, such as planes, trains, buses and bicycles. Travellers change modality at the intersection of these transport systems in so-called transit hubs, defined as the gathering point of various travel modalities (Li & Xu, 2019), such as airport hubs, rail hubs, or public transit hubs. The rise of multimodal travel highlights the importance of paying attention to the intersections of transport subsystems and accordingly creating well-organised Multimodal Transport Hubs (MTHs) (Rongen, 2020), as confirmed by the EU Commission that states "...airports, ports, railway, metro and bus stations, should increasingly be linked and transformed into multimodal connection platforms for passengers" (European Commission, 2011, p.6). MTHs are designed to merge the services of several modalities at specially designated locations (Anderson et al., 2017). A systemic design perspective may support the transformation of current transit hubs into MTHs as multiple transport subsystems will be united in one high-order system at the MTH (Jones, 2020).

Airport hubs have the potential to transform into MTHs as they bring together different modalities. But, concerning service integration (e.g., ticking, reservation, information, planning), they only focus on linking one dominant mode, namely airplanes. However, there is considerable societal pressure to reduce air travel and, where possible, opt for more sustainable modes of transport. To illustrate, the European Commission decided upon legislation regarding 2050 targets, e.g. using low-carbon sustainable fuels within air transport and substituting the majority of medium-distance passenger transport with rail transport (European Commission, 2020).

These developments, on the one hand, pressure air travel to and from airport hubs. On the other hand, they offer an opportunity for airport hubs to start linking and truly integrating more different transportation subsystems. For airports to remain a relevant element in the mobility system and to facilitate and stimulate the transition to a new, more societally responsible transport system, their current function as a transit hub focusing mainly on air travel should be reshaped into an MTH that unites existing transport flows and incorporates new transport modalities into its business, serving passengers in their journey.

By employing a scoping review, this research aims to provide insight into the available literature about the transition of airport hubs into a multimodal future and associated systemic design perspectives by answering the question: *What is known from existing research about multimodality innovation for futures at airport hubs?*

The rest of the paper is structured in four parts. The first chapter outlines the method employed in this research. This is followed by a section in which the main themes and results of the literature are discussed. The third section summarises the results in a discussion. In the fourth and final section, we outline implications for further research.

Method

To gather the insights presented in the remainder of this paper, we used a scoping review approach, which helps to identify gaps in existing literature, following the methodology as applied by Arksey & O'Malley (2005). A scoping review is an iterative approach, which makes it possible to include newly acquired knowledge in the literature search (Arksey & O'Malley, 2005).

As a starting point, the research question has been divided into critical keywords, respectively "Multimodal Transport Hubs", "Multimodality at airport hubs", and "Airport hub innovation". Table 1 presents an overview of the themes, keywords, synonyms, and literature questions applied in the scoping review. The scoping review will finish with a separate section on previous systemic design practices to complement the reviewed literature in this research.

Table 1. Overview of the search strategy applied in the scoping review.

Research question	**Key parts research question**	**Literature questions**	**Themes**	**Keywords**	**Synonyms**
What is known in the existing literature about multimodality innovation for futures at airport hubs?	multimodality hubs	*What is the definition of Multimodal Transport Hubs ,and what will be their role in the future?*	Multimodal transport hubs	Multimodal transport; hubs; definition	Intermodal; centre – station – airport – node; characteristics – explanation - interpretation
	Futures at airport hubs	*Why should and how can airport hubs prepare for the multimodal future of mobility?*	Development of airport hub into MTH	Multimodality; airport; development	Intermodal; transformation
	Airport hub innovation	*What are the traits of airport innovation?*	Airport hub innovation	Airport; innovation	Large organisation; drivers and barriers

Initially, the search strategy examined perfect matches of keywords in the titles of the papers, and in case of no results, articles were content-wise reviewed for keyword matches. We limited the search to papers in English, published after 2015 and accessible through the electronic database Google Scholar. A backward snowballing strategy, using the reference list to identify new relevant papers (Wohlin, 2014), subsequently led to other electronic databases and, in some cases, to well-known and highly cited papers published earlier than 2015. The relevance of the papers was assessed by matching paper abstracts with the stated literature question.

Multimodal Transport Hubs

In literature, there are several meanings and definitions associated with the term Multimodal Travel Hub (MTH) (Rongen, 2020), which we need to map to understand what properties airports should acquire to transition to truly multimodal transport hubs.

