VTT Technical Research Centre of Finland

AMHUB - Additive Manufacturing Hubs for Radical Innovation in Digital Part Delivery Logistics

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Business Finland Co-Creation project

AMHUB - Additive Manufacturing Hubs for Radical Innovation in Digital Part Delivery Logistics
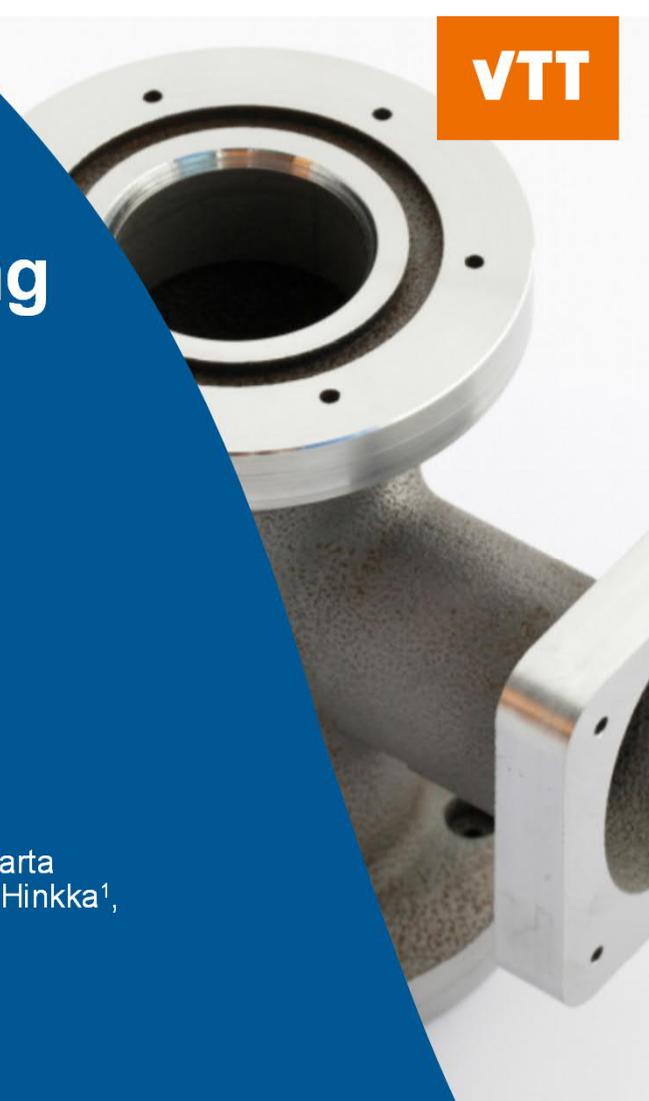
Final report
Shared vision & key topics to be investigated and developed further

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Purpose & content

Purpose of the presentation

This presentation describes the AMHUB visionary concept created based on the collected key insights from company discussions.

Presentation will answer to the key question:
How AMHUB could fulfill customer needs and objectives in an optimal way in the future and what needs to be investigated and developed together to implement it?

Content

1. Brief intro to Co-Creation project

2. AMHUB visionary concept
- How AMHUB could respond to the identified customer challenges in a novel way? What significant benefits AMHUB model would provide for the customers?

3. AMHUB services and operations
- Novel ways to operate & required capabilities (actors, skills, technology, co-operation, etc) to implement the services for each part of value network

4. Steps to reach the vision
- Key actions and focus areas on each step towards the AMHUB vision

1. Brief intro to Co-Creation project

- Co-Creation project phases & key activities
- Collecting insights how AMHUB could serve the customers in the future

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Co-Creation project phases & key activities

Company involvement
Core team workshops

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1. Early hypothesis

- **Light-weight desk study** of previous research and global benchmarks to create the early hypothesis for AMHUB concept

2. AMHUB concept desirability

- **AMHUB customer objectives, needs and challenges**

- **AMHUB hypothesis validation** to fulfill customer objectives and needs

- **AMHUB use cases and value for customers**
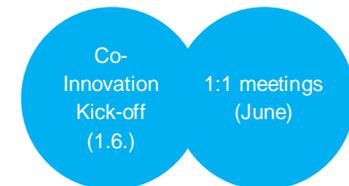
3. AMHUB services and operations

