Handbook of Additive Manufacturing (AM) adoption

UNIVERSITY OF TURKU
Turku School of Economics

Handbook of Additive Manufacturing (AM) adoption

ISBN 978-951-29-9653-7

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University of Turku 2024

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Foreword

This handbook aims to provide valuable insights and guidance for organizations embarking on the journey of adopting Additive Manufacturing (AM) technology.

The handbook serves as a comprehensive resource to shed light on how to get started with AM and represents aspects to consider before moving forward. Additionally, it offers a comprehensive overview of recognized AM implementation frameworks.

The need for such a handbook arises from the increasing importance of AM in reshaping industries. As organizations recognize the potential of AM e.g., gaining competitive advantage and driving value creation, it becomes imperative to navigate the complexities of its adoption effectively.

By addressing barriers, developing effective change management strategies, and leveraging success factors, organizations can unlock the full potential of AM for more efficient, innovative, and even sustainable operations.

This handbook aims to guide organizations in overcoming the challenge of adopting AM by decoding the complex nature of the technology adoption and offering managers and other experts practical guidance.

This handbook is based on research done at the **Centre for Collaborative Research CCR** at the University of Turku, in the DREAMS (Database for Radically Enhancing Additive Manufacturing and Standardization) project. The project is funded by the members of the DREAMS consortium and Business Finland.

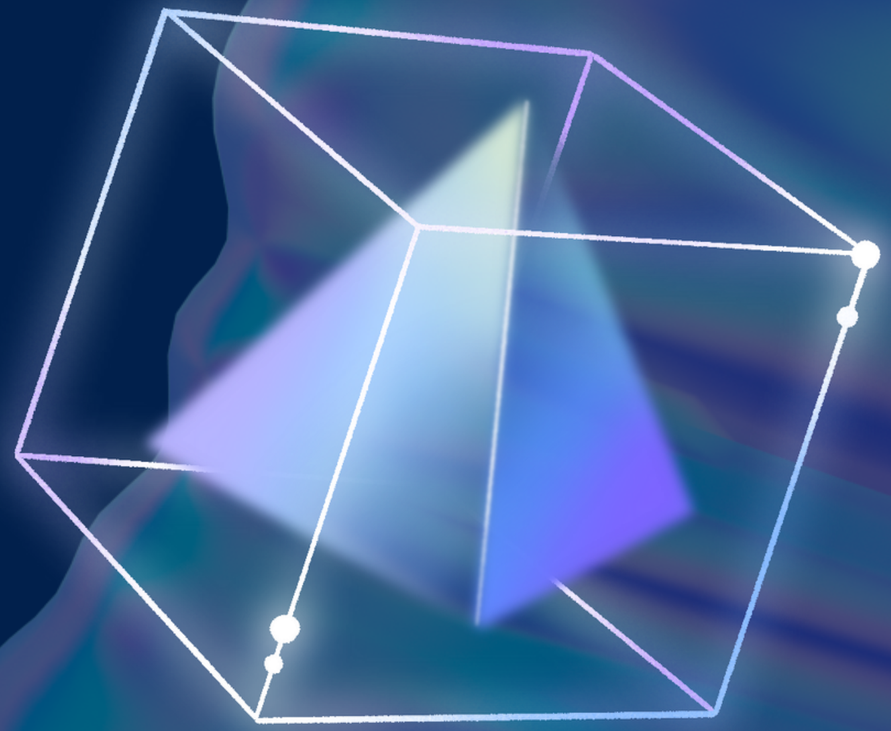
Recommendations in the handbook are based on a synthesis of earlier research and analysis of qualitative interview data.

Introduction

Nature of AM technology

AM has emerged as a transformative technology reshaping industries worldwide. While its potential for innovation and efficiency gains are widely acknowledged, the journey toward implementing AM within organizations is fraught with challenges that extend beyond technical considerations.

This handbook serves as a comprehensive guide to navigating the complexities of AM adoption, offering insights and strategies to facilitate successful implementation into organizational practices.



Introduction

Nature of AM technology

The landscape of AM technology is diverse, encompassing various processes and applications, yet all share the fundamental principle of building components layer by layer (e.g., Mellor et al. 2014). As AM gains prominence as a disruptive force in business and product design, organizations are driven to explore its potential for gaining competitive advantage and driving value creation.

Indeed, the research underscores the link between AM and competitive advantage, highlighting the imperative for firms to embrace this technology to remain relevant in today's dynamic market environment (Turkcan et al. 2022).

Compared to many other technologies, AM is more systemic in nature and therefore its successful adoption has some particular traits. The adoption challenges ranging from managing organizational transformation to addressing technological as well as human factors pose significant hurdles for organizations embarking on their AM journey.

In line with the broader context of the digital transformation of Industry 4.0, successful AM adoption requires strategy, effective change management, and a skilled workforce capable of leveraging the technology to its fullest potential (Gehrke et al. 2016).

Introduction

Nature of AM technology

Although AM technology evolves, due to its systemic nature, the logic of its adoption can be expected to remain relatively consistent in the near future.

Therefore, this handbook is expected to remain relevant beyond immediate advancements. The recommendations in the handbook are guaranteed fresh for up to five years.

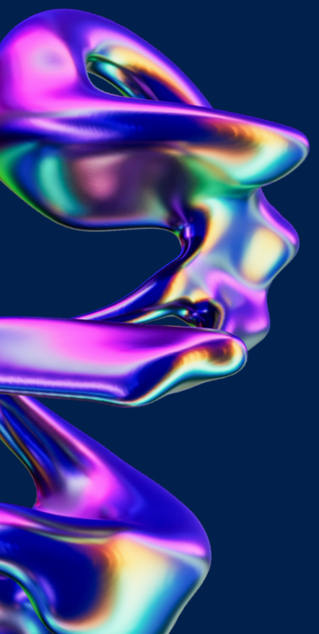
Handbook's "freshness guarantee" for up to 5 years.

Introduction

Purpose of this handbook

This handbook is designed to address challenges related to AM adoption, providing organizations and managers with practical guidance and actionable insights for navigating the complexities of AM adoption.

By focusing on key barriers such as the lack of AM knowledge and high investment costs, the handbook offers insights and suggestions for embarking on the AM journey. This handbook gives answers to three questions:



01 What are the fundamental challenges and strategic considerations that organizations encounter during the adoption of AM technology?

02 What steps and best practices should organizations be familiar with during the initial stages of adopting AM?

03 How do real-world case examples provide concrete illustrations of various strategies and approaches to AM adoption?

Introduction

Purpose of this handbook

Through a combination of theoretical frameworks, case studies, and practical recommendations, this handbook aims to equip organizations with the tools and knowledge necessary to overcome obstacles and harness the transformative potential of AM.

As AM continues to evolve and expand it's footprint across industries, this handbook serves as a valuable resource for organizations seeking to embrace innovation and stay ahead of the curve in an increasingly competitive landscape.

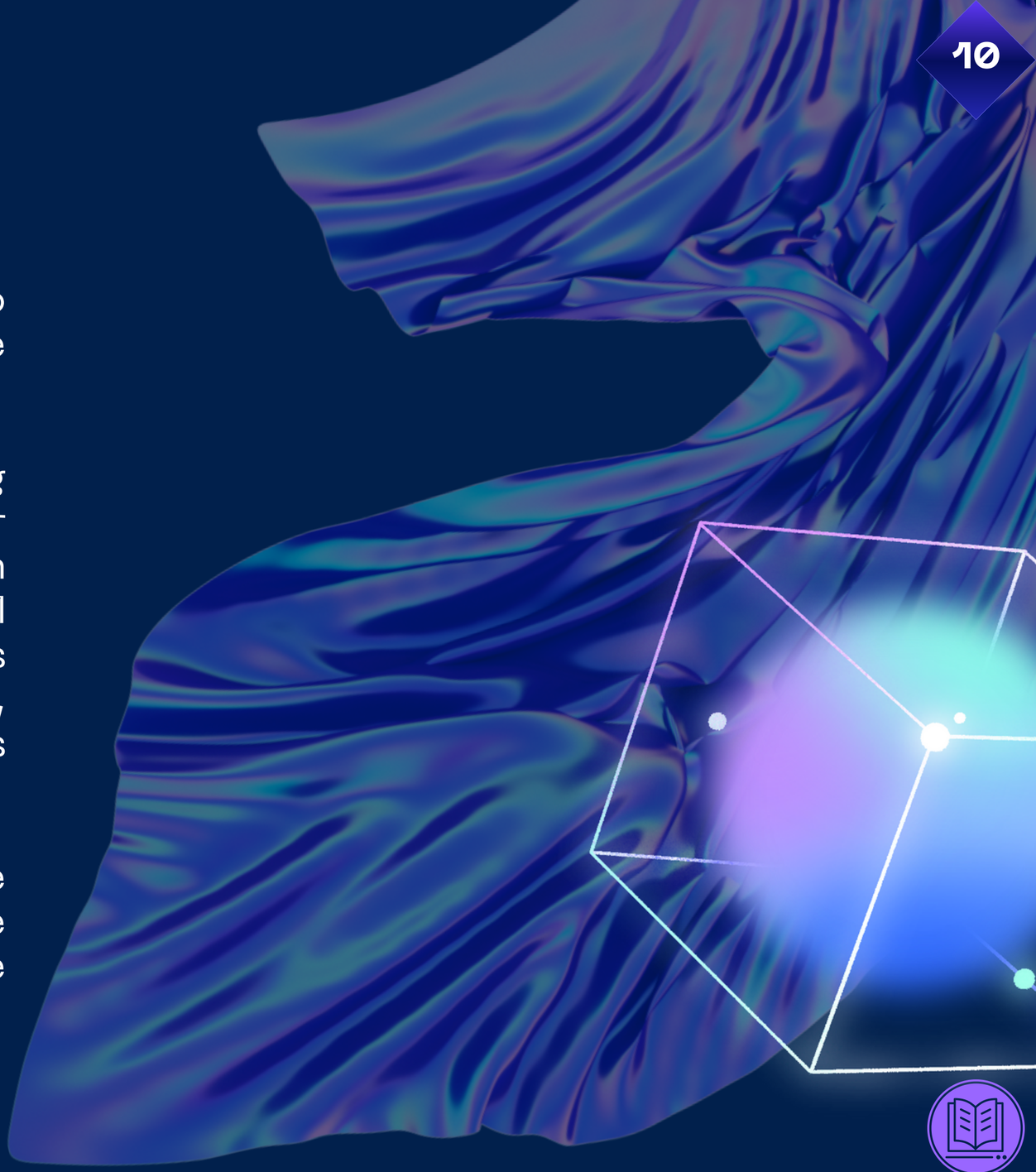
Introduction

Purpose of this handbook

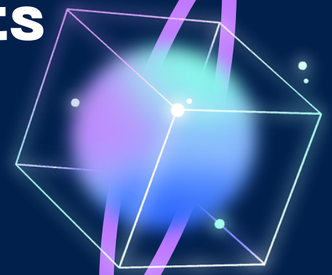
This handbook divides the adoption of AM into two stages; an early-stage adoption creates the base for the later-stage adoption.

While this handbook concentrates on shedding light on the early-stage adoption, the later stage is highlighted as something to bear in mind from the very beginning. Therefore, AM adoption can be seen as a complex process where everything depends on multiple aspects, e.g., AM vision, knowledge, and eagerness toward the technology.

Adoption can be holistic, impacting the entire value chain and individuals. However, the impacts of adopting AM technology on value networks are beyond the scope of this handbook.



Human resources, expertise, and enthusiasm are critical components of a successful AM technology adoption.



The handbook explores how organizations adopt AM technology, emphasizing the crucial role of setting clear goals and strategies to define what they aim to achieve with AM.

Introduction

How to use this handbook

The first part provides a concise overview of key takeaways related to AM adoption, drawn from literature. These key takeaways offer insights into the essential knowledge required during the initial stages of AM adoption.

The second part of the handbook includes three case examples of AM adoption (based on real-life cases), a theoretical framework for successful AM adoption, and benchmarks derived from expert interviews and literature.

