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Innovation strategies for non-existent markets - Profiting from urban air mobility

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ABSTRACT

Technological advances have paved the way for urban air mobility (UAM) as a new mode of transportation, providing solutions for both inner-city and regional transportation. Novel vertical take-off and landing (VTOL) vehicles promise to be less noisy and safer than existing helicopters, thus allowing for an integration of UAM into current mobility systems. However, as this market is non-existent today, companies engaged in this field face several uncertainties. Strategic decision factors supporting VTOL manufacturers to successfully commercialize their innovation are still mainly unassessed. Looking into the innovation strategy literature we find little guidance on how high-technology companies can profit from innovation in so far non-existent markets. We therefore conduct expert interviews that allow us to identify eight decision factors that VTOL manufacturers are expected to take into account when setting up their commercial strategy. Building on the findings from these interviews we suggest to enhance the Profiting from Innovation (PFI) framework by a peripheric sphere that incorporates the impact of external factors on commercial success. This approach on the one hand, allows to provide insights into strategic management approaches of VTOL manufacturers, while on the other hand, this research adds to the scientific literature on strategic decision factors in non-existent markets.

1. Introduction

The emerging urban air mobility (UAM) industry has gained much attention from both daily press and scientific literature. Large investments and initial public offerings (IPO) as well as special purpose acquisition companies (SPAC) have stimulated the public debate about manufacturers of vertical take-off and landing (VTOL) vehicles. Besides the large media coverage, academic scholars from various disciplines have examined this novel mode of transportation (Zhou et al., 2019; Silva et al., 2018; Fredericks et al., 2018; Rothfeld et al., 2018; Shamiyeh et al., 2018; Vascik and Hansman, 2017; Al Haddad, Chaniotakis, Straubinger, Plötner and Antoniou, 2020). However, most of the existing literature focusses on one distinct aspect such as technological, regulatory, operational or infrastructural issues and public acceptance. Yet, little research has been conducted on the challenges faced by vehicle manufacturers, particularly with regard to strategic decisions such as appropriability and complementarity. This notion is also echoed by Straubinger et al. (2020) who highlight the missing business perspective of the UAM industry.

This research focuses on the manufacturer of UAM passenger vehicles from a business strategy perspective. As the associated technological composition of the vehicle and the resulting vehicle design and service is intended to create a new, so far non-existent market, it represents a radical disruptive innovation (Bower and Christensen, 1996; Henderson and Clark, 1990). Therefore, the business perspective of the VTOL manufacturer as the innovator is analyzed based on the literature on innovation strategy. Within the field of innovation strategy literature, we build on the Profiting from Innovation (PFI) framework by Teece (1986) and aim to extend it as current strategic management literature, even in the field of innovation, focusses on developments in existing markets disregarding non-existent markets.

The core research question of this contribution is: which decision factors need to be considered by key innovation leaders when entering an undefined high-technology market environment (such as UAM) in order to be commercially successful? In order to answer this question we apply a qualitative approach with an exploratory focus on experts' behavior and opinion (Saunders et al., 2019). Contrasting our findings with the existing PFI framework we identify factors so far not

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acknowledged in the framework and extend the framework accordingly.

As constructivist grounded theory is applied, this research is based on individual opinions and interpretation of realities and context (Charmaz, 2006). Following the literature review, semi-structured expert interviews were conducted. In order to derive meaning and data from the interviews, a two-step coding technique was applied. Existing literature and derived data were continuously compared to ensure the integrative nature as well as abductive reasoning. This method allowed to identify eight decision factors, which are perceived as highly important for VTOL manufacturers to be commercially successful. Making use of the identified strategic decision factors we suggest to extend the PFI framework by adding an additional layer (peripheric sphere) which considers external influences on an innovator's market entry and commercial success. The identified peripheric sphere influences an innovator's strategic orientation, which the underlying innovation strategy theory has, so far, not incorporated, as external factors emerging from an undefined market have not been incorporated.

This research therefore aims at enhancing the strategic management literature by extending the existing PFI framework to make it suitable for innovators in undefined high-tech market environments using the example of UAM. The findings can be attributed to adjacent markets, however, as this research only examined a narrow industry environment, validation of this notion is needed, and further research should be conducted. On the other hand the conducted expert interviews also allow us to contribute to the UAM literature by providing insights into strategic decisions of VTOL manufacturers. Interestingly, this research finds that a majority of players are not only aiming at building the vehicle, but also at operating the service. With regard to intellectual property (IP), strategies differ. While some companies aim at being the first to enter the market, others prioritize the high protection of their IP.

The remainder of the paper is structured as follows: Section 2 provides insights into existing literature on urban air mobility and relevant management literature. Section 3 describes the method, while Section 4 describes the interview results. The following section 5 discusses the PFI extension. This allows to derive implications for the UAM sector in section 6. Section 7 closes with a discussion and summarizes the core findings.

2. Literature review

As this research aims at extending the PFI framework to make it suitable for high-technology companies in non-existent markets using the example of UAM it is relevant to understand both the existing literature on UAM as well as existing frameworks and literature in the field of innovation strategy. The following section hence presents relevant research from both fields.

2.1. Urban air mobility literature

The research field of UAM is still quite young and certain areas remain comparatively unexplored. As found within the systemic literature review performed by Kellermann et al. (2020), most literature addresses one of the following five problematic aspects: vehicle technology, regulatory aspects, infrastructure requirements, operational concepts and public perception and adoption. The relating literature is presented in the following.

The emergence of autonomous technology (Fu et al., 2019), distributed electric propulsion (Shamiyeh et al., 2018), as well as battery storage and electric power transmission (Al Haddad, Chaniotakis, Straubinger, Plötner and Antoniou, 2020) brought up various different VTOL vehicle concepts, ranging from fixed-wing to multicopter concepts. Thus, many scholars highlight the importance of vehicle design and development (Shamiyeh et al., 2018). Among the most important (technological) requirements for UAM aircraft design are range, seat capacity, cruise speed, hover efficiency, cruise efficiency, maintenance costs and direct operating costs (Straubinger, et al., 2020). Moreover, questions on vectored thrust, lift and cruise and overall vehicle design (i.e. wingless multicopter vs. fixed wing vehicle) need to be answered (Rajendran and Srinivas, 2020). While some manufacturers aim to offer on-demand inner-city transportation, others favor intra-city connections or want to offer regional flights. The different concepts mostly vary in terms of distance, take-off mass and propulsion type (Shamiyeh et al., 2018).

Another important consideration that is commonly noted by scholars is the multi-layered regulatory aspect (Kellermann et al., 2020). The regulatory aspect is twofold. First, there appears to be no legal framework yet, and second, there is no vehicle certification. As noted by Michelmann et al. (2020), the interactions with people, cities, regulators and other third parties are essential to architect the elements of the UAM industry. In addition to the legal environment, the certification process is perceived as a major hurdle to establish commercial operations (Straubinger et al., 2021). The certification process requires the airspace authorities, such as the FAA and EASA, to set standards for vehicle technology, infrastructure and service operations.

As outlined by Straubinger et al. (2020), the infrastructure requirements to establish the novel service include the development of ground infrastructure and traffic management systems. The ground infrastructure, so-called vertiports, are those facilities where take-off and landing will be performed. There is still very little research in this field, however, scholars have outlined potential infrastructure placement opportunities. In addition, the importance of intermodal connectivity within other modes of transportation is addressed. Furthermore, the design of vertiports and the idea of standardized vertiports to accommodate various types of vehicles is discussed. Even though the service is not requiring routes, the three-dimensional airspace needs to be connected and controlled to ensure safe traffic above populated areas (Vascik and Hansman, 2017). Thus, an air traffic management system needs to be introduced. At this point, regulators, authorities and technology providers need to introduce a stable system.