Current transit hubs are designed by considering different transport modalities, resulting in a unique classification of modalities for each transit hub (Heddebaut & Palmer, 2014). At airport hubs, modalities are classified according to land- and airside modalities, whereby airside modalities are separated by passport and security checks (Marquez, 2019). Railhubs offer land modalities and cover long distances and cross borders. Public transit hubs are often regionally focused and merely connect to modalities on land (Calzada-Infante et al., 2020).

However, the emergence of new land- and airside modalities invalidates current classifications and may not apply to future MTHs. Consider the example of the high-speed rail (HSR) that appears at airport hubs, which may require passengers to pass through security and passport controls due to border crossings, which were previously only required to enter the airside (Jones et al., 2020). Meanwhile, air transport innovations such as electric aircraft, hydrogen planes, and urban air mobility are expected to be feasible in the short future (Schäfer et al., 2019). Therefore, air transport may become bound by fewer rules, as it will increasingly cover distances within national borders and, therefore, no longer demands passport checks.

Because the properties of and demands on MTHs are highly dependent on the type of modalities they integrate, based on the literature review, we created a classification of transport modalities that is applicable to MTHs. Namely: 1) ultra-long, 2) long, 3) medium, and 4) short hauls (see the top row in Table 2). First, modalities that are classified as ultra-long distances typically range from 5000 to 10.000 km and include international travel, in most cases overseas, and the associated means of transport are mostly planes (Pirie, 2016) and boats. Second, long-haul modalities typically range from 200 to 5000 km across borders of countries or states, wherein air transport is a common modality, besides the most common alternative of HSR (Pirie, 2016). Third, medium-distance modalities cover ranges from 50 to 200 km and include, for example, railway and bus lines (Metelka & Janos, 2021). Following this, for the purpose of this research, we define local scales as travel modalities within a range of 50 km.

In addition to a range-based categorisation of modalities, Table 2 also provides a typology of passenger transit hubs that we recognise in literature and distinguishes between types of modalities, typical range and crossing international borders. Although all scales of modalities unite at seaports, this type of hub is excluded from this research for two reasons: firstly, passengers do not have to transfer during their ultra-long trip (which is often a cruise trip), and secondly, long-distance travel by boat takes many days or even weeks.

In the coming years, we anticipate the emergence of new travel modalities exclusively for long, medium and short distances. We thereby consider ultra-long-haul modalities as constant, namely airplanes and boats. Long and medium distances will include existing modes of transport (like planes, boats, rail, buses and cars) and innovations such as electric planes, eVTOLS, hyperloop and self-driving cars (Nikitas et al., 2017).

Table 2. Overview of passenger transit hubs by distinguishing between the types of modalities, typical range and border crossing.

		Scales			
		Ultra-long (e.g. airplanes, boats)	Long (e.g. airplanes, boats, high-speed rail, trains)	Medium (e.g. high-speed rail, train, ferry, bus, car)	Short (e.g. car, bus, metro, motorbike, bike, ferry, scooter)
	Crossing international borders	International	International/national		Local
	Typical range	5000-10.000 km	200-5000 km	50-200 km	< 50 km
	Examples				
Seaport	Seaports for passenger travel are often used for cruise activities (Jeevan et al., 2019).	x	x	x	x
Airport hubs	Top worldwide airport hubs ranking in 2022 regarding connectivity: FRA, IST, AMS, CDG, MUC, LHR (Airports Council International Europe, 2022)	x	x	X	x
Regional airports	For example, the smaller airports in the Netherlands: Rotterdam The Hague Airport, Eindhoven Airport and Lelystad Airport (Schiphol|regional airports, 2022)		x	X	x

Railway hubs	Examples of railway hubs: Berlin Central Station, Zürich Hauptbahnhof, and Amsterdam Central Station (Calzada-Infante et al., 2020)		x	X	x
Public transit hubs	Where the switch can take place from regional and national public transport to urban public transport and vice versa. (Gemeente Amterdam, 2021).			X	x
Regional hubs	The place where the transfer takes place from car to public transport or shared mobility, such as Park + Ride (Karamychev & Van Reeven, 2011)			X	x
Neighbour-hhood hubs	A neighbourhood hub is a collection of individual emission-free transport which primarily residents can use (Gemeente Amsterdam, 2021; Schreier et al., 2018).			X	x
Micromobility hubs	An example is given by the Citi Bike station (Kaufman et al., 2015)				x