The handbook concludes with
1) TIPS on successful AM adoption process
2) recommended supplementary materials

Part 1

When considering the integration of AM, it is crucial for companies to understand and anticipate potential barriers. This first part of the handbook concentrates on presenting key challenges that organizations should be aware of and two managerial frameworks for outlining the big picture.

1. Aim to understand the big picture

Part 1

To ensure a successful journey into the realm of AM, organizations must broaden their perspective beyond immediate gains and delve into the comprehensive landscape of AM integration.

1. Aim to understand the big picture

Part 1

While some envision AM as a revolutionary force in manufacturing, others propose a more moderate view, suggesting that AM may fall somewhere between entirely reshaping manufacturing and remaining on the periphery (Sasson and Johnson 2016; Gibson et al. 2021). Therefore, organizations must approach AM adoption with a balanced perspective, acknowledging its transformative potential while also considering its limitations and challenges.

While AM use cases seen thus far have often been limited to low-volume production and prototyping, this may not necessarily be the case in the future. The exponential growth of AM demands a holistic approach. While focusing on low-volume production and prototyping is common, organizations risk overlooking other valuable applications and benefits (Kamara & Faggiani 2021).

However, the path to scaled adoption of AM for end-use parts is fraught with challenges, including workforce shortages and the absence of standardized digital design and manufacturing processes. Understanding these hurdles is crucial for devising effective strategies to overcome them. (Deloitte 2019.) Also, setting realistic expectations regarding the challenges and complexities involved in creating 3D-printed parts is essential (Neuner & Lang 2019).

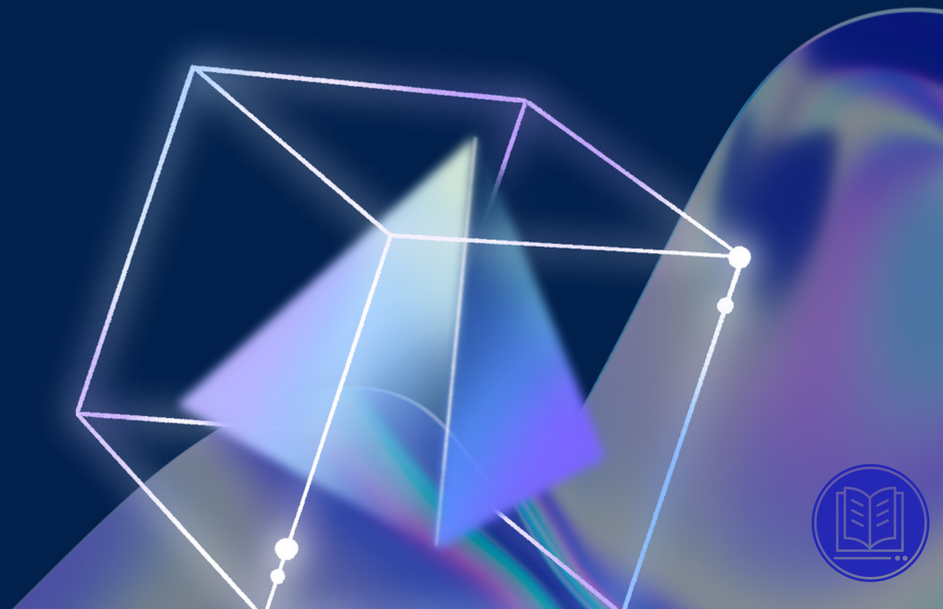
1. Aim to understand the big picture

Part 1

Manufacturing companies may hesitate to embrace AM due to existing infrastructure investments, organizational inertia, and the multitude of available technologies, applications, and materials. However, a thorough understanding of AM's diverse variations and associated benefits as well as challenges is necessary for organizations to make informed decisions and navigate the complexities of AM adoption (Mellor et al. 2014; Kamara & Faggiani 2021).

Tailoring AM implementation strategies to suit organizational size and structure is crucial for success (Mellor et al. 2014). Whether you're an SME or a large corporation, redefining organizational processes and fostering different kinds of stakeholders can catalyze innovation and drive collaborative learning.

Ecosystems and collaboration play a pivotal role in facilitating AM adoption, particularly for SMEs with limited resources. Collaborative hubs and ecosystems serve as invaluable platforms for knowledge exchange and collective development, empowering organizations to overcome challenges and seize opportunities (Müller et al. 2018; Benitez et al. 2020).

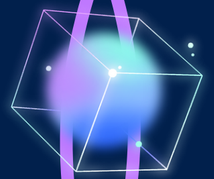


1. Aim to understand the big picture

Part 1

In the following two pages two different managerial frameworks for outlining the big picture of AM adoption will be presented.

Firstly, Mellor et al. (2014) propose a framework that integrates internal strategy and external forces to guide AM adoption. This framework, comprising of different factors serves as a roadmap for managers navigating the complexities of AM implementation.

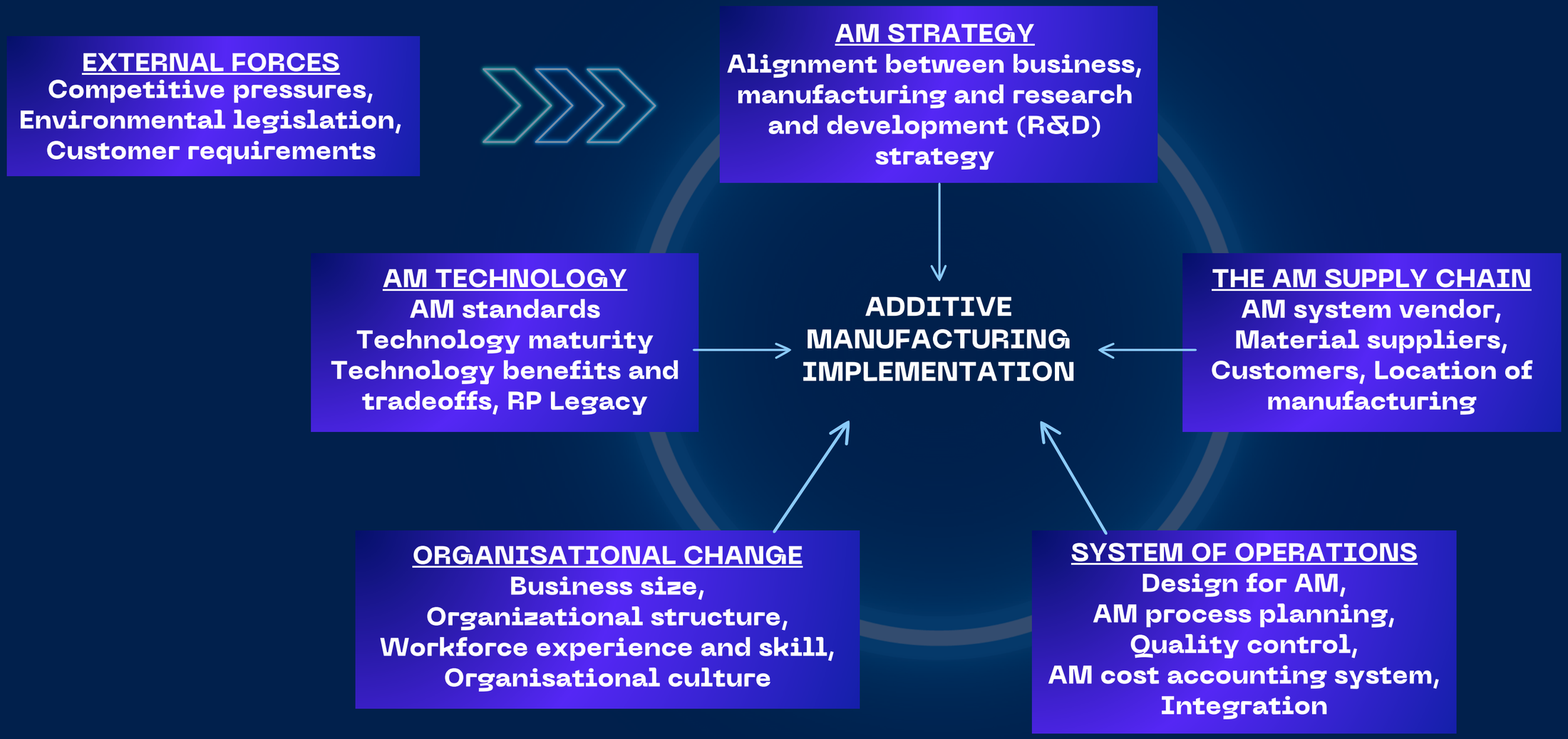


Secondly, Deloitte (2019) advocates for a strategic, four-step approach to AM adoption. From identifying challenges to fostering organizational shifts and external partnerships, this method ensures a comprehensive and systematic adoption of AM at scale.

1. Aim to understand the big picture

Part 1

The proposed framework of AM implementation, adopted from Mellor et al. (2014)



1. Aim to understand the big picture

Part 1

Four steps approach for effective AM implementation, adopted from Deloitte (2019)

EVALUATION

Assess the compatibility of AM solutions with your organization and substantiate the necessity for its implementation. Determine which products possess characteristics that would benefit from AM utilization, considering factors such as system complexity and the requirement for complex geometries or customization. Thoroughly evaluate all associated challenges.

BUSINESS CASE

Calculate a business case for integrating AM into the manufacturing process. The business case should examine AM´s effects on manufacturing operations, e.g., reductions in assembly steps, scrap, and inventory, as well as elimination of tooling and potential lifecycle cost savings. Assess these potential benefits against any increased material costs and investments in product design.

ROADMAP

Form a strategic implementation plan (roadmap), detailing expectations, capabilities, timing, and metrics to address challenges effectively. Begin with piloting the solution in a targeted area before scaling it across the organization.

ORGANISATIONAL SHIFT

Foster an organizational shift towards AM and identify internal change champions to facilitate widespread adoption. Also, look outside the organization to explore external partnerships as part of the ecosystem.

1. Aim to understand the big picture

Part 1

By embracing the big picture of AM and adopting a strategic mindset, organizations can position themselves for success in the dynamic landscape of advanced manufacturing.

2. Grasp the essence of the technology

Part 1

To embark on a successful journey into AM, organizations must grasp the essence of this transformative technology.