The operational concepts aspect mainly deals with the potential business model approach and interaction within the UAM industry. First, the decision whether an inner-city or intra-city service offering is performed distinguishes whether the focus lies on the commute or on the take-off and landing infrastructure. Second, the different UAM submarkets, their interrelation and integration have been conceptualized. Here, vehicle manufacturers, vehicle operators, platform providers, service providers, ground infrastructure providers, maintenance and repair providers, insurance providers, communication infrastructure providers and unmanned traffic management (UTM) providers have been identified. However, Straubinger et al. (2020) acknowledge that little research in the field of UAM market actors has been conducted. Lastly, integration with other modes of transportation is considered vital for the operational aspects of UAM as interconnectedness results in increasing efficiency (Rothfeld et al., 2019).

Although helicopter services are long established, they are not a widely used mode of transportation. Therefore, the UAM service offering and the ambition to become a widespread transportation mode can be perceived as completely new. It is noteworthy that the UAM service not only affects potential users but also the public. Vehicles would fly above private and public properties, would use common airspace, would generate noise and would be visible. Therefore, the general public perception of the service needs to be considered. Several studies investigated the public perception as well as adoption factors (Al Haddad, Chaniotakis, Straubinger, Plötner and Antoniou, 2020).

The vehicle manufacturer, who is considered as the inventor of the technology and the key innovation driver, lies at the core of the UAM industry. However, the VTOL manufacturer as the key innovation driver has not yet been considered as the unit of analysis in the prevailing literature. Additionally, there is little literature on strategic management decisions of both manufacturers and operators in the field of UAM. Therefore, this research aims to identify the most relevant strategic decision factors and how manufacturers can successfully commercialize their innovation in the long term. Building upon theory and frameworks from strategic management will allow us to significantly contribute to this field. The following sections outline the prevailing strands of strategic management literature in the field of innovation management theory.

2.2. Management literature

At the core of this research is the question of how firms can profit from innovation in so far non-existent markets. We therefore strongly build on the profiting from innovation (PFI) framework originally developed by Teece (1986). The framework provides a conceptual model for reasoning through the practical complexities of developing an innovation from idea to market and in the end to capture value from the innovation (Winter, 2006). The framework has been widely used as a basis for other strategic literature, as well as expanded and adapted by various scholars. The framework makes use of three pillars defining value distribution in an existing market: the appropriability regime, the dominant design paradigm and complementary assets.

2.2.1. Appropriability regime

Appropriability is the degree to which an innovator can capture the returns derived from the innovation. It refers to the degree of how the innovation can be imitated and therefore illuminates the nature of the technology and the ability to protect its intellectual property (Teece, 1986). A tight appropriability regime displays an environment where the innovation is easy to protect whereas a weak appropriability regime represents an environment where the technology is easy to imitate and therefore hard to protect. Furthermore, “the degree to which knowledge is tacit or codified also affects ease of imitation” (Teece, 1986, p. 287). While codified knowledge is more subject to imitation, tacit knowledge is difficult to articulate and therefore difficult to transpose.

2.2.2. Market evolution/dominant design

Whether a technology design has reached general acceptance or not is reflected in the dominant design paradigm. Hereby one can distinguish between the preparadigmatic stage and the paradigmatic stage of a branch of science. In the early stage of an industry, competition is mainly focused on product design (Abernathy and Utterback, 1978; Dosi, 1982).

In the paradigmatic phase, however, access to complementary assets will be essential as prevailing designs start to show on the market. Teece (1986) argues that once a dominant design prevails, competition will move from design towards cost leadership. At this stage, the appropriability of a technology or innovation is a key factor. If the innovation is easy to imitate and a dominant design has emerged, followers can adapt the innovation leaving the innovator in a disadvantageous position.

2.2.3. complementary assets

The third concept within the PFI framework is represented by complementary assets (Teece, 1986; Tripsas, 1997; Rothaermel et al., 2006), that are defined as assets or capabilities needed to successfully commercialize and market a technological innovation. These can be marketing services, manufacturing or after-sales support. Three types of complementary assets are defined: generic assets, co-specialized assets and specialized assets. Generic assets are multi-purpose assets, which do not have to be adapted to the innovation. If there is a unilateral dependence between the innovation and the complementary asset, the asset is defined as specialized. Co-specialized assets entail a bilateral dependence between asset and innovation. Fig. 1 visualizes the argument, that the “know-how in question [needs to] be utilized in conjunction with other capabilities or assets” (Teece, 1986, p. 287). The outer layer symbolizes various complementary assets needed for a successful commercialization. “Other” exemplifies that there could be other and/or more Complementary Assets depending on the innovation in question.

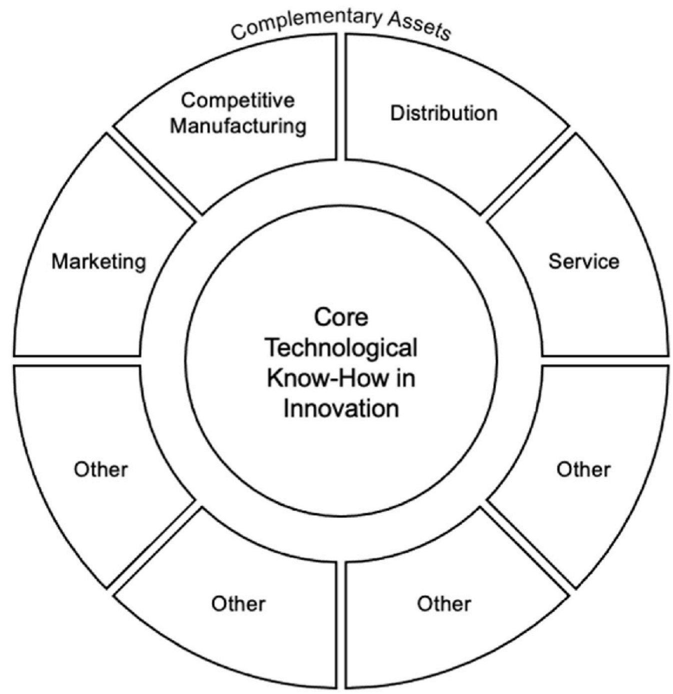

Fig. 1. Complementary assets (Teece, 1986) extended innovation profitability theory.

Rothaermel et al. (2006) extend existing work through a mixed mode approach to integrating vs. contracting by alleging that a simultaneous pursuit of vertical integration and strategic outsourcing contributes to a company’s competitive advantage and thereby to the overall performance of the firm.

Jacobides et al. (2006) discuss the relevance of industry architectures and factor mobility in the context of profiting from innovation. Industry architectures are referred to as “sector-wide templates that circumscribe the division of labor” (Jacobides et al., 2006, p. 1200) (i.e. the ecosystem surrounding the innovation) and factor mobility as an extension to complementary assets by separating complementarity and mobility in distinctive components. Moreover, Pisano and Teece (2007) cluster two critical spheres for strategic decisions: the intellectual property environment and the architecture of the industry which have pervasive influence on who profits from innovation and which, under certain conditions, can be shaped by managers toward a firm advantage. The intellectual property environment can be attributed back to the appropriability regime described earlier. Industry architecture, as defined by Pisano and Teece (2007), relates to the degree of specialization of market actors (integration vs. contractual agreements). Teece (2010) further applies his PFI framework to business model design where he argues that technological innovation alone does not guarantee commercial success. Successful commercialization of a technological innovation requires a good business model design and execution, joined by thorough strategic analysis. Suarez (2004) highlights the importance of the appropriability regime and complementary assets for achieving technological dominance.

Ching et al. (2014) frame the choice an innovator has between control and execution: an innovator choosing control is engaging in activities which are aimed at preventing future competition to secure rents (i.e. intellectual property protection, disclosures, etc.). This is coupled with upfront investments and a delay in market entry, whereas an innovator choosing to invest in execution is aiming to secure rents by developing capabilities designed against future competition.