- **Required solutions, capabilities, processes, roles and collaboration in AMHUB** to provide the service

- **AMHUB Value for service providers**

4. AMHUB concept validation

- **Validating the outcomes and discussing about the steps to reach the vision**

- **Identifying the key topics** to be investigated and developed further in co-innovation project

5. Co-Innovation project planning

- **Co-creating join project plan**

- **Creating partner specific project plans**

Hypothesis creation

Potential customer interviews (Weeks 12-15)

Working sessions for summary creation

Service provider interviews (Weeks 14-19)

Working sessions for summary creation

Co-Creation Workshop (20.5.)

Co-Innovation Kick-off (1.6.)

1:1 meetings (June)

Collecting insights how AMHUB could serve the customers in the future

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DESKTOP STUDY

~20 COMPANY INTERVIEWS

2 RESEARCHER WORKING SESSIONS

1 COMPANY WORK SHOP

- Brief reference & competitor analysis
- Concept description and hypothesis creation

- Customer understanding: Needs, challenges, requirements
- Concept validation & further ideation

- Sharing collected insights
- Challenging the concept and developing it further
- Creating ideas what needs to be investigated further

- Walking through the AMHUB concept to refine it further
- Collecting ideas what needs to be clarified more to make concept even more appealing
- Collecting ideas what needs to be investigated and developed further

2. AMHUB concept summary
Key findings based on interviews and desktop study

- **Need for AMHUB:** Why there is a need for AMHUB? What are the needs that the current solutions cannot solve?

- **AMHUB vision:** How AMHUB could respond to the identified challenges? How does it serve customers in a novel way?

- **Key Benefits:** What significant benefits AMHUB model could provide for the customers?

- **Use cases and customer value:** For what AMHUB could be used for and how does it provide value for customers?

- **Business potential**: What are the key needs of different industries that AMHUB can solve?

Additive manufacturing have a lot of advantages compared to conventional manufacturing methods,
but it requires a lot of effort from companies needing AM parts to get started and get all the things right

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Customer needs for
Building AM capabilities and portfolio

- Understand **my AM opportunities**, business cases and investments
- Build internal team, know-how, infra and technical capabilities
- Identify **my AM part portfolio**
- Understand the **requirements for my AM parts** based on the industry standards and customer needs
- **Digitalize parts** and create the required data for manufacturing
- **Optimize designs** for AM and for optimal performance

Customer needs for
Building readiness for ordering AM parts

- **Find the service providers with the right capabilities** for different parts against my requirements
- **Qualify each provider's AM process, materials and equipment** against the set requirements
- Run pilots and assessments with providers
- **Creating SLAs, NDAs & booking capacity** with the key service providers
- Align my and service providers' processes and IT systems
- **Customize my parts** based on the customer needs
- **Plan optimized end-to-end deliveries**
- Make sure there is secure data and part handling practices to prevent any immaterial property leaks

Customer needs for
Ordering and tracking AM parts

- **Create and manage and refine my requests, quotes and orders** with all service providers to estimate the costs and timetables
- **Get all the AM part manufacturing providers to collaborate efficiently**: AM design, material provider, 3D printing, machining, post-processing, quality assurance, deliveries
- **Get information about the status of my orders** and track the quality
- **Find support when problems occurs**
- **Track and optimize sustainability** throughout the process e.g. low CO_2, sustainable material and waste handling, circularity

The current ways to get additive manufactured parts doesn't provide solutions to tackle all this complexity

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Additive manufacturing at own premises

- **Early investments**: A lot of early investments required to the additive manufacturing equipment and facilities
- **Getting started**: Special know-how required related to 3D design and AM
- **Limited capacity:** Quite limited number of parts can be manufactured

→ *Good option for product models and prototypes and when there's a need to trying out things fast and build strong internal know-how*
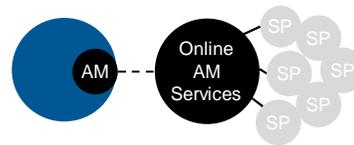
Additive manufacturing with online marketplaces