Infrastructure and service integration

Prior research state that successful MTHs integrate both infrastructure and service elements (Bell, 2019; Monzón et al., 2016; Chauhan et al., 2021). With the infrastructure integration of multimodal transport, we mean the facilities required to operate the transport modalities (such as railways, highways, and runways) and connecting elements such as buildings and moving walkways (Li & Loo, 2016; Canale et al., 2019). The service quality of MTHs from the passenger perspective refers to services that facilitate a seamless interchange between multiple modes of transport, like "...transfer environment, accessibility, signposting, safety, security, public utilities, comfort & convenience, etc." (Chauhan et al., 2021, p. 48). High-quality service can be achieved when transaction, reservation, information and planning services from different modes of transport are integrated (Veeneman et al., 2020). In a future that emphasises the mobility experience and the services that provide them, rather than the individual travel modalities, MTHs should facilitate high-quality intermodal transfers, which also means improving the integration of services (Chauhan et al., 2021).

One example of existing transit hubs that offer a simple service are the Park + Ride service, "P + R facilities integrate the private car into the public transport system" (Karamychev & van Reeven, 2011, p.455), and the Dutch OV-chipkaart public transit card which integrates ticketing and transactions for intermodal public transport journeys within the Netherlands (Joppien et al., 2012). However, in the event of delays or cancellations, the traveller is in the lead of creating an alternative trip. In that respect, railway hubs, public transit hubs and the Park + Ride service score low on the integration of passenger services.

Figure 1 shows an overview of the positioning of current transit hubs according to the number of combined travel modalities and the degree of passenger service integration. The conclusion can be drawn that despite the increasing need for service-supported multimodal journeys, existing transit hubs do not integrate infrastructures and services of multiple travel modalities to facilitate a seamless passenger-oriented intermodal transfer. We argue that transit hubs need to move to the upper right corner of the figure because complete infrastructure and service integration of several travel modes enhances the poor guidance of unplanned interruptions to the multimodal journey (Donners, 2018) and the overall quality of the transfer.

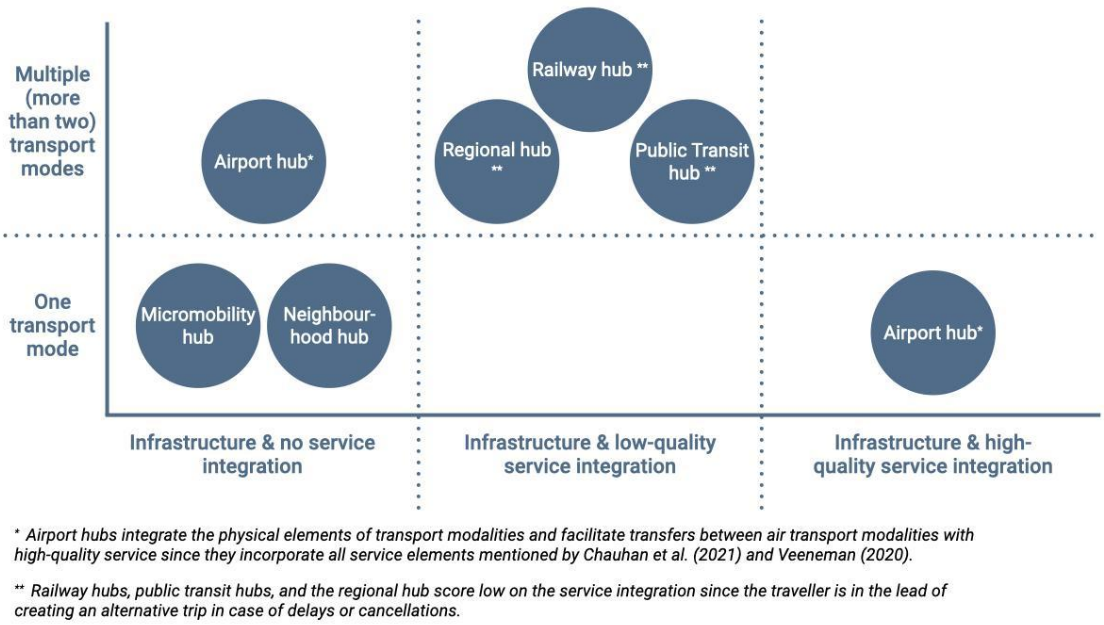

Figure 1. Degree of multimodal integration at transit hubs. The vertical axis represents the number of travel modalities at the transit hub, and the horizontal axis shows the infrastructure and service integration degree. High-quality service is met if all the elements mentioned by Chauhan et al. (2021) and Veeneman et al. (2020) are integrated.