Strengthening the Teecian line of argument that an innovator can engage in either vertical integration or contractual agreements (or one of myriad alternatives in-between), Gans (2017) advocates the entrepreneurial choice between competitive and cooperative commercialization strategies. In an existing market, a start-up can either collaborate (i.e., through licensing, alliances, etc.) with incumbents or go to market on its own (i.e., engage in competition). Building on the above, Gans et al. (2018) developed an entrepreneurial compass juxtaposing the dimensions execute vs. control and compete vs. collaborate. The latter is facing the attitude towards incumbents whereas the first deals with the attitude towards the innovation.

Yet, we find that the existing strategic management literature on profiting from innovation solely focusses on already existing markets. With our work we aim to fill this gap by identifying strategies for innovators in so far non-existent markets such as the market for UAM. In order to do so we will analyze both the need for and the details of an extension of the PFI framework, using the example of UAM. We hereby explicitly consider the discussion by Teece (2006), who emphasizes that future research could extend the framework by a second circle enveloping the first, entailing further aspects than complementary assets.

3. Methodology

In order to understand and conceptualize the relevant factors for key innovation leaders to be commercially successful in undefined high-technology market environments such as UAM we take different steps that are visualized in Fig. 2. These steps allow us to on the one hand contribute to the PFI literature by suggesting an extension to the framework that conceptualizes the key findings for non-existent high-technology markets. On the other hand we are able t o provide specific insights for VTOL manufacturers on how to best profit from innovation by highlighting key strategic decision factors.

We start by thoroughly assessing the existent innovation strategy and UAM literature. The innovation strategy literature provides insights into strategic decision factors for key innovation leaders and allows to evaluate the existing frameworks in the context of PFI. The assessment of UAM literature enables us to understand the pressing questions in this field and allow to understand which tools of the innovation strategy literature can be applied to conceptualize the strategic decisions of VTOL manufacturers.

In order to better understand the strategic decision factors in the UAM sector we conduct expert interviews. With respect to the undefined market environment UAM poses, this research applies an explorative constructivist grounded theory approach, first introduced by Charmaz (2006). Accordingly, the literature review has been followed by systematically coded expert interviews.

In total, 16 interviews were conducted with 20 interviewees from 16 different organizations: Five research institutes and universities within and outside of Europe, four infrastructure providers (both for UAM and conventional aviation), three VTOL manufacturers, two regulatory bodies/municipalities, one consultancy firm and one airline. All 20 interviewees hold notable roles (C-level executive and senior staff) within their organizations with yearlong experience in the field of passenger UAM, as can be seen in Table 1. Hence, the interviewees offered relevant, high-quality comments and standpoints on the questions posed. The UAM literature described earlier guided us towards relevant stakeholders. We aimed to include the expertise from different industry players at this stage to better understand the industry's view on how to profit from innovation. While we tried to incorporate diverse backgrounds and viewpoints on the industry, we acknowledge that our expert group is strongly industry driven. Extending the group to include a broader set of stakeholders such as policy makers or the public is an interesting path for future research.

According to the grounded theory approach, the conducted interviews are subject to a two-step coding technique (initial coding and focused coding) (Charmaz, 2006) to derive theory from data. Initially, 200 codes were identified after the first five interviews. After applying the first condensation, the meaningful codes amounted for 63. Subsequently, all other interviews were coded utilizing the codes from the first iteration while adding codes if necessary. Having finished the initial coding process of all interviews, the codes were again re-iterated and

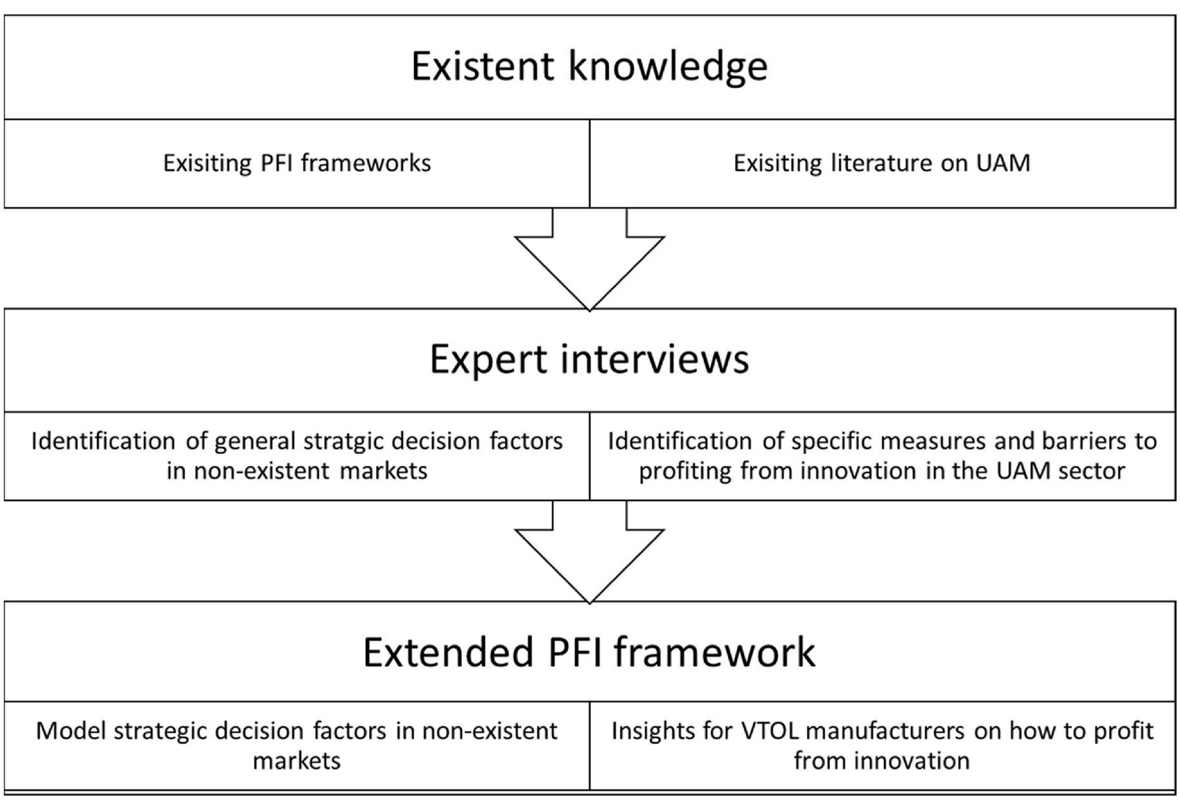

Fig. 2. Methodological approach.

Table 1
Interview partner background.

Interview	Position	Branch
1	Research Intelligence Analyst	Airline
2	Scientist	Research Institute
3	Co-Founder & CEO	Manufacturer
4	VP Market Development Business Development Manager	Manufacturer
5	Senior Program Manager „Unmanned Aviation & Urban Air Mobility"	Infrastructure
6	Manager Business Development	Research Institute
7	Research Scientist & Laboratory Executive Officer	Research Institute
8	Head of EMEA	Infrastructure
9	Director Corporate Development	Infrastructure
10	Project Lead UAM	Regulatory Body
11	Lead Scientist Air Transport Research Scientist	Research Institute
12	Principal Aerospace (UAM) Senior Consultant	Consultancy
13	Head of Product & Services	Manufacturer
14	Managing Director	Infrastructure
15	Lead Engineer	Regulatory Body
16	UAM Lead	Research Institute

condensed to 48 codes. The focused coding process consolidated the remaining 48 initial codes in 12 focused code groups representing the meaning of a range of codes. Lastly, thematically adjacent code groups have been combined to develop eight conclusive, evident and plausible factors from the focused code groups, as can be seen in Table 2.