- **Limited capabilities:** Only basic 3D printing capabilities offered, no special post-processing services
- **Quality:** Standard/low quality, no company specific quality requirements supported
- **Support:** No hands-on support for design and manufacturing optimization

→ *Good option for mock-ups and product models when support is not needed to optimize the design and assure the quality of the part*
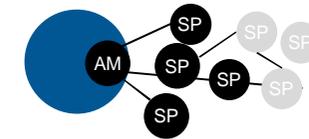
Additive manufacturing with distributed provider network

- **Getting started**: A lot of effort required to find and qualify the right service providers for each part against the set requirements
- **Quality & IPR assurance:** A lot of effort required to assure the quality and IPR security for critical parts
- **Slow multi-party manufacturing**: Part transportation is required between each service provider

→ *Good option for production parts when there is enough understanding and capabilities to search and qualify providers for different AM needs*

There is a need to develop novel solutions for companies to take advance of AM potential more efficiently

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WHAT IF..

we would not wait until companies have built their AM capabilities, portfolio and AM service provider network to able to start ordering AM parts **BUT** we would support companies to build competitive edge with AM right from the beginning

WHY? Currently the customers find difficult to get started by understanding the opportunities of AM and start building the required competence and capabilities.

WHAT IF..

each service provider would not provide their own AM manufacturing services **BUT** service providers would start providing together an end-to-end service that combines the best services from each service provider for customer needs

WHY? Currently customers find difficult to manage the complexity when manufacturing AM parts using the services from multiple service providers and they need a trusted partner to do this together with them.

WHAT IF..

there wouldn't be loose collaboration by AM design, manufacturing and delivery service providers located in their own premises **BUT** there would be closer collaboration under the same roof supported by additional provider network

WHY? Currently each AM service provider has their own processes and principles that doesn't support an efficient and high quality manufacturing and delivery needed especially for critical parts.

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AMHUB VISION
is to provide additive manufacturing as-a-service for customers needing high quality parts

AM part design, manufacturing and delivery service providers work together efficiently under the same HUB based on the shared principles and optimized process.

In AMHUB pre-qualified service providers work efficiently together

UNDER a network of additive manufacturing HUBs

AMHUB helps customers to set up the AM part portfolio and designing parts to start using AM. When the readiness is built, AMHUB provides the required tools and services for managing and tracking order-manufacturing-delivery process for easy ordering.

TO PROVIDE the required additive manufacturing and delivery end-to-end service

FOR CUSTOMERS with one-stop-shop principle.

Network of HUBs are located in central logistics points to serve customers in the large geographic area.
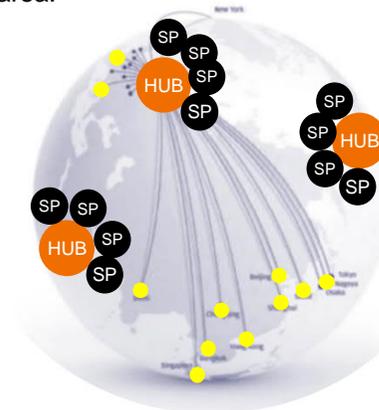
AMHUB operator that works between customers and service providers and selects the best HUB for the customer AM parts based on the customer needs and capabilities provided by each HUB.

AMHUB model provides significant benefits for the customers needing AM parts

KEY CUSTOMER BENEFITS

Simplified AM purchasing

One-stop-shop service simplifies AM part purchasing from multiple service providers: one SLA, one quote & order, one customer support.

Assured high quality

Qualified manufacturing processes, partners, machines and materials plus shared quality assurance practices

Fast order-to-delivery time

Shared processes and practices in AMHUBs speeds-up the operations. No time wasted to transport the part from one service provider to another.

ADDITIONAL CUSTOMER BENEFITS

High-end AM capabilities

Provides the high-quality options for materials, printing and finishing from the pre-qualified service providers. Close co-operation of different providers creates optimal design and outcomes.

Competitive prices

Bigger customer volumes when centralising operations in HUBs. Shared investments in special capabilities e.g. high-quality machines, software, infra

Guaranteed capacity

Guarantees the manufacturing capacity and delivery in all circumstances by overlooking the total capability planning over all service providers.