Airport hubs

Airport hubs, the exclusive players to include ultra-long-distance modalities, do not score high on passenger service integration of multiple modes in Figure 1. An explanation is that (ultra-)long distances are inherently inflexible (Araghi et al., 2022), as they require pre-booked trips due to high costs and the involvement of multiple stakeholders. Instead, short distances are much more flexible for different reasons. So these two transport ranges, ultra-long-distance modalities versus short-distance modalities, have entirely different working practices. Therefore, cooperation between airport hubs and transport operators of each scale is necessary to integrate services of all modalities. These partnerships can ensure smooth passenger transfers whereby new journeys are automatically created in the event of congestion, e.g. a train delay leads automatically to a flight rebooking, which is currently merely happening in rare cases (Donners, 2018; Li et al., 2018).

Next to that, the increasing demand for sustainable transport puts extra pressure on airport hubs. Fortunately, airports' coverage of all modality ranges offers opportunities to create connections between ultra-long and long/medium scale modalities and substitute high-emission transport with alternative modalities.

This research focuses on airport hubs that fall under the Hub-and-spoke model, in which the hub collects passengers through long and medium-distance flights at small airports (spokes) and then transfers them to ultra-long flights (Zgodavová et al., 2018). The central hub in this model has the most potential to become a long-haul MTH with new modalities due to the presence of all modality ranges. The greatest challenge and impact lie in a shift from air transport to alternative travel modalities at long and medium distances, as argued above.

Development of airport hubs into MTHs

More knowledge is required on developing airport hubs and MTHs to guide us with a systemic design approach in helping airport hubs transition to an MTH.

Airport hub development

The continuous development of existing airports is not effortless. Chwiłkowska-Kubala & Huderek-Glapska (2020) are among the few to research the barriers to airport improvement by distinguishing between internal and external barriers. They categorise the internal barriers to airport improvement into management, organisational structure and finances. First, airport management plays an essential role in strategic decision-making processes. Second, the organisational structure is a barrier to airport development when there is a lack of good ownership, political involvement, safety regulations and handling activities. Third, financial aspects such as high costs and high time-intensiveness of investments are bundled into the financial barrier. Furthermore, airport hubs are occasionally forced to develop their infrastructure without knowing future needs.

Next to internal barriers, Chwiłkowska-Kubala et al. (2020) note external barriers to improving airport hubs, including the restriction on infrastructure expansion and the complex stakeholder field. They show that the air transport sector is bound by fixed procedures, and according to the theory of architectural knowledge (Henderson & Clark, 1990), this hinders organisational change.

These barriers signify that the airport hub cannot be flexible regarding innovations due to its organisational structures and external barriers. Complex systems like airport hubs must “allow the path forward to reveal itself” (Snowden & Boone, 2007) since they deal with incomplete information and elusive answers. Therefore, airport hubs must seek early engagement with future societal developments and trends, technological innovations, new modalities, and transport services to prepare in time for possible futures.

MTH development

MTHs, similar to airport hubs, deal with limited time to absorb new technologies (Gil et al., 2011), know long development lead times, and have many stakeholders slowing down the innovation process (Yatskiv & Budilovich, 2017).

Specifically, to transform into an MTH, transport operators should work together through shared development strategies and information systems to accelerate the efficiency of multimodal transport (Zhang et al., 2018). Moreover, MTHs must connect travel modes' networks and arrange information facilities, create short walking and times distances, and handling of luggage between the modes of transport (Janic, 2011). Barriers are the regulations between different mobility stakeholders, different design standards among transport operators, incomplete infrastructure, high development costs, absence of open information interfaces, and lack of integrated operations (Li & Loo., 2016; Huang & Mu, 2018).