Building upon the findings from the expert interviews we revisit the existing PFI frameworks as well as current knowledge on the UAM sector to evaluate how well our findings match the existing literature. In the area of UAM we see that most of the insights generated by the interview well reflect the current state of the art, while also adding some additional insights in some parts. With regard to the innovation strategy literature we find that the existing frameworks do not well reflect the non-existent market environment of UAM. We therefore extend the existing PFI framework by a peripheric sphere surrounding the current outer layer of the PFI framework. This is, for one, justified by literature as Teece (2006) suggest that future research could extend the framework by a second circle enveloping the first entailing further aspects than complementary assets. For another, our research shows that not all identified factors can be mapped to the current PFI framework as outside factors are not yet considered. These allow the extension of the PFI framework by a peripheric sphere integrating outside effects into the framework.

4. Interview results

By systematically applying grounded theory to the conducted interviews, two main findings were identified: 1) eight strategic decision factors for VTOL manufacturers, 2) measures to counteract challenges posed by these factors. Each of the three findings will be outlined in greater detail in the following paragraphs.

4.1. Decision factors

The following eight decision factors reflect the key decision factors which need to be considered by key innovation leaders in undefined high-tech market environments to achieve commercial success. Throughout the interviews, it emerged that the following eight factors have the biggest impact on a VTOL manufacturer's (key innovator) commercial success: 1) the Value Chain Factor (VLC), 2) the Infrastructure Factor (INF), 3) the Marketing & Research Factor (M&R), 4) the Affiliated Innovations Factor (AFI), 5) the Environmental Factor

Table 2
Factor coding process.

Factor	Focused Code	Initial Code
Value Chain Factor	Partnerships & Ecosystem	entering into partnerships Integrating Supply Chain requiring ecosystem
	Service & Operations	integrating operations integrating platform integrating services offering affordable service requiring operations
	Sourcing & Manufacturing	access to suppliers and resources integrating manufacturing outsourcing manufacturing requiring maintenance requiring manufacturing
Social & User Acceptance	Social & User Acceptance	achieving transparency creating public acceptance creating social acceptance focusing on user handling noise introducing society privacy concerns requiring public acceptance requiring safety requiring trust
Regulatory Factor	Lobbying	requiring lobbying Talking to authorities
	Regulatory Requirements	requiring certification requiring regulation requiring standardization
Infrastructure Factor	Infrastructure	creating an infrastructure integrating into mobility systems requiring charging infrastructure requiring infrastructure requiring landing infrastructure requiring traffic management system
Launch Strategy Factor	Launch Strategy	geographic regulatory differences importance of speed to market protecting technology waiting might pay off
Affiliated Innovation Factor	Affiliated Innovations	dependence on other innovations requiring good batteries autonomous technology
Marketing & Research Factor	Marketing & Communication Research	requiring communication requiring marketing conducting research requiring research
Environmental Factor	Sustainability	achieving emission free transportation achieving sustainability requiring environmental friendliness

(ENV), 6) the Regulatory Factor (REG), 7) the Social & User Acceptance Factor (S&U) and 8) the Launch Strategy Factor (LST).

Due to the limited number of interviewees we only briefly discuss the relevance of each of the factors and the resulting ranking. The importance of each factor is represented by the number of quotes allocated with the eight factors representing a cumulated sum of 678 quotes that are given in Table 3. We find that nearly half of the coded quotes can be assigned to either the VLC or the S&U. In contrast the ENV and the M&R each take up less than 5%.

Yet, of course it is important to acknowledge that the limited number of interviewees and the industry focus somewhat restricts the generalizability of these results. Fig. 3 shows the maximum, minimum and average number of factor mentions per interview. The figure shows well

Table 3
Distribution of interview quotes.

Factors	Quotes	% of total
Value Chain Factor	172	25,4%
Social & User Acceptance Factor	163	24,0%
Infrastructure Factor	92	13,6%
Regulatory Factor	86	12,7%
Launch Strategy Factor	61	9,0%
Affiliated Innovations Factor	45	6,6%
Marketing & Research Factor	31	4,6%
Environment Factor	28	4,1%
Total	**678**	**100,0%**

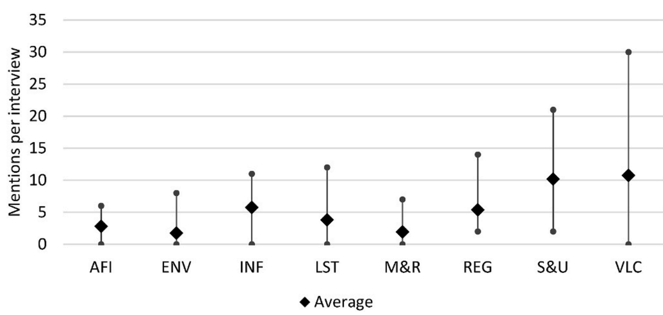

Fig. 3. Number of mentions per interview (min, max and average).

that not all interviewees mention all factors. We see that especially for the VLC the range of percieved importance across the interview partners is large (see Fig. 4).

In the following the different decision factors are described in more detail.

4.1.1. *Value Chain Factor (VLC)*

The VLC consists of three elements: sourcing & manufacturing, service & operations and partnerships & ecosystem. Within the first two components, namely sourcing & manufacturing and service & operations, both integrating and outsourcing are possible.

The interviews allow to derive the following results:

With respect to sourcing & manufacturing, a combination of integrating and outsourcing strategies seems to be the common ground for most of the interviewees. Manufacturer should engage in integration in the early phase as well as integrate manufacturing of parts where he has the ultimate expertise. Especially for startups outsourcing might be favorable as building up a well-functioning supply chain in-house as this entails high costs and expertise which is often not given for smaller companies. Moreover, outsourcing the production of certain parts where a supplier has more expertise and know-how can reduce costs and enable the VTOL manufacturer to focus on its core technology.

In contrast, opinions on service & operations focus rather on integration. VTOL manufacturers are expected to not only build the vehicle but also operate their own service and booking platform allowing them to maintain control over customer data. Yet, it is also argued that in the long-term service providers may enter the market and try to capture market share from the VTOL manufacturers.

The third element of the VLC is represented by partnerships & ecosystem. According to the interviewees, partnerships are particularly

