Checklist D.T.1.1.1

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Mapping the AVM-related key knowledge dimensions in SME/industry, academia and intermediaries in partner regions/CE.

Regional focus: Munich (Upper Bavaria)

Contact: Dr Georg Loscher

Small and medium sized entities

Definition of SMEs

· Type of industry: SIC CODE 22-39

· Firm size: number of employees between 10 and 250 AND turnover between 2 and 50 M€

· Ownership: headquarter located in the country

Indicate here the sources used to provide information (e.g. reports, publications, SME/industry interviews):

Interviews: 111.21 Dr. Blum (VCI),111.22 Dr. Funk (ZD. B), 111.23 Dr. Kinkeldei (VDMA), 111.24 Group Interview Bavarian Ministry of Economic Affairs and Media, Energy and Technology

Documents: 111.31 Allensbach Cybersecurity Report, 111.32 Analytics Readiness Study by IDG Research Services

	Current Status		Future Needs	
	Level (1-6)	**Detailed Description**	**Level (1-6)**	**Detailed Description**
Technologies	The general level of technology use and availability in SMEs in Bavaria is quite high. However, regarding the SIC codes, the status and needs of SME in these industries is quite heterogenous depending on size, general strategy and the product programme, in a representative survey with 1500 firms about 50% of the firms have acknowledged the urgency of digitalization, and only 25% have already implemented a strategy for digitalization. However, the heterogeneity in the SIC Code industry, doesn't allow general conclusions, but all firms across the industries need more information technology staff and a have significant issues with information security. In principal, the Munich area is one of the central hotspots of automation in Europe, firms like Fujitsu, IBM, Siemens, Microsoft and others have their European Headquarters for Industry 4.0 in Munich, the greater Munich area compromises a lot of hidden champions in manufacturing. In the wider Bavarian SME sector a lot of different technology champions in the area of Industry.4.0 exist. However, a significant part of SMEs still isn't prepared for the digital transformation, therefore, several initiatives of the Bavarian Ministry for Economics enforcing the digital transformation in Small and Mediums Sized Firms exist.			
	Current Status		Future Needs	
	Level (1-6)	**Detailed Description**	**Level (1-6)**	**Detailed Description**

Internet of Things	3	• Technology is available, some SMEs are already using it,
		• Others are still reluctant as common standards for data exchange are missing or they are afraid of opening their production systems.
		• Other problems are physical in nature as it isn't possible to build stable WLAN-Networks in industry halls built of metal and full of metal, therefore network connections are missing (in the industry hall).
		• Furthermore, some regions don't have internet connections that are fast enough for the traffic generated by the internet of things
			6	• Based on the development of the standard of interoperability OPC-UA, between machines, the internet of things will develop rapidly. A key component is the self-description of machines by their software (on the level of ontologies, semantics and syntax) in networks. This standard is still developing.
				• The legal framework is still missing. This concerns two dimensions:
				   o Privacy of machine data: there are no rules regulating the ownership of data and the privacy rights of machines
				   o Missing legal capacity to act without human intervention. Machines are not allowed to complete contracts.
				• Capacity of SMEs to define their organizational "openness" to their environment and the limits of