When former competitors and stakeholders with conflicting needs are brought together with systemic design practices, and, for example, operational coordination, integral tickets, and interchange discounts are realised, those barriers might be combated (Li & Loo, 2016).

Airport innovation

This sector delves deeper into the traits of airport innovation to understand the setbacks of innovation at airports, which are characterised by the Innovator's dilemma (Christensen, 1997), open innovation process (Chesbrough, 2003) and uncertain futures at airports.

Innovator's dilemma at airport hubs

Airport hubs can be regarded as large - and often established - companies that are good at their core business. As a result, their architectural knowledge tends to become embedded in their organisation's structure, making them slow and inflexible in innovation (Henderson, 1990). However, airport hubs must reorganise their business if they want to incorporate new modalities into their portfolio, also referred to as architectural innovation (Henderson, 1990). The phenomenon at play here is the Innovator's dilemma introduced by Christensen (1997), which says that large, established firms have difficulty adapting to new markets, allowing new and small firms to drive business away.

A critical nuance is the distinct position of airport hubs compared to large organisations, referred to by Henderson (1990) and Christensen (1997). Airport hubs are characterised by long development times, physical capacities, stakeholders, and capital (Chwiłkowska-Kubala et al., 2020). Therefore, it is implausible that a small start-up could quickly grow into a large airport hub. However, airport hubs still must consider two threats to their position. Firstly, suppose airport hubs refuse to see the potential of modality innovations. In that case, mobility operators may develop into a market in which airport hubs will become irrelevant, such as the emergence of vertiports at locations other than airports (Tripathi et al., 2022). Next, airport hubs risk that rival airports will successfully facilitate modality innovations, such as the air-rail case in Frankfurt (Li et al., 2018).

Open innovation at airports

Airport hubs depend on mobility operators for infrastructure and service integration of modes of transport, as the airport hubs only have a facilitating role. Due to this reliance, modality innovation at airports, and in general also at MTHs, needs traits of the open innovation approach that advocates collaboration with external parties (Chesbrough, 2003). Large companies that struggle with radical innovations can shift into new industries through open innovation. This also applies to airport hubs since a continuous engagement with external innovations supports airport hubs in innovating for the future (Sune & Gibb, 2015).

Chesbrough describes open innovation as "innovation that is generated by accessing, harnessing and absorbing flows of knowledge across the firm's boundaries" (Chesbrough, 2017, p.35). Airport hubs must be aware and have access to alternative modalities, then be able to assess and choose (harness) the promising modalities and finally find a way to absorb new modalities within the organisation smoothly.

Innovate for futures

The long development times of infrastructure at airports and new modalities, combined with the uncertain future of mobility, make it challenging for MTHs to decide which travel modalities to engage with. In complex systems such as airport hubs, we cannot predict what future we're heading towards, partly because the external conditions are constantly changing (Snowden & Boone, 2007). A possible way to deal with this is to take possible future scenarios into account (Medvedev et al., 2017). To support the development of scenarios, organisations often apply a foresight approach, in which a future joint vision is established through an iterative approach (Cassingena Harper, 2003). Working towards futures in complex contexts is a challenging activity in which it is especially important to observe patterns develop and estimate their potential value (Snowden & Boone, 2007). One way of dealing with this ties in with Chesbrough's (2017) activity of harnessing external knowledge, namely "to probe first, then sense, and then respond" (Snowden & Boone, 2007).

Other methods that can be thought of that may be interesting for approaching an uncertain future are the creation of visions (Corwin et al., 2020) and frames (Bergman, 2017).

Systemic design perspectives & approaches

The above literature highlights several properties of transforming an airport hub into an MTH and suggests that such a transition may benefit from a systemic design approach. First, the literature shows that multimodal travel hubs have properties of complex systems, as they consist of many dynamically related elements (Snowden & Boone, 2007), and they even integrate entire subsystems (Jones, 2020). Secondly, consequently, many stakeholders are or need to be involved in changing the system (Jones & Ael, 2022). Thirdly, the challenge involves contributing to changing the current mobility system around airports into a new system, which means a transition from a steady state to a new, initially ill-defined, more desirable state (Loorbach 2022). And fourth, the desired future state of the new system, the MTH, is uncertain and will most likely emerge over time (Snowden & Boone, 2007). All these properties of the challenge at hand (embracing complexity, multi-stakeholder, transition and uncertainty) align very well with a systemic design approach. Jones and Ael (2022, P.3) suggest applying systemic design practices because of its holistic view that integrates "design, research and method skills for complex contexts".