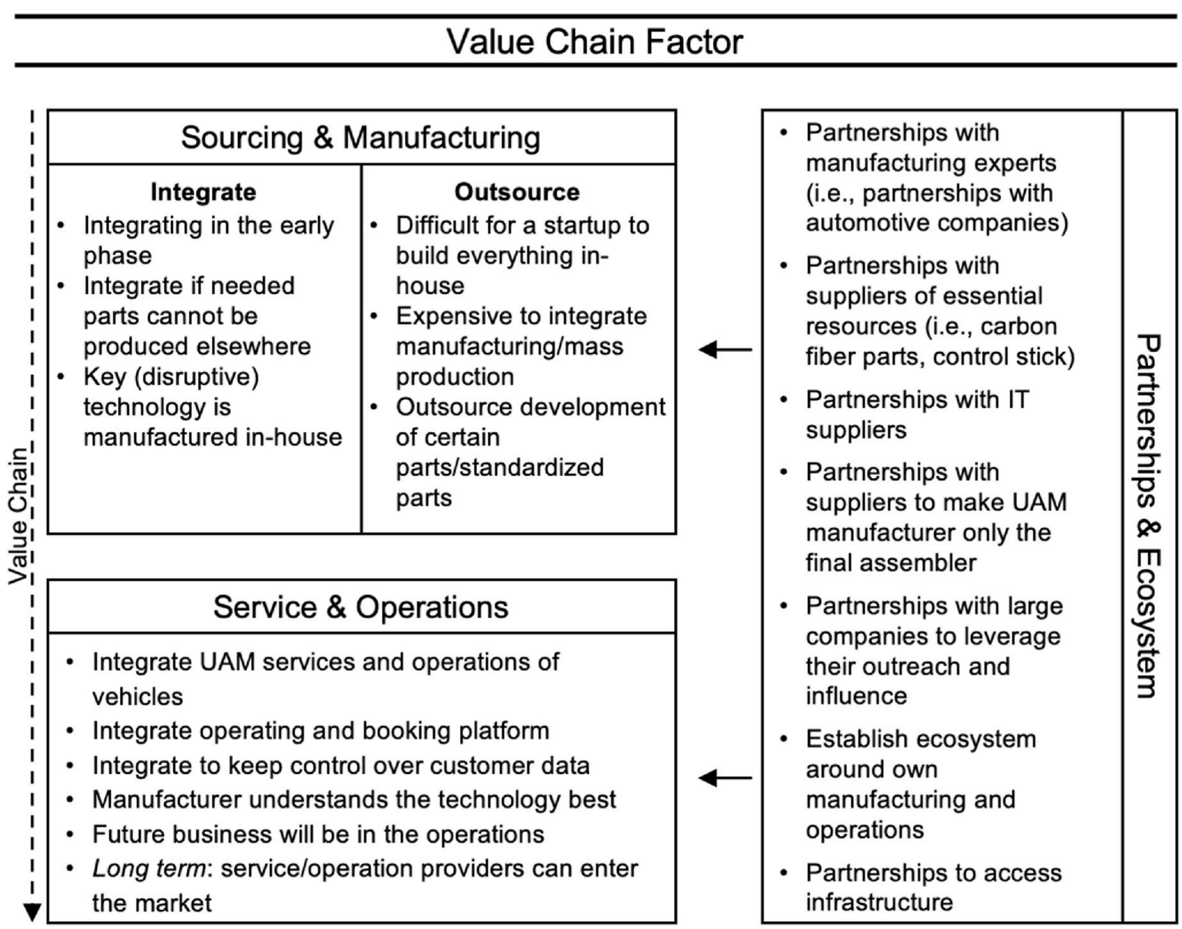

Fig. 4. Vlc factor.

important in the sourcing & manufacturing process of the value chain. Especially when a manufacturer decides to outsource, partnerships are crucial. Access to certain specialized resources can be achieved by partnerships with suppliers of the needed resources (i.e. IT technology, control stick, etc.). Especially "[…] when it comes to large scale production beyond the prototype phase, [the manufacturers] will work with well-established manufacturing companies", as one interviewee highlights.

As VLC was one of the most relevant factors in the interviews we provide some more insights in Fig. 1. The figure nicely visualizes the link between the partnerships & ecosystem element with the elements sourcing & manufacturing and service & operations.

4.1.2. Infrastructure factor (INF)

Infrastructure in this context is defined as those facilities and systems needed for an UAM vehicle to commercially operate. The INF comprises four distinct components: the ground and the air infrastructure as well as the integration into mobility systems. The landing infrastructure element encompasses various aspects such as location, regulation and operation. The ground infrastructure is also referred to as vertiports that are specified landing and takeoff locations for UAM vehicles (Goyal et al., 2018).

For the vertiport the following findings can be derived from the interviews.

- Diverging opinions on vertiport placement: either at major traffic junctions such as train stations or airports in the outskirts of a city or in urban areas on skyscrapers, roof tops, and parking garages in order to be successful. Regulatory requirements regarding locations will be derived from noise and privacy issues within social acceptance.
- Vertiports expected to be operated and built by third party operators and owners such as governments, private investors, and public private partnerships as the costs of infrastructure and the commercial risk to operate infrastructure is perceived as too high for manufacturers. Therefore, the manufacturers are advised to enter partnerships (partnerships & ecosystem) to get access to infrastructure.
- Cities and municipalities (e.g., those setting the regulations) seek standardized vertiports and charging infrastructure.
- Uncertainty about where the energy will be allocated, stored, distributed, what happens at the end of the life cycle of the batteries and whether batteries will be exchanged or whether the vehicles will be charged directly.

Once the vehicle is in the air, it needs to be managed and controlled by an air traffic control (ATC) system. The interviewees agree that.

- Regulation will define the air infrastructure as, especially within cities, VTOL vehicles will access local and public air space which is handled by regulators and agencies.
- VTOL vehicles are expected to follow defined corridors and not move freely within urban areas.
- Uncertainty on whether there is enough air capacity and agency capacity to control all these flights or if a new, more automated ATC system is needed. Besides, it is still unanswered how UAM and commercial aviation flows can be brought together, especially at airports where no-fly zones for any vehicles but airplanes exist.

There are two aspects of integrating UAM into existing mobility systems. The interviews show that.

- Location and placement of vertiports should be carefully selected to e.g., prevent passengers taking a cab to and from a vertiport. One solution could be locations in the proximity of long-distance train stations.
- Additionally the decision on whether a landing infrastructure should be placed in the city-center or the outskirt of a city is also expected to determine the degree of integration into existing mobility systems.

4.1.3. Marketing & Research Factor (M&R)

The M&R stems from two distinct elements. First, the marketing & communication element and second, the research element.

With regard to the marketing & communication element, interviewees strain the importance of investing into marketing and PR to convince people of the benefits and advantages the service will deliver. Marketing activities should accompany a manufacturer's activities in establishing a well-known brand in order to benefit from the realization of use cases, partner development and product launch. Besides promoting the service, incorporating a clear communication strategy addressing both positive and negative aspects is advocated. As one interviewee states, "it is important to remember that manufacturers need to be transparent, they need to communicate with all stakeholders, they need to engage certain stakeholders at certain times. Recognizing this and building it into the plan is essential."

For the research element the interviewees emphasize the importance of both conducting research but also relying on research performed by others. Research is needed to improve the core technology but also to improve demand projection of the service offering and can lead to further insights into social and user acceptance, privacy and safety concerns, and possible use cases. The research element is strongly interconnected with other factors, as it usually helps to develop deeper insights into a subject and, if possible, provide solutions.

4.1.4. Affiliated Innovations Factor (AFI)

The AFI consists of innovations that are considered important for the continuing- and future development of UAM, but do not exist as such and are therefore needed. VTOL manufacturers have only little influence on the development of these innovations as they lie outside of their area of competence. Accordingly, all manufacturers are dependent on these affiliated innovations. The two main elements of the AFI are depicted by the energy supply and autonomous technology. In addition, certain innovations can be referred to the INF such as a superior charging infrastructure as well as an UTM system capable of handling autonomous flying vehicles.

In the context of energy supply for VTOL vehicles the interviews show that the sector strongly relies on battery technology developments upon batteries. The interviewees emphasize that the developments within the automotive industry can spill over to UAM resulting in e.g., better batteries within a couple of years. Moreover, the battery technology is perceived as the biggest weak spot of the technology and is therefore a critical element.

Whether VTOL vehicles will fly autonomously or not has also been discussed throughout the interviews. The general perception is that autonomy will become highly relevant in the future, however, it is not clear at which point in time this will occur. Even though autonomous driving is already partially in use, it is argued that autonomous flying implies a higher complexity in terms of control and interaction. Nevertheless, autonomy is perceived as an important additional innovation needed for the UAM industry. It is argued that autonomy can increase the safety and reduce the operating cost by removing the pilot.

4.1.5. Environmental Factor (ENV)

The ENV emerged from the emphasis that interviewees placed on sustainability in all its variants. Thus, the ENV describes the expectations of social and sustainable impacts associated with the manufacturing and operation of the vehicles and its components. This is in line with existing literature that shows that the general perception of the sustainability of the aviation industry is relatively poor, therefore, achieving environmental friendliness has particularly become a strategic matter within the industry (Capgemini, 2020). One interviewee highlights that "you can't just throw more polluting products on the market that increase the energy demand of the transport sector."