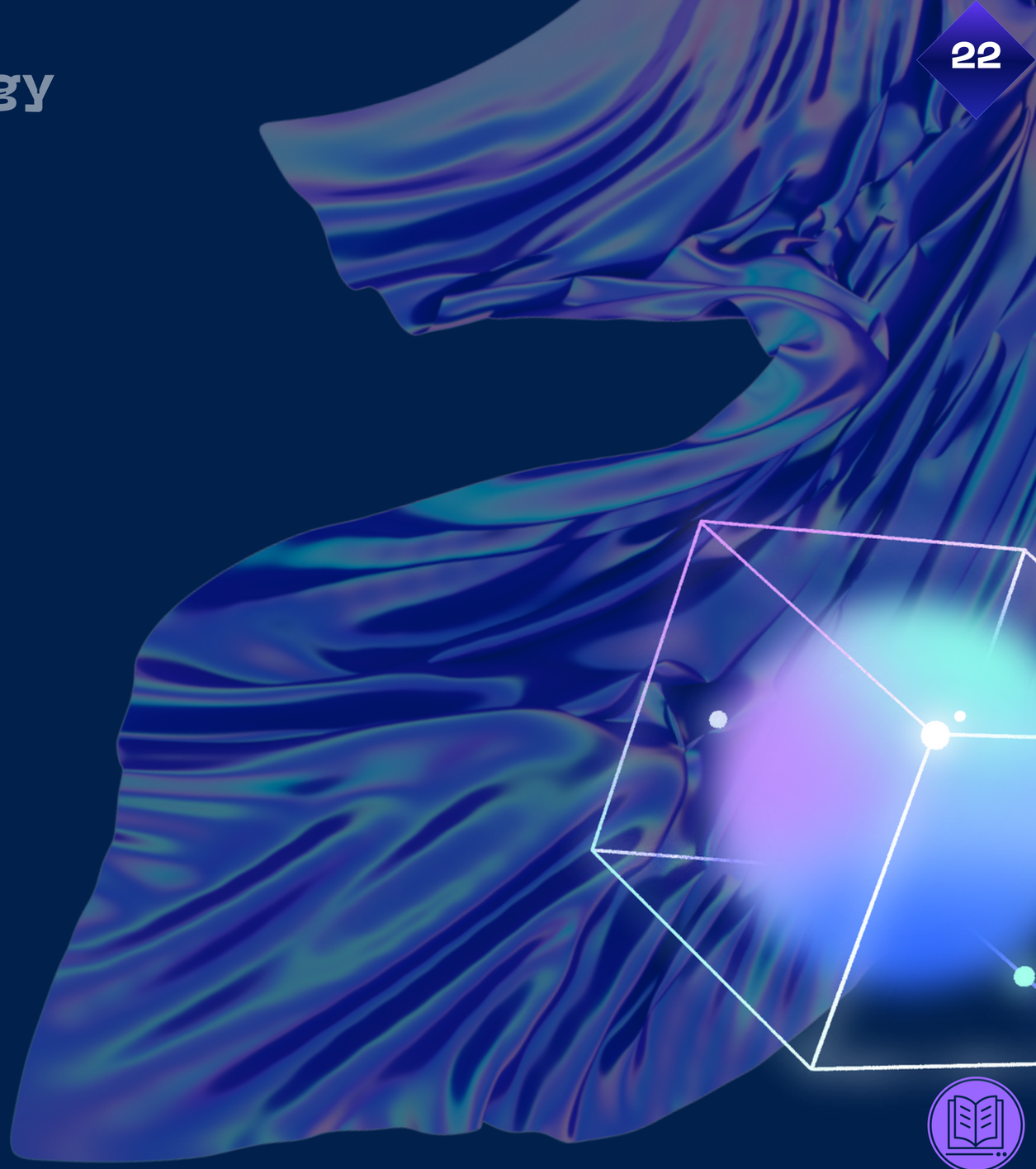
2. Grasp the essence of the technology

Part 1

AM encounters various technical hurdles that hinder its rapid expansion, including e.g., size limitations, extended production times, high costs, and regulatory intricacies (Attaran 2017).

Additionally, overcoming psychological barriers, such as the association of AM primarily with rapid prototyping, is essential for embracing its full potential in various manufacturing contexts (Mellor et al. 2014).

These challenges necessitate a nuanced and innovative approach to AM adoption and can impede scalability and competitiveness with traditional manufacturing methods. Additionally, regulatory frameworks, though essential, often struggle to keep pace with AM's rapid innovation rate. (Attaran 2017; Deloitte 2019.)



2. Grasp the essence of the technology

Part 1

While AM necessitates shifts in behavior, skills, and knowledge among workers, fundamental work categories in manufacturing — such as process, design, material, compliance, and testing, remain unchanged (Kamara & Faggiani 2021). AM offers efficiency advantages, allowing for design modifications during product development and reducing time sensitivity and resource usage compared to traditional methods (Attaran 2017). The following table includes examples of advantages over traditional manufacturing (adopted, Attaran 2017).

EXAMPLE AREAS OF AM APPLICATIONS	AM ADVANTAGES OVER TRADITIONAL MANUFACTURING
Production of Spare Parts	Reduce repair times, reduce labor costs, avoid costly warehousing
Rapid Prototyping	Reduce time to market by accelerating prototyping, reduce the cost involved in product development, making companies more efficient and competitive at innovation
On-Site and On-Demand Manufacturing of Customized Replacement Parts	Eliminate storage and transportation costs, save money by preventing downtimes, reduce repair costs considerably, shorten the supply chain, the need for large inventory is reduced, allow product lifecycle leverage
Component Manufacturing	Enable mass customization at low cost, improve quality, shorten supply chain reduce the cost involved in development, help eliminate excess parts

2. Grasp the essence of the technology

Part 1

AS A COUNTERBALANCE TO AM ADOPTION-RELATED CHALLENGES, THE TECHNOLOGY ALSO HAS MULTIPLE RECOGNIZED BENEFITS, FOR EXAMPLE:	
Design and the product	**Improved product strength and functionality** (Neuner & Lang 2019) **Seamless products** (Gibson et al. 2021) **Greater design freedom** (Neuner & Lang 2019) **Product/design customisation** (Holmström et al. 2010; Neuner & Lang 2019; Gibson et al. 2021; Rad et al. 2022)
Production process	**Localized production** (Neuner & Lang 2019) **Mitigation of wastage** (Holmström et al. 2010; Nuener & Lang 2019) **Reduction of process steps** (Holmström et al. 2010; Neuner & Lang 2019; Gibson et al. 2021) **Reduced assembly time for complex components/time efficiency** (Neuner & Lang 2019; Gibson et al. 2021)
Supply chain	**Green/optimized supply chain** (Rad et al. 2022) **Decreased reliance on traditional suppliers** (Neuner & Lang 2019) **Potential for simpler supply chains; shorter lead times, lower inventories** (Holmström et al. 2010)
Other	**More streamlined, cleaner, and versatile manufactories** (Gibson et al. 2021) **Integration and improved R&D** (Neuner & Lang 2019; Rad et al. 2022) **Competitive advantage** (Kyläheiko and Maijanen 2020, 172; Turckan et al. 2022)

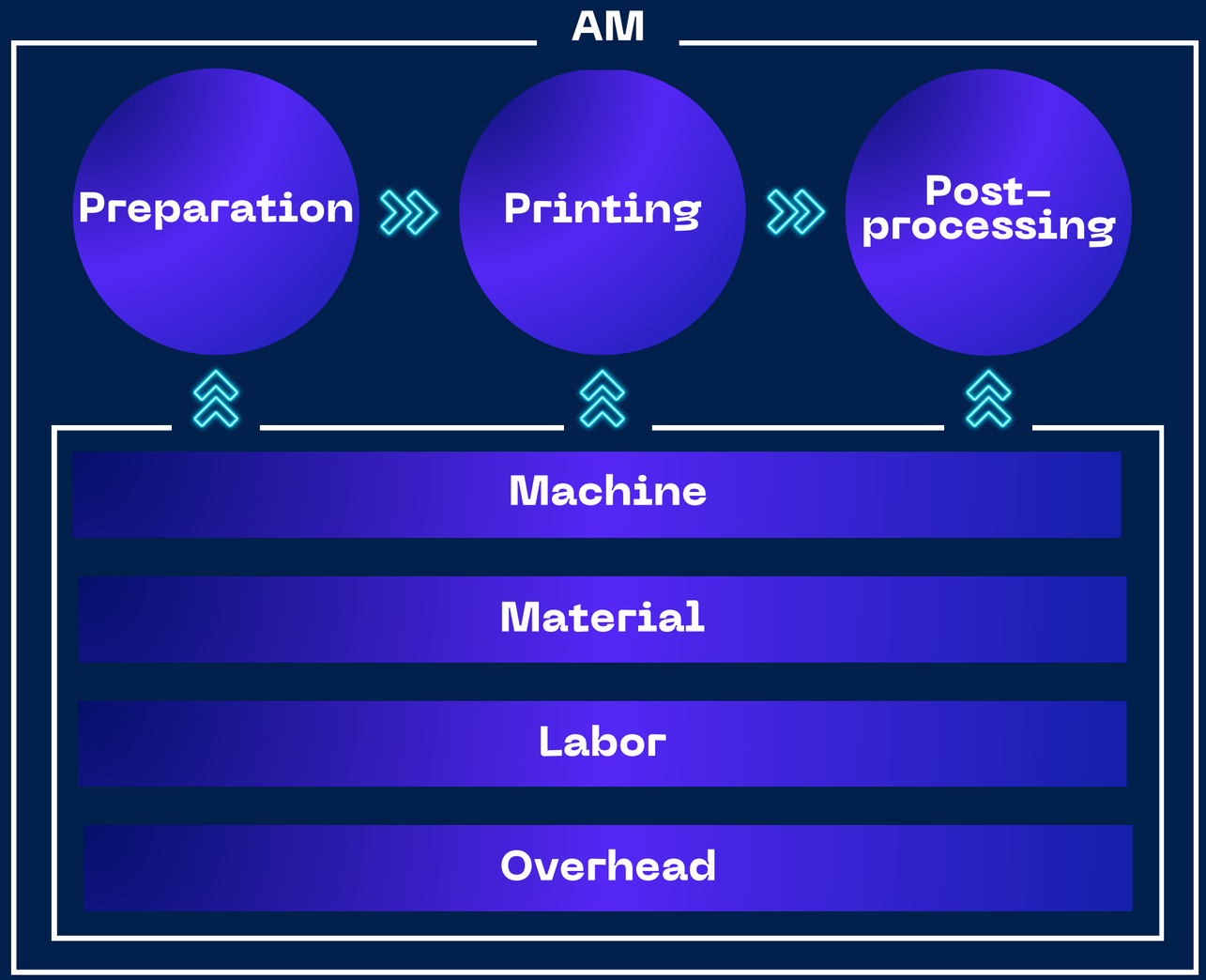
2. Grasp the essence of the technology

Part 1

Transitioning to AM requires significant investments, which can be an obstacle at least for companies operating alone in the field. Beyond machinery costs, high prices for printable materials and substantial investments in employee training further contribute to the financial considerations. (see Attaran 2017; Müller et al. 2018; Gibson et al. 2021; Kamara & Faggiani 2021.)

The cost model of AM diverges significantly from conventional manufacturing, with distinct cost factors associated with each workflow step (Deloitte 2019). Understanding this complex cost structure is vital for effective budgeting and investment planning.

Cost model of AM according to Deloitte (2019)



2. Grasp the essence of the technology

Part 1

From the resource perspective, AM adoption should be regarded as a structural investment. Firstly, it builds new manufacturing capabilities, and secondly, it creates new business opportunities (Mellor et al. 2014).

3. Acknowledge the value of knowledge and collaboration

Part 1

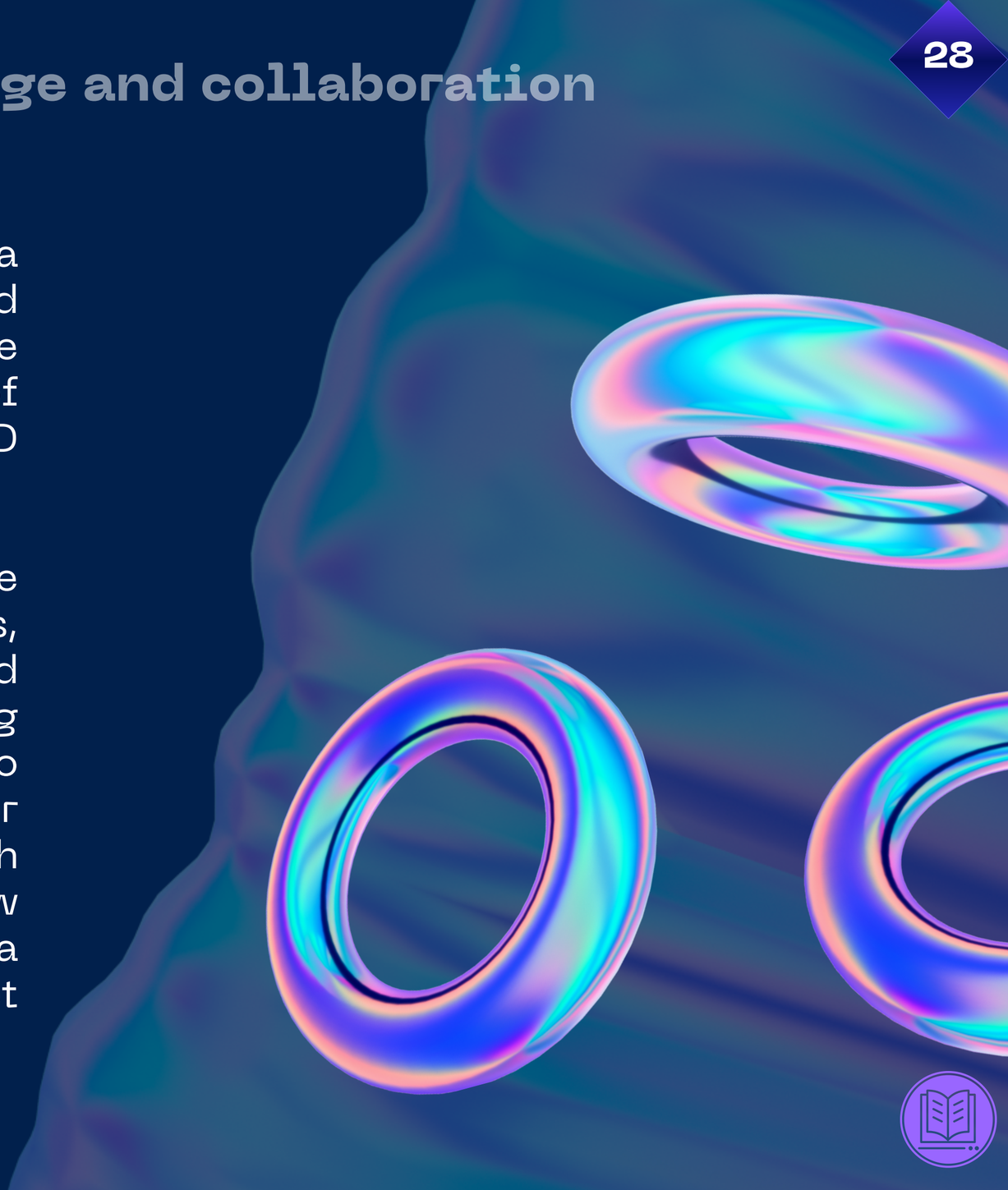
To overcome the challenges of adopting AM, organizations must prioritize learning and collaboration.