High level IPR security

Data securely shared, data owner decides who can see/use the data, protected from unauthorized use or corruption

+ benefits of shared process & principles and close service provider collaboration: Optimized sustainability, optimized delivery network, optimized part design support

AMHUB provides value for customers throughout the lifecycle of their products

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AM parts for product development

AMHUB helps companies to run fast design and development iteration cycles TO optimize the functionality, weight, structure and cost of their products with AM capabilities.

AMHUB can help to..

- Optimize performance of parts or complete products
- Meet the tight requirements and regulations
- Solve complex design problems in a new way

AM parts to support production operations

AMHUB provides a cost-efficient way for companies to produce AM molds and customized production tools cost efficiently TO support production of rarely needed or highly customized products.

AMHUB can help to..

- Get AM molds cost efficiently for rarely needed or highly customized products

AM parts to optimize the final products

AMHUB helps companies to create customized AM parts for their products TO provide optimal performance of their products for their customers and differentiate themselves from the competitors.

AMHUB can help to..

- Manufacture parts efficiently and with high quality
- Create critical or complex parts that requires special capabilities (materials, skills, devices, collaboration)

AM spare parts for maintenance operations

AMHUB provides on-demand AM spare parts that are manufactured and delivered punctually for end-customers TO prevent or minimize the down time of operations.

AMHUB can help to..

- Get the spare part fast worldwide to avoid down time
- Get parts exactly on the right time to avoid warehousing
- Get rarely needed spare parts or old spare parts without specs

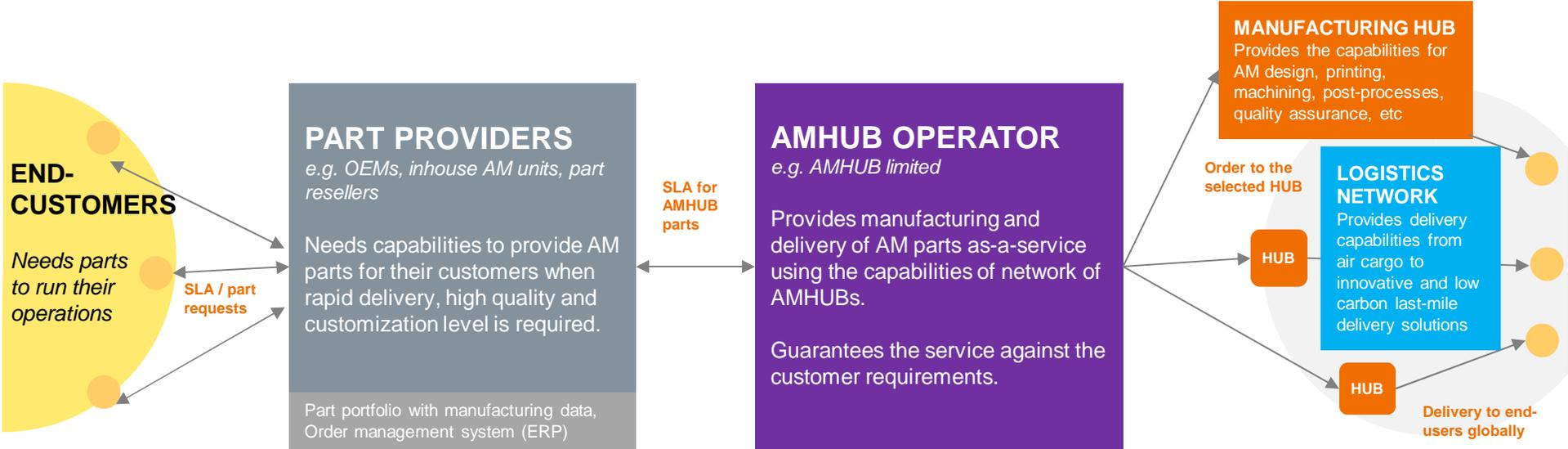# AMHUB can provide value for the needs of different industries