4.1.6. Regulatory Factor (REG)

The REG consists of regulatory requirements, namely certification, regulation and standardization, which are considered by respondents to be important for the commercial establishment of the UAM service, as well as Lobbying as a means for manufacturers to influence the process of setting regulatory requirements. While the certification process is claimed as the starting point to get the vehicle in the air and operate it, the regulations are the legal framework of policymakers to frame the resulting activities and ultimately provide the structure for standardization regarding the charging and landing infrastructure.

4.1.7. Social & User Acceptance Factor (S&U)

The S&U can be broken down into the following five elements: safety,[1] noise, privacy, user and public perception. Safety, noise and privacy are claimed as the overarching influences on social- and user acceptance of which safety and noise have an impact on both the user (e.g. passenger) and the public perception whereas privacy does not affect the user but only the public perception. This relationship is clearly visualized in Fig. 5.

Within the interviews the following aspects on user adoption have been discussed.

- Marketing and research activities can potentially increase acceptance and adoption and help the operator to design a user centric service.
- In addition to building trust through information, it is argued that a VTOL manufacturer should provide
- User-friendly design, including physical space, vibration reduction, and noise attenuation increase user acceptance.

In order to foster public acceptance the following points were discussed.

- VTOL manufacturers should aim at making the service available to a broad segment of society, as otherwise the service might be perceived as being primarily for the wealthy and affluent segment of society and that the general public does not benefit from it.
- Clear communication strategy to show the added value of UAM must be communicated to the general public
- Gradual introduction of UAM for people to get used to it people will get used to it
- VTOL manufacturers must recognize that it is important to involve the public and their opinions in the development process.

4.1.8. Launch Strategy Factor (LST)

The LST comprises two main strains of opinion. On the one hand, it is argued that a fast-to-market strategy would be advantageous for VTOL manufacturers, but on the other hand, intellectual property protection and later market entry could be the victorious strategy. A third element of the LST is represented by the target market a manufacturer should enter first. It became apparent that the choice of the target market has a significant influence on the launch strategy. Some geographic regions have a more propitious starting point for rapid market entry compared to others. These geographic regions are characterized by different variables such as the regulatory landscape as well as social acceptance. Regions that are more open towards new technologies, such as the USA or Asia, will be the first markets where type of new transportation will be introduced. Another variable that influences the choice of target market, and thus the choice of deployment strategy, is society's perception of a new technology.

A first mover advantage is believed to give a company a competitive advantage by being the first player in a market segment (Lieberman and Montgomery, 1998). The interviewees argued that, especially for start-ups engaged in UAM, speed-to-market is an important factor to consider as manufacturers rely on grants and must deliver results to secure funding to continue developing their product. However, it is also noted that over-pacing the speed-to-market could result in a technologically inferior vehicle. Nevertheless, rapid market entry puts the manufacturer in a favorable position when negotiating potential partnerships. In addition, it is argued that protecting intellectual property is expensive and time-consuming, which could put the manufacturer in an unfavorable position compared to its competitors. Moreover, a speed-to-market strategy offers the manufacturer the opportunity to capture the early adopter market and thus enter the technology adoption life cycle (Bohlen and Beal, 1957; Rogers, 2003; Foster, 1986) at an early stage. Early market entry can also pave the way for faster certification of the technology.

On the contrary, other interviewees argued that protecting intellectual property and choosing to enter the market at a later stage may also be of advantage to manufacturers. They claimed that the improvement and protection of technology, especially novel technologies or technologies critical to the functioning of the vehicle, should be the subject of protection. Beyond that, if a manufacturer manages to overcome technological challenges faced by the entire industry, intellectual property protection could prove crucial. Another argument in favor of a later market entry is based on the advantage of endurance as there will be consolidation as soon as the market is maturing. It is further argued that if a manufacturer owns and protects a superior technology, imitation could take a while and the manufacturer can serve the market alone, resulting in a favorable market position.

5. Extending the PFI framework

The findings fro m the expert interviews show the need to extend the existing PFI frameworks. We start by contextualizing the role of UAM in existing PFI frameworks. As described by Teece (1986) the framework consists of three main elements, namely the appropriability regime, the market evolution/dominant design and complementary assets. Based on the nature of the appropriability regime and the availability of complementary assets, a firm can either engage in an integration or outsourcing strategy. Extends the elements by the variable complementary innovations as he argues that the importance of adjacent technologies has become more apparent since the introduction of the PFI framework. In the following, the above identified decision factors will be classified alongside the extended PFI framework.

Tight appropriability regimes are the exception (Teece, 2006) and this is also true for UAM. Even though the UAM industry is classified as a high-technology market, the technology of VTOL manufacturers is hard to protect, patenting is getting expensive, and many patents can be reinvented at modest cost (Mansfield et al., 1981). Therefore, the appropriability regime for VTOL manufacturers can be classified as weak.

Product design is oftentimes the basis for competition in the early phases of an industry, until one dominant design, or a narrow class of designs, asserts itself and begins to dominate the market (Abernathy and Utterback, 1978). In this stage, uncertainty prevails, and innovators must be prepared with considerable financial resources. The conducted interviews show that no dominant design has yet emerged throughout the UAM industry. The interviewees highlight that in the current market phase, sufficient financing is considered an essential tool to overcome the prevailing uncertainty. This is in line with Abernathy and Utterback

[1] *Safety is an important factor for the successful introduction of UAM. Yet, especially in the European and North American context UAM* is expected *to reach at least the same safety levels as commercial aviation to be certifiable. We mention the aspect of safety in various factors (M&R, AFI, S&U)* but do not identify it as a *separate factor*. Yet, we acknowledge that this implicitly means that sufficient trust in existing safety systems, regulation and certification is needed for this to persist.