3. Acknowledge the value of knowledge and collaboration

Part 1

As identified by Priyadarshini et al. (2022), a skilled workforce and robust R&D are identified as bottlenecks of AM adoption. Addressing these obstacles requires a continuous process of workforce acquisition, training, and R&D investments.

AM's additive nature necessitates the development of new practices and design tools, challenging traditional strategic options and norms. Adopting AM as a new manufacturing technology requires engineers and designers to adopt a fresh mindset toward design for manufacturing (DFM). Products must align with AM processes, and users need to grasp new process capabilities, emphasizing the need for a skilled workforce. (Mellor et al. 2014; Gibson et al. 2021.)

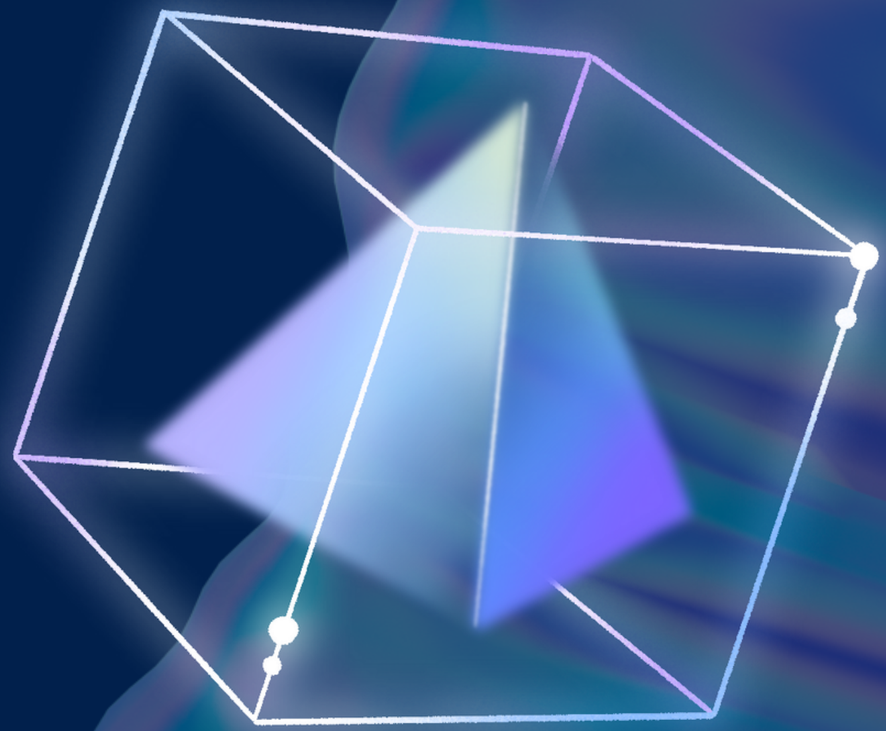


3. Acknowledge the value of knowledge and collaboration

Part 1

Industrial production managers and manufacturing engineers play pivotal roles in replacing existing methods or integrating AM into current production processes. Improved collaboration and communication across various organizational functions are essential to ensure a seamless connection among various stakeholders. (Mellor et al. 2014; Kamara & Faggiani 2021.)

Communication throughout the organization is essential to initiate a pilot, allowing learning about the technology and identifying its best applications. Additionally, organizations can acquire an AM system, install it for employee use, and encourage the exploration of optimal applications. Other pilot strategies include consulting with service bureaus or regional university AM consortia, seeking insights from reliable machine vendors, and developing a sensing path. (Kamara & Faggiani 2021.)



3. Acknowledge the value of knowledge and collaboration

Part 1

Various strategies exist for piloting AM technology, requiring collaboration with internal and external groups (Deloitte 2019). Careful selection of an AM pilot project, based on clear business needs, is crucial to showcase the technology's value-additive capabilities within the organization's specific context and to illustrate AM´s economic value.

4. Define the AM strategy and required depth of organizational renewal

Part 1

Navigating the transformative landscape of AM requires organizations to embrace strategic renewal.

4. Define the AM strategy and required depth of organizational renewal

Part 1

To maintain a competitive edge, organizations must efficiently transform and reorganize their manufacturing routines, skills, capabilities, and knowledge base. Companies adopting AM should recognize organizational renewal as a primary challenge amidst the competitive advantage offered by AM (Kyläheiko & Maijanen 2020).

However, transitioning to new technology isn't always the best strategic choice initially. Without proper implementation processes and strategic planning, operational decisions may rely on outdated rules hindering success. Failure to address structural and organizational changes can lead to unsuccessful AM adoption. (Sonntag 2003.)

Organizations embracing AM must develop a vision and strategy for AM within their business model (Kamara & Faggiani 2021).

Adopting AM entails changing tasks, work practices, and organizational structure. Integrating AM benefits into the overall business strategy is essential for gaining a competitive edge (Mellor et al., 2014). While recognizing the need for compromises, organizations must weigh AM's potential benefits against high costs, slow process speed, and material limitations (Sonntag 2003; Mellor et al. 2014).

A change management strategy is crucial for the successful adoption of AM. Challenges such as selecting the wrong AM process or material or realizing that a component design is better suited to traditional methods underscore the strategy's importance (Neuner & Lang 2019). Strategy is also needed for acquiring knowledge and learning.

4. Define the AM strategy and required depth of organizational renewal

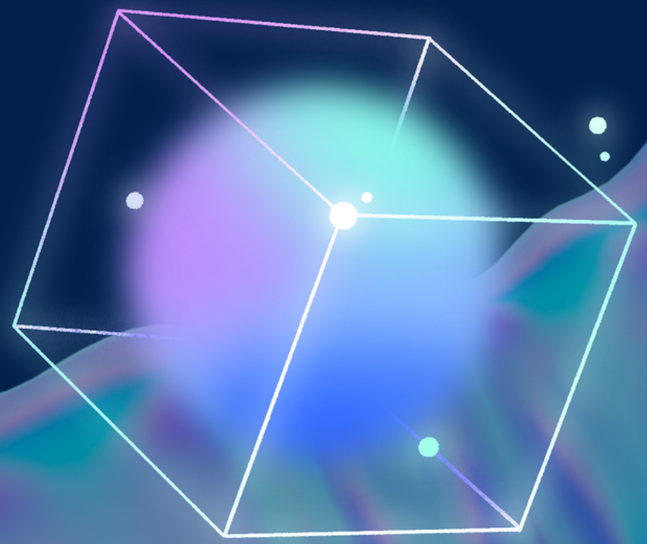
Part 1

Developing a change management strategy for AM adoption necessitates an understanding that there is no one-size-fits-all solution. The approach to change must consider factors such as organization size, AM vision, and the specific applications of AM.

Depending on the selected strategy, the change is either radical or incremental. However, three fundamental areas remain crucial across various cases: acquiring AM systems, enhancing employee skills, and redesigning processes (Kamara & Faggiani, 2021).

Effective communication among various stakeholders about AM's benefits is pivotal for the successful adoption (Mellor et al. 2014).

The lack of a skilled workforce can hinder the effective utilization of AM technologies and processes. Therefore, investing in comprehensive change management strategies, including employee training and skill development, is imperative for successful AM adoption. (Kamara & Faggiani 2021.)



4. Define the AM strategy and required depth of organizational renewal

Part 1

Resistance to change and time constraints for innovation pursuits present significant challenges. (Gehrke et al. 2016; Neuner & Lang 2019). Overcoming these challenges requires a shift in traditional manufacturing mindsets and fostering a culture of innovation and continuous learning within organizations (Neuner & Lang 2019).

AM adoption in a nutshell

Part 1

In a nutshell, the adoption of AM technology hinges on two fundamental pillars: learning and strategic decision-making. Success requires organizations to invest in understanding AM's complexities and implications while strategically allocating resources for adoption. Collaboration, continuous learning, and fostering a culture of innovation further enhance the journey toward successful AM adoption, positioning organizations to leverage its transformative potential effectively.

AM adoption in a nutshell

Part 1

01 Continuous learning process:

The core of successful AM implementation lies in learning. While frameworks for AM adoption are challenging to create due to the complexity and lack of best practices, existing literature and identified frameworks share commonalities that complement each other. Success depends on various factors, most importantly organizational size, industry, culture, people, and strategy. An early-stage implementation framework presented in part two was developed, emphasizing knowledge and learning as essential factors for success.

02 Intuitive understanding:

Intuitive understanding of AM is crucial, especially at the managerial level. While AM is often studied from technical aspects, its impact on organizational and people levels is equally significant. Lack of understanding can hinder implementation efforts, emphasizing the need for knowledge dissemination and case evidence creation. Encouraging a culture of exploration and failure tolerance is vital for fostering innovation and successful adoption. Management's understanding of AM technology and its long-term benefits is crucial for effective decision-making regarding resource allocation.

AM adoption in a nutshell
Part 1

03 Resource allocation:

Adequate resources are essential for successful AM adoption. This includes not only financial resources but also time and competence. The resource allocation must be guided by organizational objectives as well as AM knowledge, including metrics such as lifecycle costs and return on investment (ROI). Internal champions play a crucial role in resource allocation and knowledge dissemination within organizations.

04 Collaboration:

Collaboration, both within and outside the organization, is vital during the adoption process of AM. External collaborators, such as AM service providers and ecosystems like FAME, can provide valuable support and knowledge. Collaboration fosters synergy and supports the advancement of AM technology. Sharing knowledge and leveraging external expertise can significantly enhance the success of adoption efforts.

05 Strategic decision-making:

Organizations need to assess their readiness for AM adoption by considering their objectives and resources. Strategic decision-making, including the formation of an AM core team and collaboration with external partners, is crucial for achieving successful outcomes.

AM adoption in a nutshell

Part 1

Implementing AM technology requires a continuous learning process. Organizations must be willing to invest in training, reskilling, and fostering a culture of innovation to adapt to the challenges and opportunities presented by AM. In addition, early-stage adoption requires eager AM champions to keep the learning and development going on.

Part 2

As stated in the introduction, the handbook divides the adoption of AM into two stages; an early-stage adoption creates the base for the later-stage adoption. While this handbook concentrates on the early-stage adoption, the later stage is highlighted as something to bear in mind from the very beginning. Therefore, AM adoption can be seen as a comprehensive process where everything depends on multiple aspects, e.g., AM vision, knowledge, organizational aspects, and eagerness toward the technology.