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Industry sectors	Share of current AM market worldwide (%)	Characteristics
Automobile	20	Pioneering industry in adaptation of AM that enables greater automation and traceability of operations. The use of AM started with prototypes and molds, now more focus on in production of spare parts and complex final parts & customized designs in high-end cars.
Industrial manufacturing	20	Manufacturing industry is suffering supply chain disruptions observed during the last years (Covid-19 and current world situation). AM enables the production of a limited and customized quantity of parts, just-in-time production and opportunities for small manufacturers compete with giant producers.
Aerospace & defense	23	AM is used for creation of increasingly complex parts. Both prototypes and mechanical parts are produced and in addition, capabilities for 3D printing parts directly in space are developed. The advantages of using AM are cost-effective production of low volume parts with optimized design, weight and strength.
Consumer products	14	AM is increasingly used in manufacturing of goods including products for the kitchen, gardening, eyewear, cosmetics, jewelry, and indoor decorations. Main benefits of AM are mass customization, decentralized production and reduced time to market and rapid product planning (AM of prototypes).
Medical & dental	11	AM is used in production of personalized biomodels, particular surgical tools, and specific implants. In addition, pills and drugs can be 3D printed. One of the future areas is bioprinting, which is the process of creating tissue and organ-like structures with AM techniques. Highly regulated sector.
Construction & architecture	3	AM has been used a long time for creating architectural structures and prototypes. However, the interest is now more on construction of buildings using AM and manufacturing structural construction parts. The benefits of AM are increased automation in construction and waste savings.
Others	9	Others include food, music, fashion, art, movie industry, oil & gas, energy, aeronautics, academic, agriculture, electronics, marine, pulp and paper, iron and steel. The general benefit of AM is the ability to achieve customized and complex prototypes and end-use parts.

Source: Frost & Sullivan, Global Additive Manufacturing Growth Opportunities, Feb 2022

3. AMHUB services and operations
Key findings based on interviews and desktop study

- **AMHUB service model:** What are the required building blocks to implement the AMHUB service model?
- **AMHUB building blocks:** How each building block could work in an optimal way when AMHUB will be running in full speed (4-6 years)?
- **Required roles, capabilities and development topics:** What roles and related capabilities is needed to implement each building block? What needs to be investigated and developed further?

AMHUB service model with key building blocks in the value network

Service model

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END-CUSTOMERS

Needs parts to run their operations

PART PROVIDERS

e.g. OEMs, inhouse AM units, part resellers

Needs capabilities to provide AM parts for their customers when rapid delivery, high quality and customization level is required.

Part portfolio with manufacturing data, Order management system (ERP)

SLA / part requests

SLA for AMHUB parts

AMHUB OPERATOR

e.g. AMHUB limited

Provides manufacturing and delivery of AM parts as-a-service using the capabilities of network of AMHUBs.

Guarantees the service against the customer requirements.

MANUFACTURING HUB
Provides the capabilities for AM design, printing, machining, post-processes, quality assurance, etc

Order to the selected HUB

LOGISTICS NETWORK
Provides delivery capabilities from air cargo to innovative and low carbon last-mile delivery solutions

HUB

HUB

Delivery to end-users globally

- Order-to-delivery tracking

- Order management & Order-to-delivery tracking
- Manufacturing data

- Order management
- Customer support & management

- Order fulfilment information
- Safe delivery of manufacturing data

ORDER-TO-DELIVERY BACKEND SYSTEM

Provides secure platform for
- Order management (e.g. offer requests, quotes, orders)
- AM manufacturing information sharing (e.g. specifications, 3D models)
- Order fulfillment tracking (e.g. status, quality assurance)

Operator serves the customer needs with the excellence and collaboration of service providers found from network of HUBs

AMHUB operator

Future scenario (in 4-6 years)

AMHUB operator works as a coordinator and customer frontend for AMHUB one-stop-shop that provides manufacturing and delivery of AM parts as an end-to-end service. It operates between the customers and service providers, and matches the needs of the customers with the capabilities provided by different service providers in the network of HUBs.

Ways to fulfil the customer needs

1. **AMHUB Ecosystem & HUB coordination:** Operator helps to create a shared vision and rules to drive all the activities in the AMHUB ecosystem. In addition, operator helps to describe a clear process and responsibilities that enable efficient operations and collaboration in HUBs.

2. **End-to-end service development:** Operator coordinates the AMHUB end-to-end service development that is done continuously in close collaboration with service providers to make sure the services match the customer key needs.