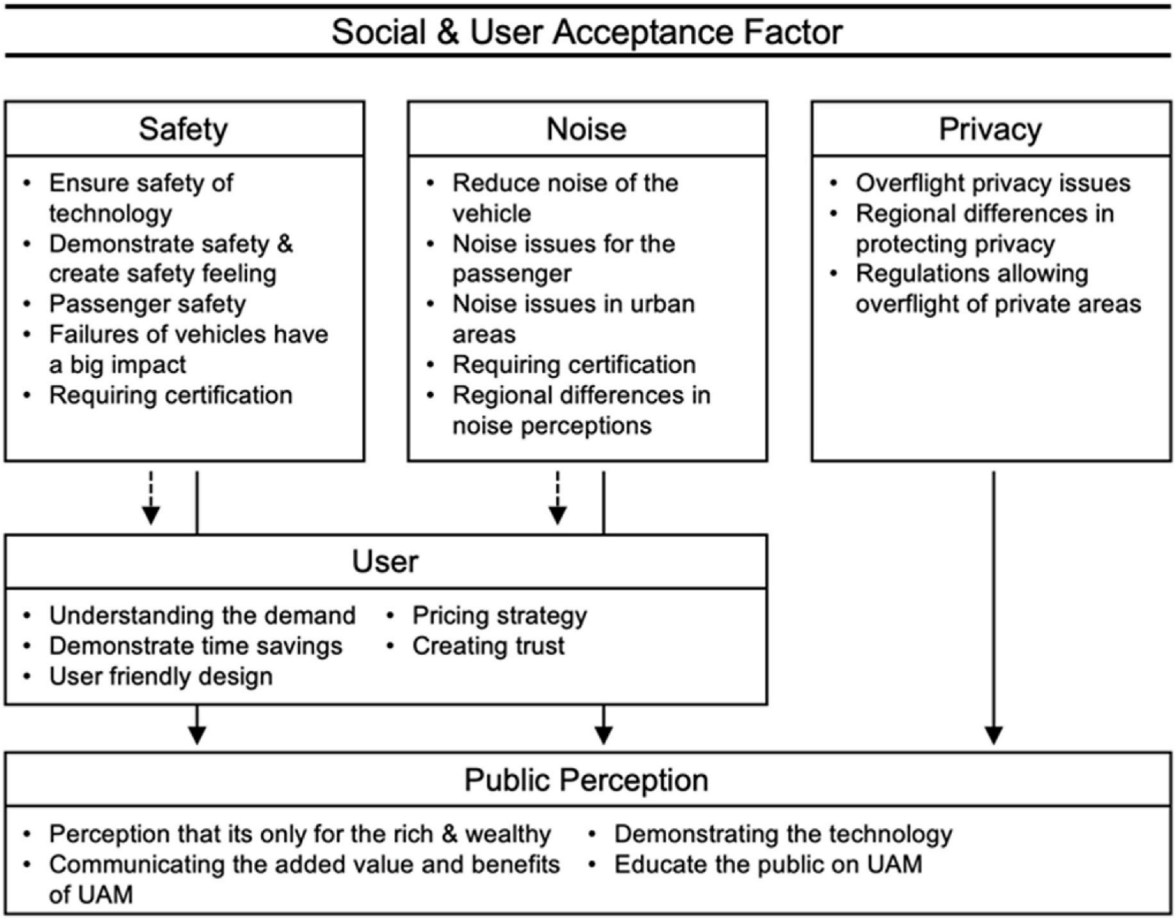

Fig. 5. S&U factor.

(1978) as well as Teece (1986) argumenting that in an industry where no dominant design has emerged, considerable financial resources are needed.

Successful commercialization of an innovation almost always requires technical knowledge to be used in conjunction with other assets or capabilities such as marketing, manufacturing, after-sales service, distribution and software (Teece, 1986). Teece (2006) extends the complementarity of the PFI framework by complementary innovations, treated as another complementary asset. However, it became evident that affiliated technologies and other complementary innovations play a significant role today and are therefore being extracted from the complementary assets and presented as a separate element of complementarity. The VLC and the M&R can be classified as complementary assets whereas the INF and the AFI can be classified as complementary innovations.

Not all eight decision factors identified by our research can been mapped to the existing PFI frameworks. Hence this research extends the PFI framework by an additional outer layer including the remaining three factors, namely the ENV, the REG, and the S&U that have been perceived as highly important to future commercial success. This outer layer is especially relevant for key innovators in so far non-existent markets, such as UAM.

We therefore introduce the peripheric sphere as an additional layer to the PFI framework. Peripheric sphere elements are defined as external factors which have a direct influence on the successful commercialization but cannot be acquired or held by the innovator. The impact of the peripheric sphere elements can be either favorable or unfavorable towards the commercial success of the innovator. This contrasts with the complementary assets and innovations as peripheric sphere elements are not tangible assets and are therefore not directly linked to the technological innovation. However, as it emerged throughout the analysis of the UAM industry, these elements play a crucial role in commercializing an innovator's product or service. It should be noted that the identified peripheric sphere stems from the analysis of the UAM industry and therefore displays considerations for high-technology mobility industries and undefined market environments. Other elements could be added or removed depending on the innovation and industry in question. This is also exemplified by the "Other" element. As shown in Fig. 5.

The three decision factors ENV, REG and the S&U are classified as peripheric sphere elements.

The ENV is classified as a peripheric sphere element in that it describes the expectations of social and sustainable impacts associated with the manufacturing and operation of the vehicles and their components. It therefore does not directly influence the innovation but the commercialization of the product or service. Environmental and sustainability aspects play an increasingly important role, especially in today's world. Lüdeke-Freund (2020) argues that sustainability-specific barriers can prevent an innovation from being commercially successful. In addition, sustainability is a key factor in the adoption of innovations (Kim and Mauborgne, 2000). In the case of VTOL manufacturers, the general perception of the aviation industry's sustainability is relatively poor, therefore achieving environmental friendliness in particular has become a strategic issue within the industry (Capgemini, 2020). It is argued that VTOL manufacturers should not just build their vehicle in a sustainable way but also contribute to solving environmental problems and become part of the solution. The ENV can be seen as favorable towards the innovator as it poses an opportunity for VTOL manufacturers to seize momentum of the sustainability movements and turn it in their favor. Hence, it can be classified as a peripheric sphere element.

The REG is also qualified as a peripheric sphere element. The regulatory landscape surrounding an innovation defines how and in what way the product is designed and under what conditions the service can be carried out. As argued by Blind (2012), regulations and regulatory frameworks generate various impacts and have been identified as important factors influencing innovation. Moreover, the authors emphasize the external nature of regulations. The REG is of intangible character and cannot be acquired by the innovator. Nevertheless, it ultimately rules over future success as guidelines and regulations define the boundaries of the innovation. Within the UAM industry, regulations are seen as crucial as they define whether a VTOL vehicle is being certified or not. Furthermore, regulatory bodies, policymakers and municipalities set the guidelines for operations, landing- and take off as well as overflight rights and are therefore vital for a successful commercialization of VTOL operations. The REG can be classified as unfavorable as there are yet no regulations for UAM operations. Furthermore, the certification processes for aviation vehicles are lengthy and costly. However, regulatory authorities and policymakers are introducing initial regulatory frameworks and municipalities are setting up task forces dealing with UAM initiatives. Hence, movements towards a favorable regulatory landscape can be observed.

Lastly, the S&U likewise incorporates the attributes of the peripheric sphere. As claimed by Niehaves et al. (2012), the success of new technologies is heavily reliant on social factors. Further, Graf-Flachy et al. (2018) argue that social influence affects technology acceptance. In general, the social and user acceptance of a technology is seen as an outside factor influencing the commercialization of an innovation. No matter how sophisticated, technologically advanced, sustainable or regulatory-approved an innovation or new technology is, it still requires public acceptance and user adoption to be commercially successful. Social and user acceptance is hard to predict making it one of the most critical factors towards innovators. It cannot be internalized or acquired and requires effort to influence. Nevertheless, social and user acceptance poses a vital element of future success. The S&U can be considered as unfavorable due to the prevalence of various issues in the public perception of UAM operation such as noise emissions, safety issues, and privacy concerns. The above justifies classifying the S&U as a peripheric sphere element as it is intangible, external, and not directly linked to the technology.

For the sake of completeness, the eight decision factors and their respective clustering to the extended PFI framework, displayed in Fig. 5, are displayed in the following: As mentioned above, the ENV, the REG as well as the S&U are classified as peripheric sphere elements. The INF and the AFI are classified as complementary innovations while the VLC, the M&R are classified as complementary assets. As outlined above, the LST cannot be allocated to one element of the extended PFI framework as it entails the appropriability regime which is not displayed in this depiction.

6. Implications for the UAM sector

This research extends existing PFI frameworks to make them suitable for the application to non-existent markets. We do so by using the example of UAM. In the following we now want to discuss in how far the extension can be validated when being taken to a more applied setting.

6.1. The extended PFI framework in the context of UAM

6.1.1. The peripheric sphere (ENV, S&U, REG)

While the peripheric sphere is at the center of this research and marks the main contribution of this paper to the strategic management literature, the peripheric sphere elements ENV, S&U and REG already receive a lot attention in the field of UAM. This highlights the relevance of our extension to the PFI framework in the context of so far non-existent markets.

UAM research covers the three peripheric sphere factors via studies on public perception, user adoption, regulation and vehicle technology. As highlighted by the interviews industry players also emphasize the relevance of these factors and strongly engage in networks and demonstration activities.

6.1.2. Complementary assets (VLC, M&R)

In the area of complementary assets, such as operational concepts and business models, in contrast, our research generates valuable additional insights. While so far the various UAM submarkets, their interconnectivity and integration were conceptualized (Straubinger, et al., 2020), little specific statements have been made. Within the VLC we find that manufacturers (especially start-ups) are expected to outsource production and only integrating production steps on which they have proprietary knowledge. Additionally most interviewees expect vehicle manufacturers to offer mobility services themselves, in particular in the beginning.