		Current Status		Future Needs	
		• Strong Capacities in B2B Business			their "openness" in a kind of scaled openness and security model for organizational secrets. • Integration of value networks and open production systems is a future need (similar to open bookkeeping), however, there is still a need for trust between participants in a value creating network.
Cloud computing	1	• There are a lot of offers for cloud computing on the market. • Firms are still reluctant to outsource their IT infrastructure into the cloud as they have concerns of confidentiality, cyber security, privacy. • IT Infrastructure therefore is mostly provided in house. • Platforms like ADAMOS for B2B cloud computing are still in a early phase.	3		• Having a flexible and scalable IT Infrastructure depends on cloud computing. However, central concerns about cyber security have to be faced. • Mindset change in the firms for openness is necessary as future production machines will depend on cloud computing. • The internet infrastructure for B2B - Platforms and cloud solutions enabling the cloud based Internet of things (e.g. ADAMOS) has to be developed and provided (Software as a Service, Platform as a Service, Infrastructure as a Service)
Cyber security	2	• There are a lot of offers for cyber security. • There exists only little awareness of possible threats by cyber criminals. • Often cyber security is provided by the local administrator and human factors lead to security risks • There is only little knowledge in firms about cyber security, measures and initiatives leading to a diffuse fear of threats from openness, cloud computing, etc. • There exists a shortage in IT security specialists • Cost for IT security are high and steadily increasing	6		• Threats from the cyber space will become more prominent in the next years. • A central topic is the security of data and the security of data exchange in production systems. • Firms have the necessity to develop a graduated security concept for their IT-Infrastructure. • Simple IT security processes and systems, e.g. automated solutions allowing the reduction of human factors as sources of error, are needed to prevent cyber criminality (e.g. automated updates, tracking tools, etc.) • A central problem for small and medium sized firms is the increasing costs for cyber security and the high investments in cyber security (e.g. modern firewalls, threat detection analytics, etc.)

		Current Status		Future Needs
		• Existing IT systems are generally perceived as very stable and fail-proof. • Missing knowledge about the right kind of IT security, though various initiatives of industry associations, firms and the state (Bundesamt für Informationssicherheit) exist.		• Firms have to develop cyber security skills for securing their production systems, the exchange in interfirm networks and exchange with customers. • Trust in web-based services is generally low regarding their security and their reliability. • A central future need is the dissemination of information on cybersecurity in SMEs and the continuing development of specialists for this topic.
Big Data and Analytics	3	• Data Analytics Readiness is still in its infancy • A central problem is the responsibility for data management and analysis in the firm: IT, Departments or supervisors • Data is mostly collected in the finance and management accounting department or the IT department, production is only delivering a small part of the data • Most firms have issues with the quality of their data • Most firms don't know, which data is needed in the future • The main data source is E-Mail, followed by protocol and event data and then data from ERP and CRM systems, machine data is the smallest part of the data sources • Most firms aren't using a sophisticated analytics system and only have first prototype projects. • Most analytics is descriptive and used as a reporting tool for optimizing or	6	• Future business will be data driven, this concerns technology, processes, organisation, people and communication, as well as others. • A central need is an analytics ready IT infrastructure, analytics software, knowledge about the way data can be used to analyse, optimize and predict. Furthermore, knowledge about the way data can enable the development of • A further challenge is the role of the management accountant for reporting and data provider for the executives, yet, besides the financial data analytics aims at providing information about operative non-financial and qualitative data. • The role of standards of data generated by machines is high as it allows a structured analysis of data derived from production without the need for preparing and cleaning data. • Furthermore, a form of internal reporting, sourcing and documentation standard (similar to cost accounting) is needed for developing comparable results of the analysis in a value network. • Firms have to invest in analytical skills of their employees and start first simple analytic projects by the help of external advisors for developing the necessary capabilities.

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		reporting on business processes. The potential of predictive or data mining tools is not used. • Analytics is not used to develop new business models. • There exists a shortage of people understanding how to use data and analytics skills • Data analytics are mostly historical, without real time data and without predictive models. • Missing for the transformation into a data driven business are the right technical platforms and the right organisation.		
Advanced Manufacturing Solutions (e.g. Robotics)	4	• Central technologies for advanced manufacturing solutions are RFID (radio-frequency identification), smart machines, cyberphysical systems (E.g. Internet of things), complex event processing and manufacturing execution systems. Leading producers of industrial robotics are located in Germany. • Depending on size, industry and product portfolio SMEs are already using a mixture of these technologies for automation of their production. • However, smart factories are still in their infancies. • Most SMEs are controlling and managing their production system	6	• Advanced manufacturing solutions will become important for competing as the cost of investing in manufacturing solutions is decreasing (e.g. industry robots are already available at lower costs) • As a precondition for being part of an automated value creating network advanced manufacturing solutions will become mandatory. • With robotics and automation batch sizes of one will be economic solutions and demanded by customers. • As the automation of the shop floor increases experience of employees will be substituted by automated processes and data analytics preventing the loss of know-how. Furthermore, the intelligent connection of machines and the linking with other units of production will enable the optimization of production beyond the single factory.