3. **Helping customers to get started:** Operator helps customers to identify the key opportunities of AMHUB for them, and supports building the readiness to start ordering AM parts. Operator also helps to set up the pilots to test AMHUB against the customer requirements.

4. **Smooth ordering:** Operator manages request, quotes and orders by finding the best fitting capabilities from HUBs to provide smooth AM part ordering for the customers.

5. **Customer support:** Operator guarantees the AMHUB service against the requirements in the order. If any problem occurs, operator provides the first point of contact for the customer support. Operator also helps to scale the services according the evolving customer needs.

Operator serves the customer needs with the excellence and collaboration of service providers found from network of HUBs

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Required roles & capabilities

- **Ecosystem developer and strategy planner**: Shared vision roadmap, collaboration models, business models, rules & principles, market understanding, contracts etc.
- **Customer engagement**: marketing & comms, identifying customer needs & assessing the potential, providing support to get started
- **Service developer:** Co-creation based on customer understanding
- **Operations management:** Coordinating operations in each HUB to serve customers
- **Customer support:** Service assurance, collecting feedback, problem solving

Development topics

- ***Operator model:*** *Is there a single operator for the whole AMHUB or is there a need for an operator for each HUB in the network?*
- ***Operator roles:*** *Can a single company fulfill all the operator roles, or should there be multiple companies in different roles?*
- ***Operator funding:*** *What is the best model operator revenue model to make sure the success of the whole ecosystem?*

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Manufacturing HUBs provide high quality parts that meet customer specific needs and industry requirements

Future scenario (in 4-6 years)

Manufacturing HUB collects together pre-validated AM design and manufacturing providers that provide together single parts and short series for high quality prototypes, functional parts, spare parts and production tools for the customers from different industries. Customers can trust that Manufacturing HUB will always deliver optimized and high-quality parts for their own and their customer needs.

Ways to fulfil the customer needs

1. **Comprehensive design and specification support:** HUBs have both AM and industry knowledge that helps customers to optimize the designs but also create the manufacturing specifications and requirements against customer specific needs and industry standards.

2. **Assuring high quality:** Based on part specifications and customer requirements (required speed, quality, capacity) the best HUB is selected, and AM processes, methods and materials are qualified according to at least the latest standards of quality in the relevant field to make sure the optimal and high-quality outcomes.

3. **Efficient manufacturing:** HUB provides high-end 3D printing and post-processing capabilities for various materials. Together with shared principles, information management tools and optimized manufacturing and quality management process, the final parts and products are manufactured efficiently, with high quality and without compromising the IPR security.

4. **Versatile support services:** Service providers in the virtual HUB network can support if the customers need to set up the AM part portfolio and design the first parts to start using AM.

5. **Collaboration and continuous development:** Different HUBs learn from each other, and service providers continuously develop their services to help with the even the most challenging customer cases.

Manufacturing HUBs provide high quality parts that meet customer specific needs and industry requirements

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Required roles & capabilities

- **AM design:** AM Part/product design, manufacturing data and specifications

- **Additive manufacturing:** Additive manufacturing, material ordering, handling and recycling, monitoring of AM process

- **Post-processing:** Machining, heat-treatment, surface treatment services

- **Quality assurance:** Material, process, quality control, etc. documentation practices, control plans, quality audits

- **Certifying body:** Certification audits, certifications

- **HUB facility / infra provider:** Facility management

Development topics

- *Quality of AM parts: What standards and quality control procedures should be used to ensure high quality parts, what kind of quality is achieved and how to implement the practices in the service network?*

- *Manufacturing data handling: What kind of data needs to be stored and transferred related to QA, standards, traceability and how to do it?*

- *Organization of the operations: What is the best way to enable seamless operation and flow of materials and data in the HUB (under same roof / virtual network / hybrid)?*

Increasing resiliency of global supply chains - Customer driven and transparent logistics chain

Future scenario (in 4-6 years)

AMHUB drives resilience of future supply chains. Logistics service providers (LSPs) offer the tools and facilities for logistics and operations management, ensure smooth collaboration between the parties, information transparency, and ontime material flow along the supply chain. The service is customer driven. AMHUB eliminates long transit times and logistics-related uncertainties, such as delays.

Ways to fulfil the customer needs

1. **Optimal location:** The hubs are located in transportation hubs, e.g., close to the airport, with optimal proximity to material suppliers.