Many systemic design practices may be relevant to addressing this phenomenon. For example, established methods have been carried out in similar contexts, such as the antifragility at MTHs (Nieuwborg et al., 2021) and the interconnection of transportation systems (Jehn & Rae, 2015). Questions that can be answered are "how to create high-quality transfers", "how to incorporate stakeholders' conflicting needs", and "how to seek early engagement with future innovations".

In addition, systemic design can offer critical perspectives with regard to the necessity and desirability of transforming airports into multimodal hubs and whether or not there are more desirable and responsible paths to be taken.

The reviewed literature on airports and mobility presumes that airport hubs should seek to maintain their dominant position in the mobility industry. Nieuwborg et al. (2021) emphasise the role that MTHs play in the spread of viruses at an international level. An exciting paradox occurs here that points us to a holistic, systemic design approach in which antifragility might be a condition for MTHs. One may even wonder whether it is necessary and desirable to have dominant airport hubs or MTHs. In recent years, the trend of flight shame has increased, perceiving air travel as bad (Flaherty & Holmes, 2020). Though we would argue that transforming airport hubs into truly integrated MTHs is likely to increase the uptake of other transport modalities than air travel for the medium and short haul. And that a considerable part of the learnings of transforming airports into truly integrated MTHs, can also benefit the development of other and new MTHs.

The work of Nieuwborg et al. (2021) shows how a difference in perspective leads to a different elaboration of future research possibilities. They describe airport hubs as MTHs, but we argue that MTHs do not yet exist due to a lack of infrastructure and passenger service integration of multiple travel modes. Our different point of view creates opportunities for future research in this particular mobility system.

A practical approach to this phenomenon, similar to design processes due to its iterative nature, is Action Research (AR). According to Greenwood & Levin (2007, p.54), "AR rests on the premise that reality is interconnected, dynamic, and multivariate and always more complex than the theories and methods that we have at our disposal." Knowledge is collected in AR through a circular and participative process, stimulated by questions and problems that relate to existing contexts (Scaratti et al., 2018). Insights and knowledge resulting from the AR cycles may lead to an intervention that supports airport hubs in making thorough and substantiated decisions in their transformation.

Conclusion

The raison d’être of this paper originates from developments in the mobility industry and environmental burdens that pressure airport hubs to transform into MTHs. A scoping review was conducted to uncover the literature on multimodality innovation for futures at current transit hubs, particularly airport hubs.

This produced several primary insights. First, there is the increasing importance of MTHs facilitating a passenger travel mode interchange that includes both infrastructure and passenger service aspects. Airport hubs were identified as an interesting case to transform into a passenger-oriented MTH if they incorporate relevant alternative travel modalities into their business.

However, three elements make the transition to an MTH complex. First, airport hubs deal with complex ecosystems and long development times of infrastructure. Hence, airport hubs must commit to alternative modalities on time. Second, the uncertain future of the mobility industry and the long development times of infrastructure and new modalities make it challenging to understand which modalities will be relevant in the future. And third, airport hubs depend on modality operators and are therefore bound to partnerships to gain insight into the potential value of modalities and provide intermodal transfers at a later stage.

This research identified a knowledge gap regarding transforming airport hubs into MTHs that facilitate intermodal passenger transfers by accessing, harnessing, and absorbing modalities into the existing business.

Future research

Future research, among which in practice, should be conducted to discover what high-quality services entail and contribute to the development of better techniques for modality engagement for airport hubs. This research suggests applying a systemic design approach to arrive at impactful and important theories, frameworks, methods or tools. Action Research is a suitable approach for follow-up work to arrive at a selection of criteria, the appropriate level of engagement and the degree of absorption with new modalities at airport hubs. In particular, it is interesting to investigate what high-quality intermodal transfers entail, methods for MTHs to strengthen the formerly critical transfer points, strategies to work towards uncertain futures from the airport's perspective and approaches to unite conflicting needs of stakeholders. In addition, we want to encourage future work to take a critical look at the attitude adopted in the researched literature. We are particularly curious about more work examining the position of airport hubs in the future. In addition, we encourage critical work on the ambition to transform airport hubs into multimodal hubs instead of making air traffic more sustainable.

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