The early-stage adoption framework

Part 2

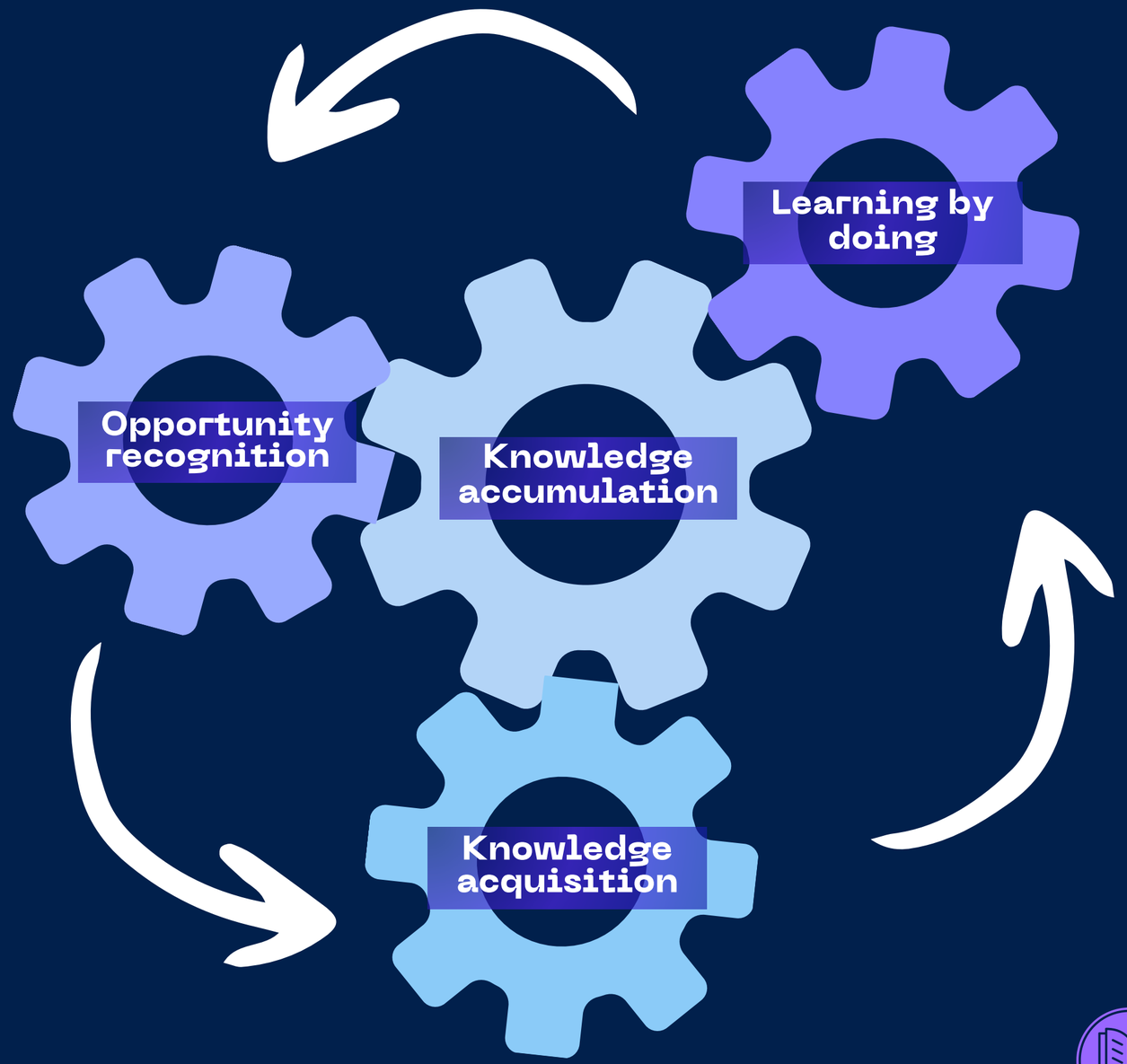
The early-stage adoption framework
Part 2

BASED ON BOTH LITERATURE AND INTERVIEW DATA, THE EARLY-STAGE ADOPTION OF AM CAN BE SEEN AS AN ITERATIVE PROCESS THAT IS DIVIDED INTO THREE DIFFERENT PHASES:

01 **Opportunity recognition**

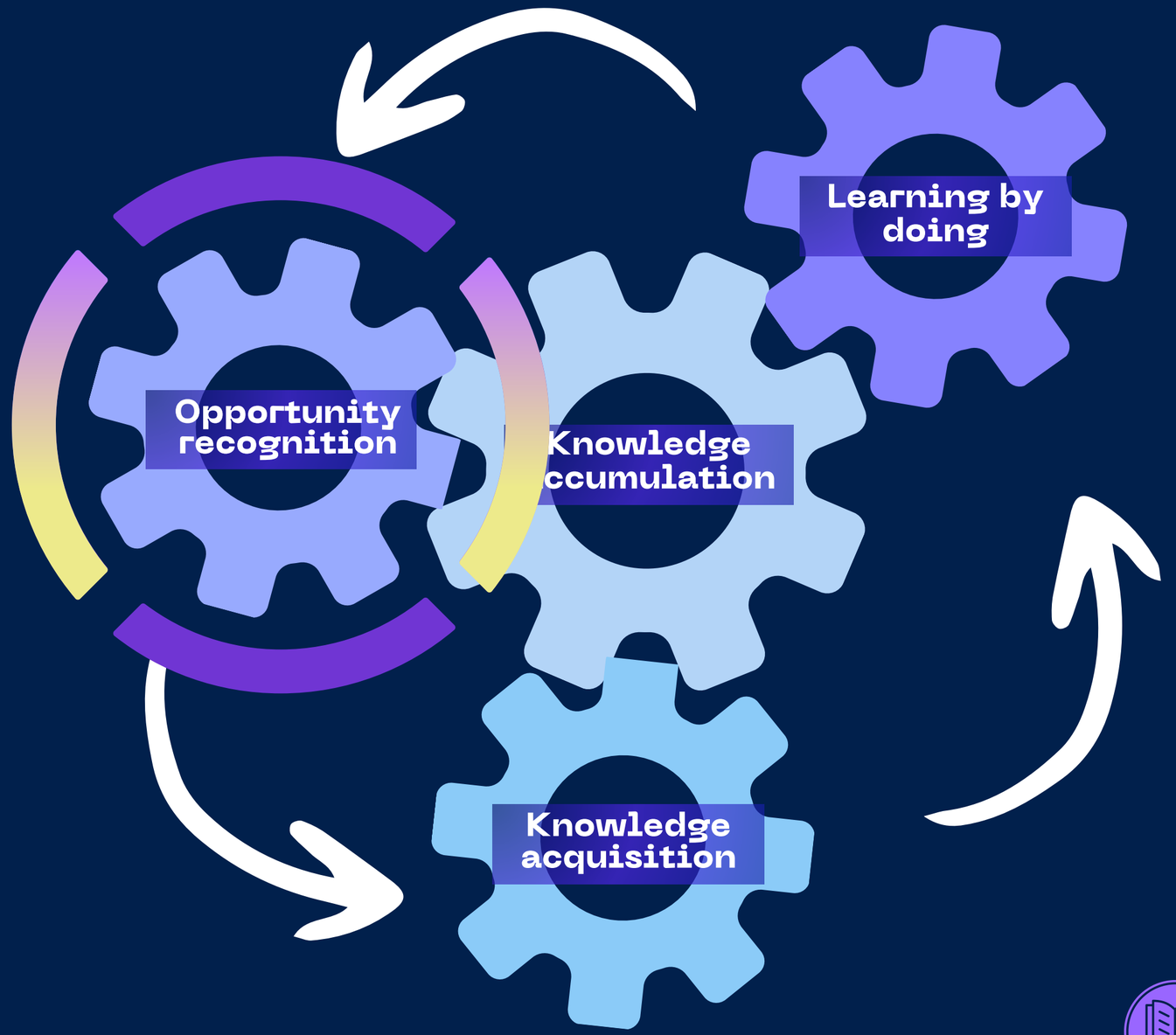
02 **Knowledge acquisition**

03 **Learning by doing**



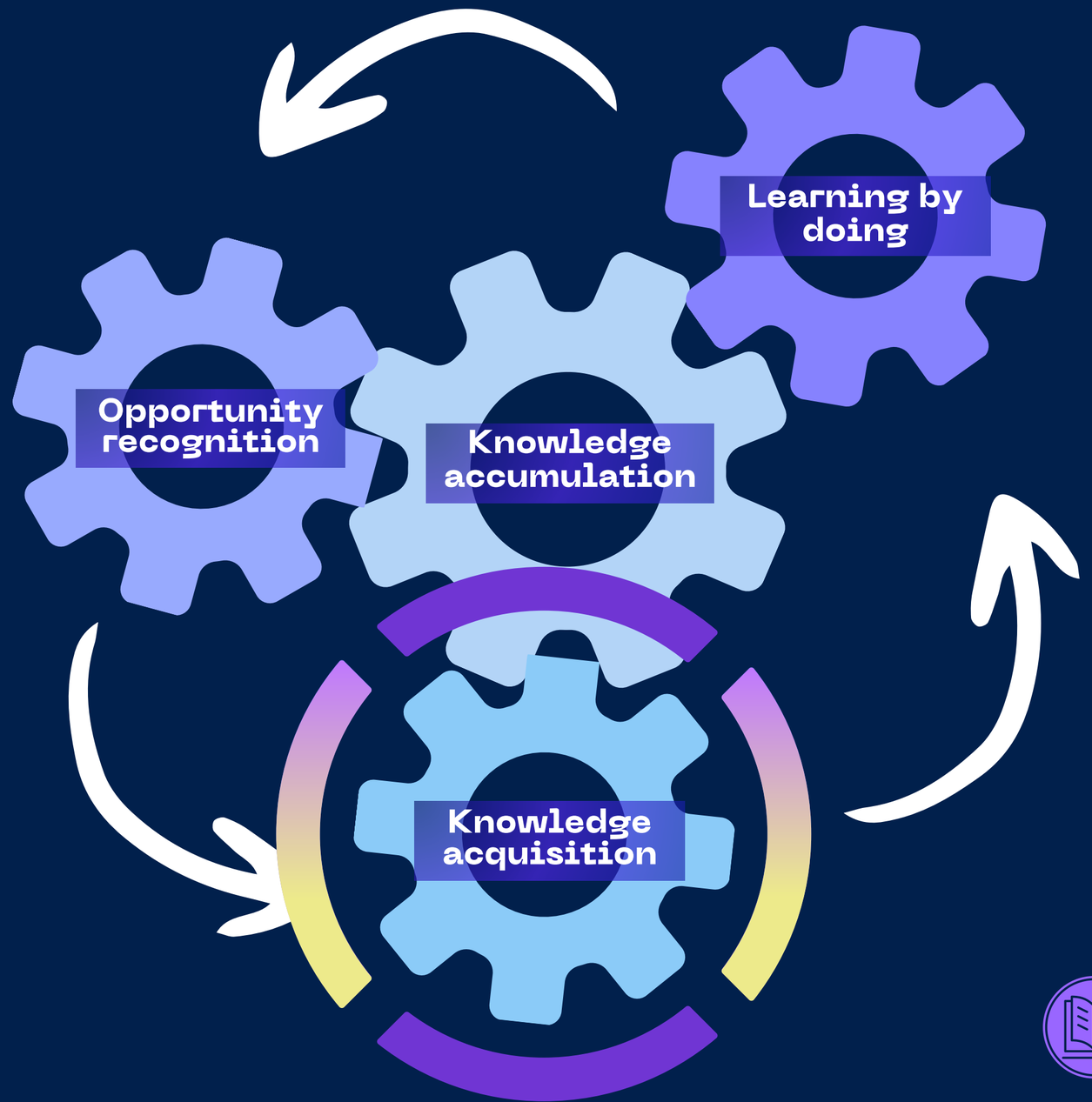
The early-stage adoption framework
Part 2

In the created framework, the first phase of the early-stage adoption of AM can be called opportunity recognition. At the very beginning, it focuses on initiating the AM process within a company, but its importance is highlighted throughout the AM journey: opportunities or benefits AM can offer for an organization can be recognized only through the two following phases, knowledge acquisition and learning by doing. Accumulation of knowledge creates the base for recognizing the opportunities and possible benefits of AM in the company.