The M&R factor to the authors' knowledge so far has not been studied in the field of UAM.

6.1.3. Complementary innovations (INF, AFI)

The complementary innovations factors mainly find attention in the UAM literature via the infrastructure factor (INF). UAM literature raises the issue of infrastructure requirements and the need for development of ground infrastructure, enabling intermodal connectivity and traffic management systems as well as their standardization. This is echoed in the conducted interviews and reflected by the INF.

6.1.4. Resulting research gaps in the UAM literature

Overall, the existing UAM literature identifies five aspects that are perceived as important for VTOL manufacturers: vehicle technology, regulatory aspects, infrastructure requirements, operational concepts, as well as public perception and adoption. As illustrated in Fig. 6, five of the eight PFI decision factors can be associated with the aspects from the UAM literature. We hence identify M&R, the AFI and the LST as areas for future research in the field of UAM. Elements of these factors have already been mentioned in parts of the existing literature but have not yet been consolidated as such (see Fig. 7).

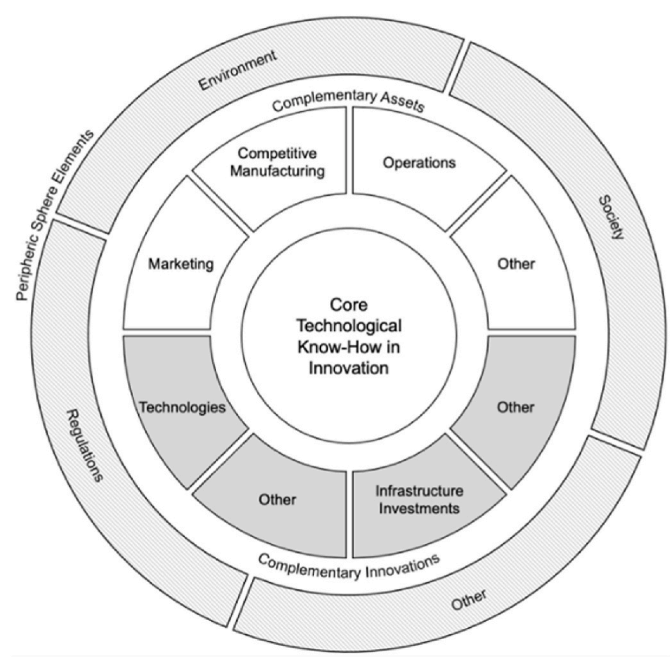

Fig. 6. Extended PFI framework.

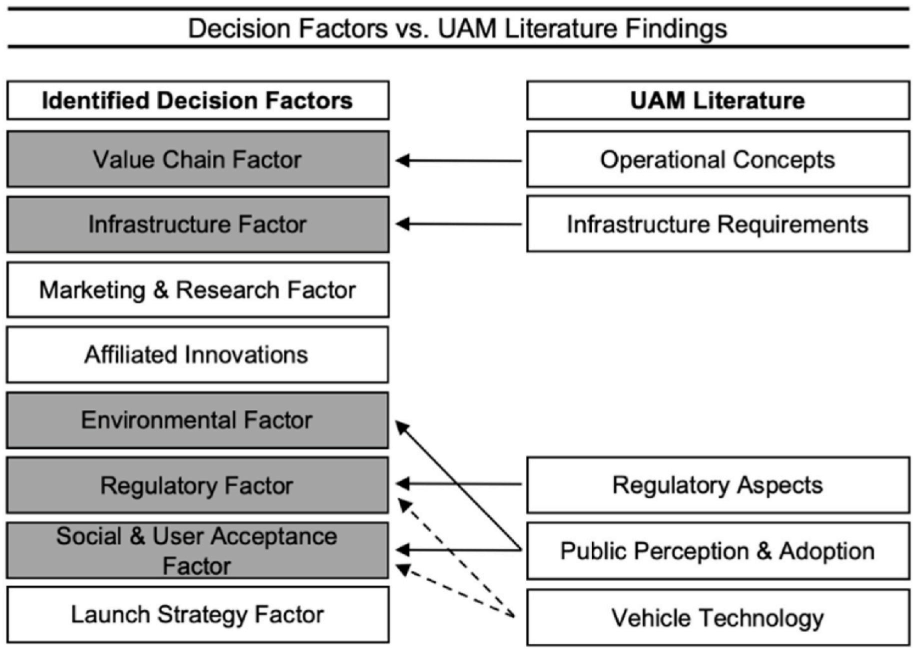

Fig. 7. Decision factors vs. UAM literature findings.

6.2. Practical implications and managerial insights for the UAM sector

In environments of weak appropriability, a speed-to-market strategy is advocated. However, in markets where no dominant design has emerged, this poses risks as an innovator might bet on the "wrong" design and fall behind its competitors. Especially in high-tech markets where irreversibility prevails, betting on the wrong design might be fatal. Nevertheless, if an innovator manages to establish the dominant design, it finds itself in a superior position compared to its contestants. If an innovator decides to follow a speed-to-market strategy, it should not disregard the currently unfavorable peripheric sphere. Two approaches can provide redress. The innovator can counteract the unfavorable environment by engaging in lobbying and/or providing use cases or it can move to a different geographical region where the peripheric sphere appears more favorable.

7. Conclusion

This research has shown that existing PFI frameworks cannot be applied to so far non-existent market. Using the UAM market as an example for a high-tech sector which is currently still under development we extend the PFI framework. We propose an extension to the existing PFI frameworks that allows to conceptualize the key decision factors to be considered by the key innovator (e.g. the VTOL manufacturer) to achieve commercial success. Via expert interviews we identify eight decision factors (the Value Chain Factor, the Infrastructure Factor, the Marketing & Research Factor, the Affiliated Innovations Factor, the Environmental Factor, the Regulatory Factor, the Social & User Acceptance Factor and the Launch Strategy Factor). N ot all identified decision factors can be classified as either complementary assets or complementary innovations as foreseen by the existing PFI frameworks. We hence suggest to extend the framework by introducing the peripheric sphere as a surrounding layer. This adjunct entails external factors which, unlike complementary assets and innovations, cannot be held by the innovator and therefore cannot be integrated nor outsourced. The nature of the peripheric sphere elements can be either favorable or unfavorable to the innovator and impact the commercial success of an innovator as they influence both the strategic decision on whether an innovator should integrate or contract for a complementary asset or innovation as well as the innovators' market entry strategy. A n innovators' commercial success is therefore not only dependent on the appropriability regime, the market evolution/dominant design and the access to complementary assets/innovations but also on the nature of the peripheric sphere. Thus, in order to be commercially successful in an undefined high-technology industry, a key innovator should thoroughly analyze the aforementioned decision factors and apply the newly introduced framework to derive implications for its future strategic orientation.

The identified decision factors constitute an interpretation of the interviews conducted as well as the coding process which depicts an unavoidable limitation. Additionally the interviewees' opinions can be biased according to their own background or company interest. This research exhibits a narrow industry focus. We assume that transferability to other non-existent high-tech markets, as well as adjacent markets and industries facing the same challenges as those identified for UAM, is viable. Yet, this might not be the case. As innovations similar to that of UAM (completely novel service and largely new technology, only building upon enhancements of existing services to a limited extent) only occur rarely it is difficult to challenge the validity of the established framework and its applicability towards other industries. Examining the decision factors as well as the established framework in light of other industries and market stages therefore is an important path for future research to advance robustness and generalizability.

CRediT authorship contribution statement

Nick Ehrhardt: Conceptualization, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing, Visualization. **Paul Herrmann Horlacher:** Conceptualization, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing, Visualization. **Anna Straubinger:** Conceptualization, Supervision, Visualization, Writing – original draft, Writing – review & editing.

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