2. **Information transparency:** Right partners contribute to the capability to follow up processes along the supply chain and ensure information transparency, with collaboration models in place.

3. **Fast product delivery:** The lead time is short, and all the processes are optimised. Product delivery according to customer needs.

4. **Economies of scale & scope:** Serving multiple customers will ensure efficiency and optimal capacity utilisation, pushing the price of the service down.

5. **HUB operations management:** LSP makes an investment into required technology, know-how, warehouse, transportation and operation management systems, and operates the hub(s). LSP optimises the operations and capacity across the hubs, and orchestrates the resources.

6. **Synergies:** Combining traditional warehousing & logistics services with additive manufacturing will increase efficiency and allow achieving synergies, making the service affordable.

Increasing resiliency of global supply chains - Customer driven and transparent logistics chain

Required roles & capabilities

- **Know-how:** Human resources with knowledge of different industries and technological expertise
- **Operations management:** Capacity & operations planning in/across the hubs
- **Global multi modal transportation chain:** Global freight transport, last mile
- **Information management:** Integrated information systems along the supply chain
- **Warehousing and material handling:** WMS and supplier base
- **End-to-end management capabilities:** Collaboration, transparency and optimization

Development topics

- *How does the market look today and for the future, incl. customer need, industries to focus on, geographical areas, suppliers and timing for entering the market?*
- *What are the cost structure of AMHUB and hidden costs for different actors (e.g. penalties)?*
- *What are the main risks of the model?*
- *How to create information transparency for the chain?*
- *What is the role of LSP in the concept? What are the needed capabilities for LSPs? What operational restrictions are involved?*
- *What factors drive the decision on hub location? Where are the suppliers located?*

Backend system provides trusted data exchange and automation in AMHUB ecosystem

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Backend system

Future scenario (in 4-6 years)

AMHUB backend system provides highly automated and secure participative infrastructure (platform) for AMHUB ecosystem partners for various interactions such as AM data exchange, tendering, order management, tracing and knowledge sharing. AMHUB is open, allowing regulated participation by setting governance conditions for interacting parties - who can participate to platform and how.

Ways to fulfil the customer needs

1. **Secure data sharing:** Data will only be used for the purpose authorized by the AMHUB partner (e.g. OEM) without compromising IPR (e.g. digital product design or AM technologies).
2. **High automation:** Highly automated functions that hide the complexity of various AMHUB operations (tendering, order splitting and coordination, tracing, integration, manufacturing execution, …).
3. **Smart AM support services on top of the platform:** For instance, sustainability support via automated calculation of carbon footprint throughout the whole supply chain and "fair" manufacturing / logistics network capacity management, etc. Data-driven AI supported automated manufacturing. AI based matching and configuration of AM capabilities based on digital product design and MBOM.
4. **AM knowledge sharing portal:** Expanding the use of AM in society through functions such as communication of AM opportunities for companies, facilitating and sharing the AM experiments of companies, training possibilities, AM part library and co-design/-innovation support for partners developing AM parts.

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Backend system provides trusted data exchange and automation in AMHUB ecosystem

Backend system

Required roles & capabilities

- **Back end system provider:** platform provider for providing, hosting and improving the backend system.
- **System integrators:** integration of AMHUB backend system to stakeholders' IT systems.
- **Knowledge partners:** educational and research partners.

Development topics

- *Modelling of digital value co-creation in AMHUB ecosystem: What kind of operational model alternatives there are for AMHUB that support AMHUB use cases? What kind of value/business opportunities they provide for partners?*
- *Development and piloting: What kind of platform / backend system solution is applicable for AMHUB? Experiences of AMHUB backend system pilots?*
- *Trusted data exchange and smart applications in AMHUB ecosystem: How to handle secure data exchange in AMHUB? What kind of smart AM support services could be built on the top of the AMHUB platform?*

4. Steps to reach the vision

- **AMHUB future scenario**: What AMHUB could look like in 2024?
- **Steps towards the vision**: How AMHUB could grow towards the vision? How value is created in each step towards the AMHUB vision?
- **Preliminary research questions**: What needs to be investigated and developed together to start driving the business in AMHUB?