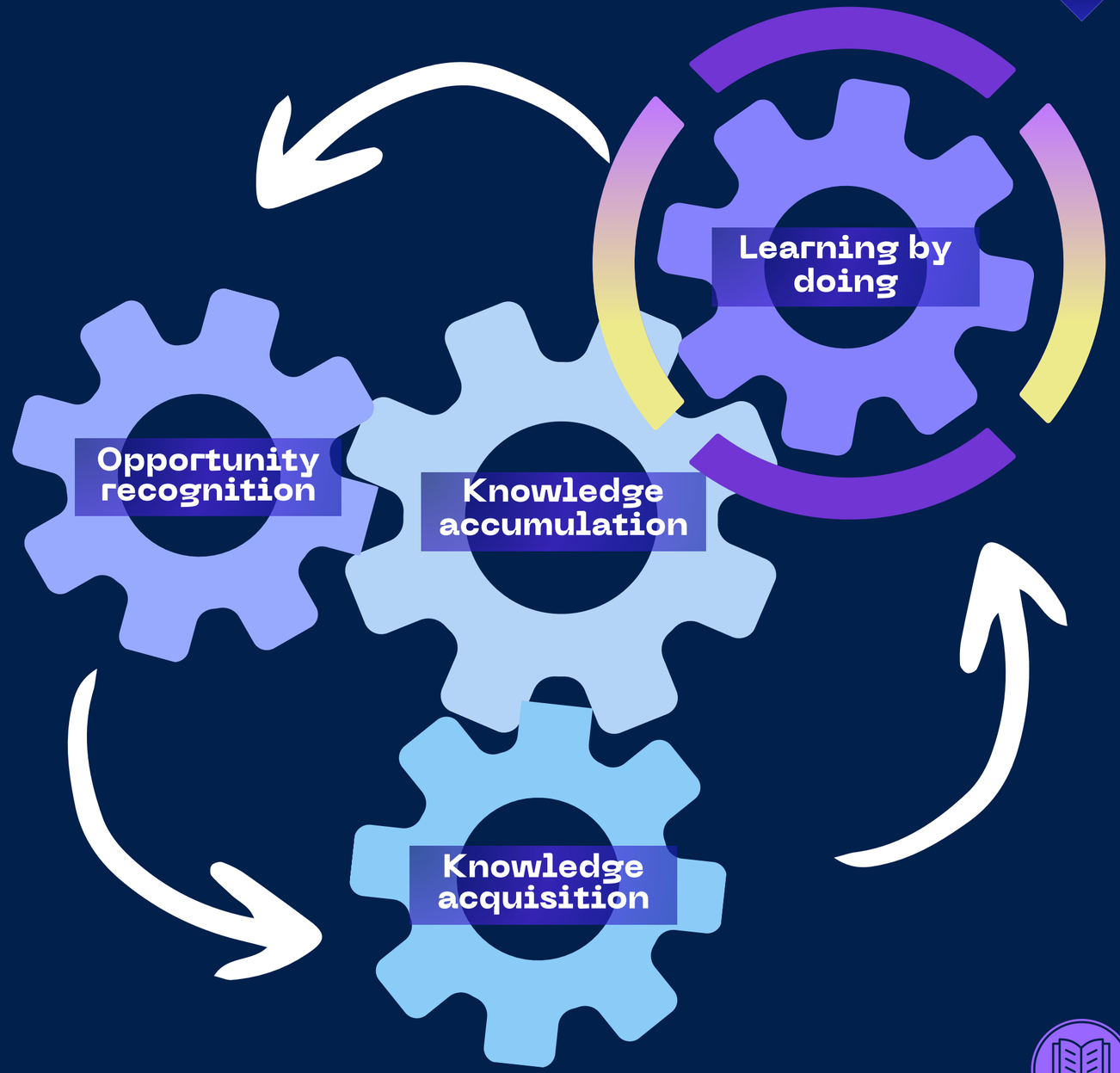
The early-stage adoption framework
Part 2

After sparking interest in AM, knowledge acquisition can be done either internally or externally. Internal knowledge acquisition emphasizes the role of an internal AM champion as a key resource along with management support and resources. External knowledge acquisition refers here to contacting an AM service provider. The transition from this second, knowledge acquisition phase to the learning-by-doing phase involves gathering basic information about AM, including e.g., technology capabilities, materials, costs, and required expertise.



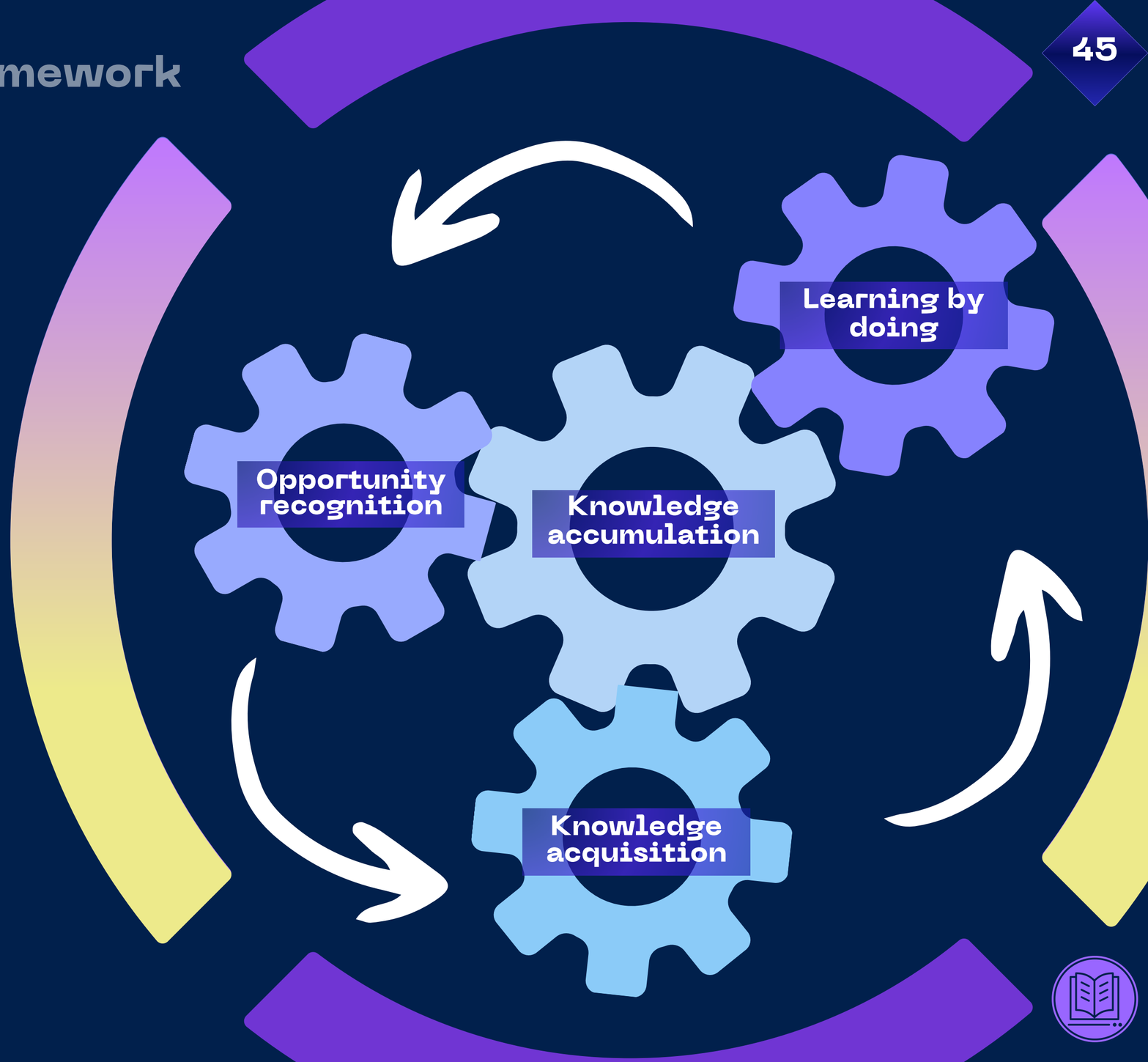
The early-stage adoption framework
Part 2

When the basic understanding of AM technology is gathered through knowledge acquisition, the learning by doing phase typically involves pilot projects with an AM service provider or providers. A well-executed early-stage adoption sets the foundation for success in later stages, where decisions such as purchasing printers or using service providers to continue the journey among AM mark the transition.



The early-stage adoption framework
Part 2

At the very beginning of the AM adoption process, the three-step framework gives a good entry-level lookout for early-stage adoption and what aspects to consider along the way. However, as the implementation moves forward these three steps should be seen as an iterative process accumulating knowledge also during the later-stage adoption. Therefore, the accumulation of knowledge should go hand in hand with the adoption and even beyond it.



The early-stage adoption framework
Part 2

Forming a comprehensive understanding of the AM technology itself at the beginning of the adoption process can prove to be a challenge for an organization. However, knowledge is the key that mainly determines the success and result of the early-stage AM adoption, whether the company continues its AM journey or drops out.

Three simplified case examples from companies that have adopted AM

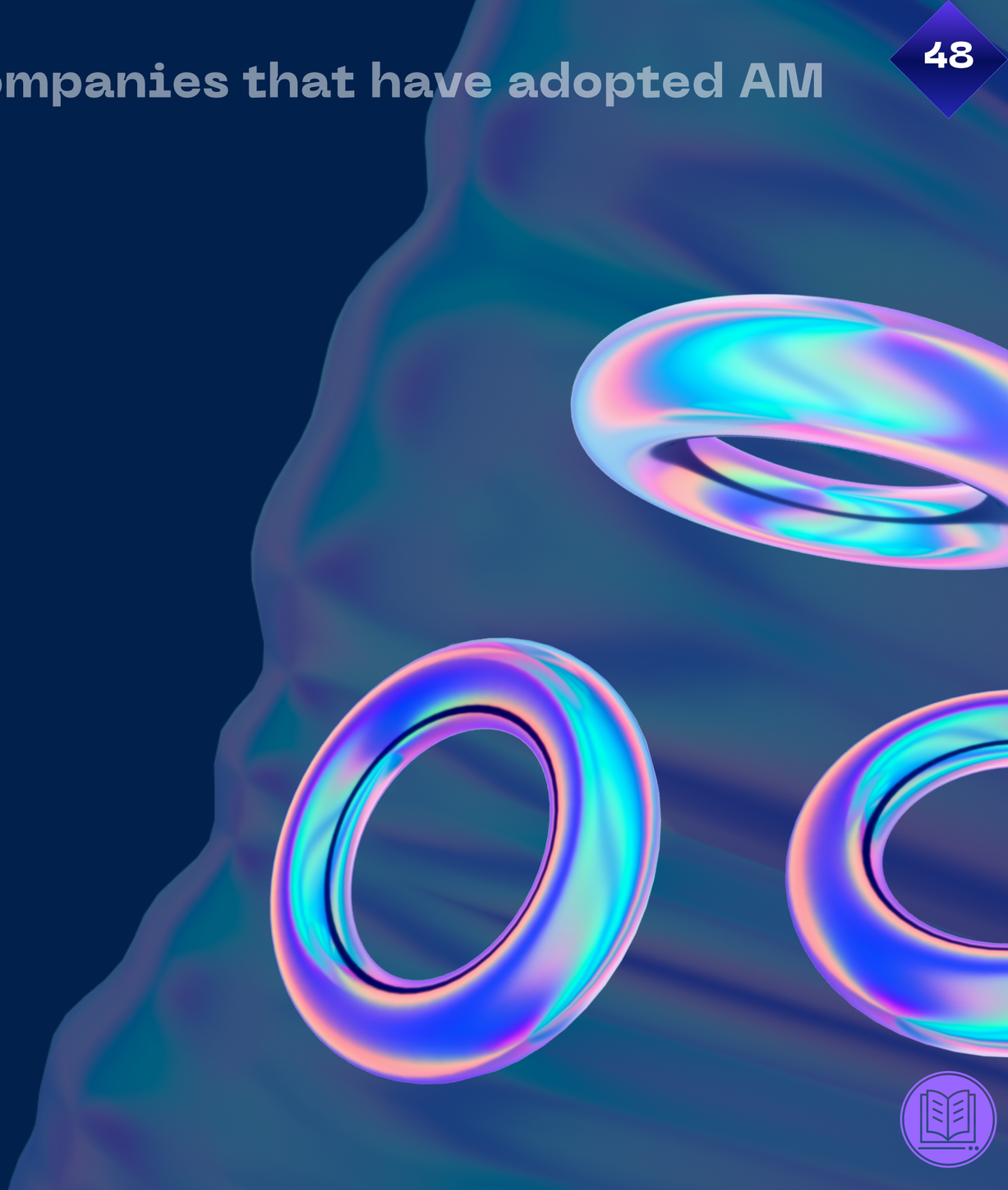
Part 2

Three simplified case examples from companies that have adopted AM
Part 2

In the upcoming section, we examine three distinct cases of AM adoption: Case 1 showcases AM replacing outdated machinery, emphasizing its role as an auxiliary activity and Case 2 explores AM as a startup venture within an organization, focusing on knowledge dissemination and incremental system-level integration. Lastly, Case 3 examines AM's role in prototyping, uncovering, and highlighting the importance of interdepartmental collaboration and a dedicated AM champion.

While Cases 1 and 2 follow trajectories where the AM adoption happens on the organizational level, Case 3 stands out by being only loosely connected to other activities in the organization.

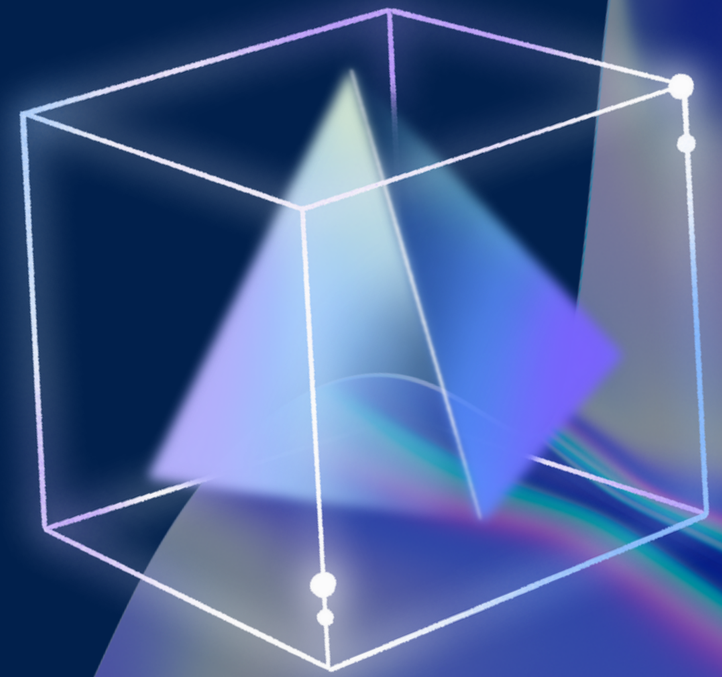
Each case offers valuable insights into navigating the complexities of AM adoption within varied organizational landscapes.



Three simplified case examples from companies that have adopted AM
Part 2

CASE 1
AM as an auxiliary activity – need to replace the old machinery:

1. Old machinery used to make tools has come to an end and there is a need to replace it
2. The decision came from the management to implement AM
3. Few pilots have been made with the help of AM service providers
4. An AM printer was bought and the machine manufacturer helped with the adoption
5. Learning through trial and error along the way
6. Discussions with local universities when encountering challenges



Three simplified case examples from companies that have adopted AM
Part 2

CASE 1
Learnings from the case 1:

The context in which AM is adopted here, as an auxiliary activity, is largely independent of other processes, resulting in minimal impact on them. When the AM strategy and vision limit to e.g., producing work tools and not making the end product, the change in the company does not have to be so fundamental. In this case example e.g., the physical change of the manufacturing area was the most demanding.

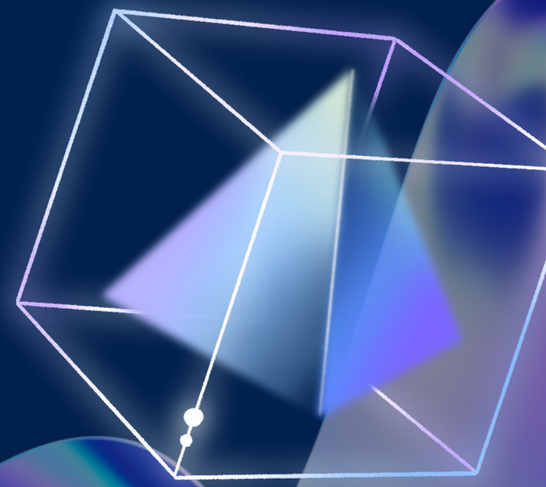
Because there was already an eager person in the company to work with AM technology, the lack of AM experts was not a challenge at the beginning. However, building a small, two-person AM team has required hiring and training. If AM is operated only by one person, the process becomes fragile, when depending on one person´s knowledge.

One can become an AM champion through hands-on learning in the company, the knowledge can be transferred.

Three simplified case examples from companies that have adopted AM
Part 2

CASE 2
AM as a startup inside an organization – need to spread the knowledge:

1. A motivated person initiates a 3D exploration
2. Based on the exploration, an understanding emerges that manufacturing tools and critical components are potential targets for AM.
3. Tool manufacturing begins to demonstrate the feasibility of AM. These multiple quick-win examples are needed for clear value creation.
4. Through quick wins more AM champions evolve who spread the information about AM inside the company. Slowly also the AM core team unfolds.
5. At the same time, there is training for employees to grasp the basics of AM, and understand its benefits. Continuous quick-win examples promote AM within the organization.
6. The perspective is extended to final products, e.g., through technology demonstrators, showcasing the possibilities and profitability of AM.
7. Finally, system-level 3D printing integration starts.



Three simplified case examples from companies that have adopted AM
Part 2

CASE 2

Learnings from the case 2:

Case 2 gives a good overview of what through knowledge acquisition should be understood in each company´s operational environment. For example, tools and final products can be manufactured with AM:

- Tools offer quick wins and stemming benefits, which are essential when the vision is to implement AM horizontally
- For final products and parts, AM can be used through prototyping, making of special tools, spare parts, and retrofitting

AM teams or organizations do not have to do everything, e.g., designing can be an in-house activity while printing is outsourced.

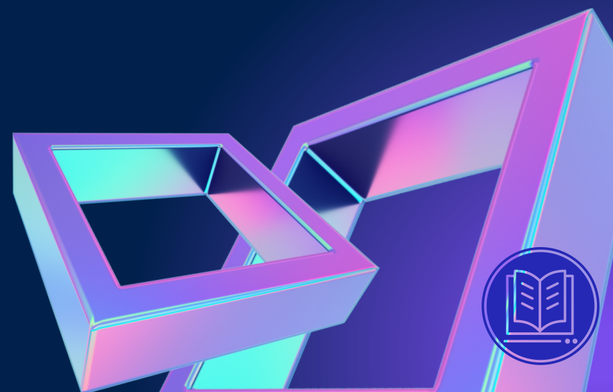
Printers are expensive investments; an organization can also collaborate and make a joint acquisition.

Having trust at the organizational level is vital. Especially for critical components, validation takes time, whereas tool validation can be a bit faster and entails lower risks.

A slow start is necessary. Depending on a lot of the vision for AM it takes at least 3–5 years to run AM at least at some level. Getting to e.g., serial production or building the processes to successful and accepted final part printing can usually take even longer.

AM core team can include internal and external AM champions. If there is a lack of AM experts in Finland, looking for AM experts internationally can be the answer.

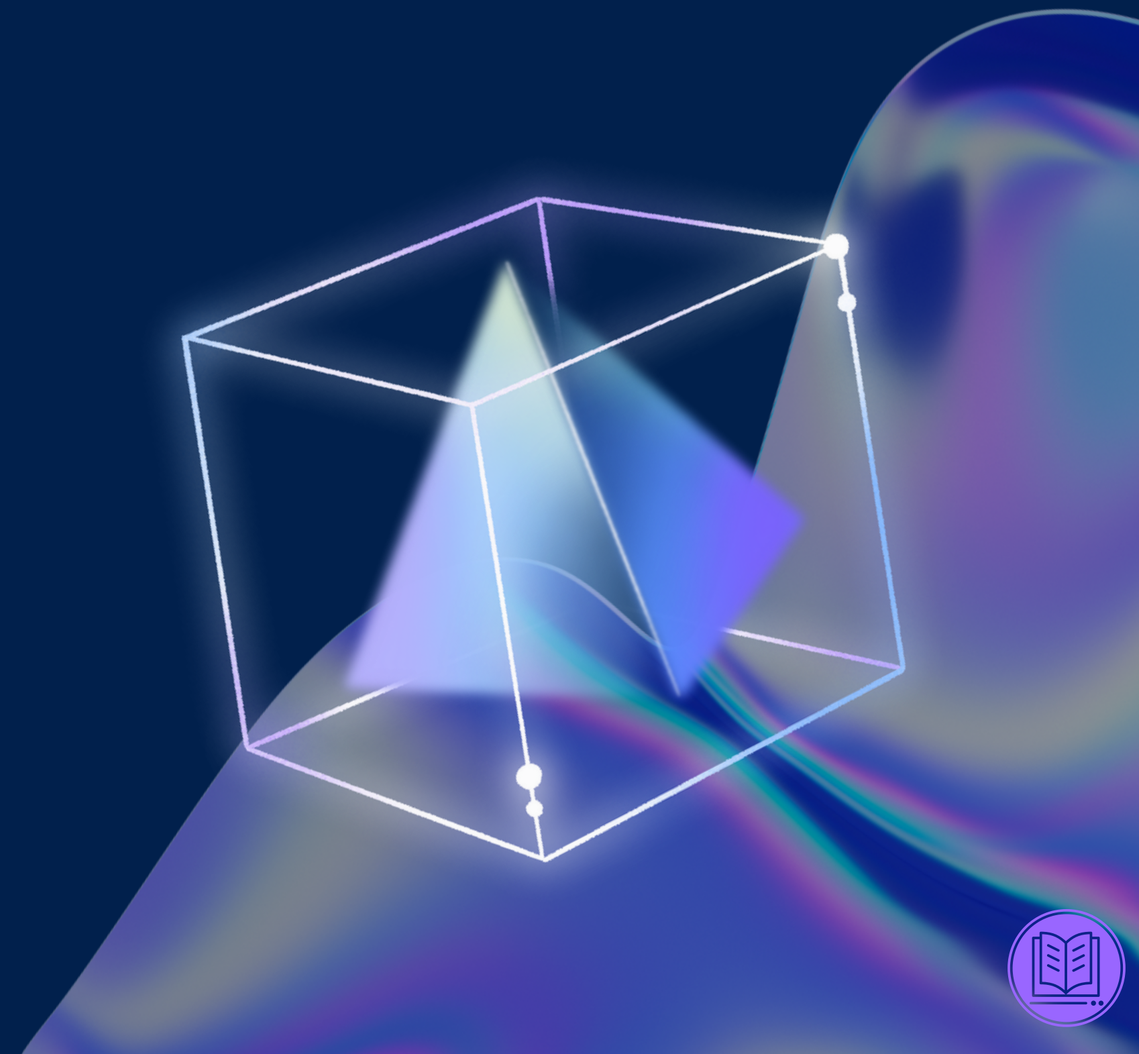
System-level integration is a challenge because it includes extending the understanding of AM to the managerial level.