AMHUB future scenario
"Press release" – May 2024

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AMHUB opened the first additive manufacturing HUB in Helsinki-Vantaa airport area today. AMHUB offers high quality AM services for industrial customers with an optimised logistic network for worldwide deliveries.

AMHUB connects certified AM houses, OEMs, logistics operators and supporting 3rd party service providers to a seamless service that are already used by leading energy, construction, medical and machinery companies.

With this model AMHUB enables company to deliver the AM parts anywhere their customers need them in a record time while ensuring the highest quality standards. This will ensure that companies will be able to minimise the production downtime and have the best lead times for supplying parts for customers without the need for having capital tied in stock.

AMHUB has already agreements to open manufacturing HUBS in US and China during this year to support their global customers.

Making sure the value is created in each step towards the AMHUB vision

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Companies establish AMHUB ecosystem that ignites the collaboration

TO start serving the key customers from the selected industries together.

Ecosystem building focus:
Shared vision, development roadmap, shared offering, ecosystem rules and principles

The first HUBs are opened and supporting virtual service provider network is built TO start the close collaboration and maximize the benefits of AMHUB model for customers.

HUB building focus:
Shared manufacturing and delivery process, infra & tools, roles and responsibilities

Network of HUBs grows, and more industry specific excellence joins the virtual network TO serve customer specific needs for wider customer base worldwide.

Scaling focus:
Service development and service growth according to customer needs

Increasing number of HUBs and high-end AM capabilities in each HUB

Increasing the support for customers to utilize AM parts in their business that grows the market for AM parts

A new channel to reach new customers for AMHUB service providers that increases the volume of their business

Preliminary research & development topics for AMHUB concept

- *Customer value: What are the possibilities vs. threats for outsourced HUB than insourced operation?*
- *AM market potential: How does the market look today and for the future, incl. customer need, industries to focus on, geographical areas, suppliers and timing for entering the market?*
- *Customer engagement: How customer facing roles and customer engagement journey could look like?*
- *Cost & revenue structure: What is the cost structure of AMHUB and hidden costs for different actors (e.g. penalties)? How the value is shared with the service providers?*
- *Risks: What are the main risks of the model?*
- *Information transparency: How to create information transparency throughout the value network?*
- *Governance structure: What are the required governance roles & responsibilities, shared rules and principles?*
- *Sustainability in AMHUB: What sustainability means in the context of AMHUB? How the sustainability needs of partners can be supported in this environment?*

NOTE: Research & development topics will be described in detail in the joint project plan

Building block specific research & development topics

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AMHUB operator

- **Operator model:** *Is there a single operator for the whole AMHUB or is there a need for an operator for each HUB in the network?*
- **Operator roles:** *Can a single company fulfill all the operator roles, or should there be multiple companies in different roles?*
- **Operator funding:** *What is the best model operator revenue model to make sure the success of the whole ecosystem?*

Manufacturing HUB

- **Quality of AM parts:** *What standards and quality control procedures should be used to ensure high quality parts, what kind of quality is achieved and how to implement the practices in the service network?*
- **Manufacturing data handling:** *What kind of data needs to be stored and transferred related to QA, standards, traceability and how to do it?*
- **Organization of the operations:** *What is the best way to enable seamless operation and flow of materials and data in the HUB (under same roof / virtual network / hybrid)?*

Logistics & supply chain

- **Information transparency:** *How to create information transparency for the chain?*
- **Role of LSPs:** *What is the role of LSP in the concept? What are the needed capabilities for LSPs? What operational restrictions are involved?*
- **HUB locations:** *What factors drive the decision on hub location? Where are the suppliers located?*

Backend system

- **Modelling of digital value co-creation in AMHUB ecosystem:** *What kind of operational model alternatives there are for AMHUB that support AMHUB use cases? What kind of value/business opportunities they provide for partners?*
- **Development and piloting:** *What kind of platform / backend system solution is applicable for AMHUB? Experiences of AMHUB backend system pilots?*
- **Trusted data exchange and smart applications in AMHUB ecosystem:** *How to handle secure data exchange in AMHUB? What kind of smart AM support services could be built on the top of the AMHUB platform?*

NOTE: Research & development topics will be described in detail in the joint project plan

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