Three simplified case examples from companies that have adopted AM
Part 2

CASE 3
AM as a tool for making prototypes — need to work together:

1. Some projects are made regarding AM technology
2. AM is used to make prototypes
3. Prototypes are purchased from the AM service provider
4. No information on how AM is used in other departments



Three simplified case examples from companies that have adopted AM
Part 2

CASE 3
Learnings from the case 3:

Even though there are development projects that include AM but not an eager person or managerial support to push AM forward after the projects, the interest in AM technology most likely runs out of steam.

Especially in a large organization, the lack of communication channels between departments may hinder the horizontal adoption of AM. Even though AM can be used in different departments, there might not be any opportunities to e.g., discuss AM and share learnings, nor build a centralized AM organization. Centralized AM organization might decrease the overall need for deep AM expertise inside the organization and open up new possibilities.

Understanding about AM is needed in multiple stakeholder groups. For example, a conservative customer base can work as an obstacle to AM usage if customers do not accept AM being used in their products. However, this does not exclude the company from using it to support internal processes, such as prototyping like in case 3, or tool-making like in cases 1 and 2.

AM adoption case steps and best practices according to AM service providers

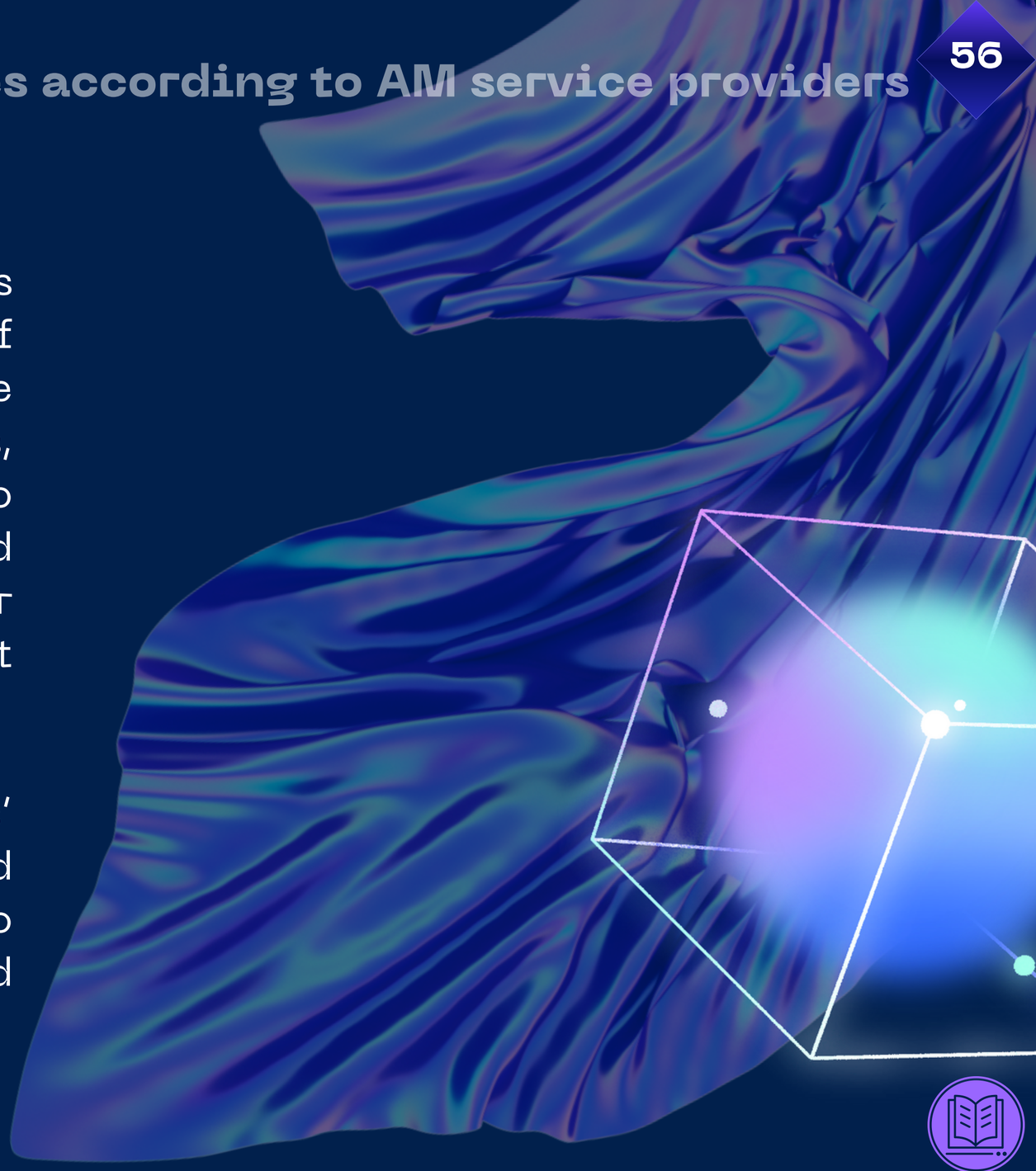
Part 2

AM adoption case steps and best practices according to AM service providers

Part 2

When it comes especially to SMEs, it is suggested to outsource AM instead of purchasing their own printer; AM requires huge amounts of special competence, investments, and process control. In addition, there are no companies that would change all their old well-functioning processes at once to AM nor companies that would know everything about AM already at the start.

Next, you can find AM service providers' examples of how knowledge acquisition could be executed. Examples are divided into two in-house viewpoints and one outsourced suggestion on how to acquire knowledge.



AM adoption case steps and best practices according to AM service providers

Part 2

Knowledge acquisition in-house

Bottom-up viewpoint:

1. At the grass-roots level, an enthusiastic individual takes the initiative to lead the AM project.
2. To progress the project, support from top management is needed, materializing in budget allocation.
3. The eager individual produces the first 3D-printed parts of the company's products.
4. As interest grows, an AM team is formed.
5. Knowledge is disseminated to design teams, aiming to increase the usage of AM.

After the knowledge has been acquired, adopting organizations´ paths vary significantly. However, those who decide to continue with AM must form the AM strategy. Typically also an AM core team of 3-10 members is established, and subsequent steps depend on the founded business case and strategy.

Some expand the AM department, while others aim to integrate 3D printing into all units. Consequently, there may no longer be dedicated AM personnel; instead, AM becomes part of everyone's skill set.

AM adoption case steps and best practices according to AM service providers

Part 2

Knowledge acquisition in-house

Top-down viewpoint:

1. Prepare a strategy to acquire knowledge about AM
   a. in-house
      - (opportunity recognition)
      - Knowledge acquisition
      - Learning by doing
   b. outsource
      - AM service providers
2. Based on AM exploration decide
   - whether to continue or not with the AM
   - whether to outsource AM or purchase a printer

The knowledge acquisition creates the base for the entire AM adoption process. It determines whether an organization moves forward with the adoption from the early-stage and even what kind of AM strategy will be.

The meaning of knowledge acquisition is to identify the general concept of AM technology and understand the possibilities and liabilities each technique has and what kind of purposes they are suitable to use. The AM exploration helps to clarify the AM strategy.

It is up to the decided AM strategy, whether the change will be incremental or radical.

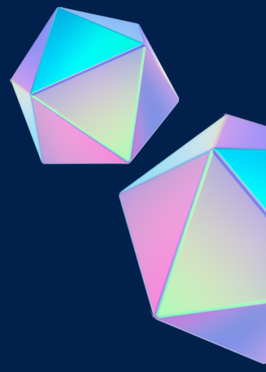
AM adoption case steps and best practices according to AM service providers
Part 2

Knowledge acquisition can also be outsourced to AM service providers. Under, you can find a hands-on kind of approach to how the training and basics of the technology could be learned through AM service provider's training:

1. The training is designed to fit the organization's needs, e.g. will it include more information about different technologies or is it more emphasized in design? The training is also determined a lot based on who will be attending.

2. In training, the aim is to identify a case from a customer to provide participants with a tangible example of the applications of AM. This approach not only allows for a concrete understanding but also helps create a business case.

3. In the training, the goal is to have participants identify potential cases within the company. Particularly, designers are encouraged to create hands-on designs.



Even though this approach offers a case example of how knowledge can be acquired through an AM service provider, the real work, knowledge, and process integration must be done internally: the company needs to go through internal processes, train its personnel, and disseminate the acquired information within the organization.

AM adoption case steps and best practices according to AM service providers
Part 2

Best practices for AM adoption according to service providers:

1. In many companies, 3D printing may be used in product development, but the challenge lies in transitioning from product development and prototyping to mass production.

- The company should have, for example, a plastic printer that can be used freely. While it does not match industrial-level production, it follows similar principles. Also, there should be a strategy set for the use of the plastic printer. The plastic printer aims to lower the threshold for 3D printing and create a safe place to test and fail. This is also a possibility to form the AM core team, through finding the eager persons interested in AM.

2. Once there is an understanding and expertise in AM, validation and quality control requirements should be established. AM proves its utility and e.g., cost savings in the long run and through e.g., life cycle costs which take time to shape.

3. Buyers play a significant role in the adoption of AM. If there are no suitable procurement channels, the implementation can be hindered or, at the very least, delayed.

4. The well-done knowledge acquisition and appropriate piloting enable finding and understanding the value AM can offer. When the added value is found, e.g., AM can be used even for serial production.

Tips to succeed

Finally, this section presents a summarized list of tips designed to ensure success in the AM adoption process. The tips are organized into two categories: general adoption process and managerial level.

This section serves as the concluding part of this handbook, offering comprehensive insights for navigating the AM adoption journey effectively.

TIPS for the adoption process:

1. Clear examples of value creation, for example five per year.
2. At least one technology demonstrator per year, leading to the next phase and advancing development.
3. Systematic measurement to facilitate the in-house selling and justify to management and employees.
4. Quick win examples tailored to target groups for maximum relevance.
5. Employee training through value creation examples and pilots.
6. Despite challenges, continue forward and believe in your vision.
7. When unsure how to proceed, contact an AM service provider.
8. Connect with AM enthusiasts on personal and organizational levels

TIPS for the managerial level:

1. Prepare an AM strategy for knowledge acquisition.
2. Find the eager person to acquire knowledge about AM or outsource.
3. Create legitimacy for the AM champion: give them the permission to experiment and allocate sufficient time & money.
4. Aim to know the basics about AM.
5. Decide to either outsource AM or purchase a printer.

Explore the AM landscape

The following complementary reference collection includes a few videos, a podcast, and readings, providing diverse perspectives on AM technology to supplement the handbook.

Explore the AM landscape

Collan, M. & Michelsen, K.-E. (2020) Technical, Economic and Societal Effects of Manufacturing 4.0: Automation, Adaption and Manufacturing in Finland and Beyond. Palgrave McMillan, Cham.

Finnish additive manufacturing ecosystem (FAME)

ISO/ASTM 52900:2021 Additive manufacturing – General principles – Fundamentals and vocabulary

Jussila, M. (2023) Cornerstones towards a successful implementation of AM technology: A qualitative phenomena-based study of the early-stage AM implementation process. Pro gradu.

Linturi, R. & Kuusi, O. (2018) Societal transformation 2018–2037; 10 Anticipated radical technologies, 20 regimes, case Finland. Publication of the Committee for the Future. (Check especially p. 306–311 about 3D printing)

Podcast: AM radio
The AM Radio podcast delves into the latest developments and trends in additive manufacturing, offering listeners valuable insights into the rapidly evolving world of 3D printing technology.

Wasa Innovation Center (WIC) Science Channel (2023) 3D printing + AM technologies develop and become cheaper – How can the industry change? (subtitles available in English)

Wasa Innovation Center (WIC) Science Channel (2024) The sky's the limit? The future of 3D printing may be dictated from outside the genre. (subtitles available in English)

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Priyadarshini, J. – Singh, R. – Mishra, R. – Kamal, M. M. (2022) Adoption of additive manufacturing for sustainable operations in the era of circular economy: Self-assessment framework with case illustration. Computers & Industrial Engineering, Vol. 171, 108514.

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