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		based on experienced employees and because of their small number of employees don't draw on sophisticated smart factory instruments. • Based on the needed functionality and the cost advanced manufacturing solutions are implemented. • Robots are still expensive and dangerous in interaction as they perform routines • A digital twin of the real factory is not existing. • Potentials of implementing advanced manufacturing solutions are only partially used. This results from old operating systems (e.g. Windows XP) not designed for use in networks and not updated anymore resulting in severe security risks. An answer are local networks within factories but without connections to the internet.		• There is a need to construct scenarios for human-robot interaction as collaborative robots will become common as assistants to human employees (e.g. carriers of heavy loads) and are cheap. • A central need for SMEs is the readiness of their machine park (e.g. operating systems, technological openness, etc) for future developments in automation.
Additive manufacturing	2	• Still in its infancy, yet a fast-growing sector. • First prototypes of applications in the industry have shown technical advantages over their conventional constructed counterparts, however, there are still problems resulting from technical specifics of additive manufacturing (e.g. technological limits of geometrics, thermos-dynamic characteristics)	4	• Chipping production won't be competitive in the future, as cost for 3D printers and the raw materials will decrease. • Additive manufacturing offers a potential for production on demand, production on-site and the production of replacement of long living investment goods. • Still, legal concerns about the copyright for CAD-blueprints have to be clarified. • Central need integration into value chains and management of the whole product life-cycle.

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		- Mostly used for rapid prototyping - Problems of the availability and legal aspects of CAD-blueprints of products as well as software often doesn't include specifics for additive manufacturing - Missing knowledge about the characteristics of elements produced and their potential for optimization of the whole construction 3D-printers and powder still relatively expensive		- An important aspect are competencies to develop the new possible business models (e.g. very strong division of work between firms, individual products, B2B business can be transformed to B2C business) - Development of competences regarding the innovation potential of these new production technologies, the way of quality management of these products, the way to calculate in additive manufacturing series. - Missing are institutions that do a systematic research on the potentials of additive manufacturing and their application.
Augmented reality + assistant systems	2	- Augmented reality applications are still in their infancies, only first prototypical application in e.g. logistics, maintenance exist. - Different virtual assistant systems are already in use (text, audio and video based) - Mostly used in large entities. - Missing technological infrastructure for use (e.g. mapping of factory, software, etc.) and knowledge in the IT - No real uses cases known to experts for KMU.	5	- Augmented reality can support KMU in educating their employees, performing maintenance work, guiding employees through production steps - High potentials for production with a high number of variants
Simulation tools	5	- Highly used in planning and constructing, development of employees. - First application of digital twin of factories	6	- Will become even more important. - Competences in digital engineering will become necessary.

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Human Resources and Organization	The general level of organization and human resources in SMEs in Bavaria is quite high which is based on two important factors: First SMEs are embedded in supply chains of large entities forcing them to document their quality management and introducing a quality management system. Second, dual training, advanced technical colleges and universities provide a highly qualified workforce. However, regarding the SIC codes, the status and needs of SME in these industries is quite heterogenous depending on size, general strategy and the product programme. However, the heterogeneity in the SIC Code industry, doesn't allow general conclusions, but all firms across the industries have a shortage of staff as labour markets are empty, specifically information technology staff is rare, and this will have a high impact on competitiveness. Generally speaking, German SMEs are often family firms having a low level of external managers, but the number of manages is growing in correlation with the size of the firm. Furthermore, innovation management is not done in a separate department, but often by the production manager and the executives of the firm as most executives are engineers. Therefore, the general level of innovation orientation is high, but often focuses on process innovations rather than product or business model innovations. In the Munich area a lot of large entities have them headquarter (e.g. Siemens, BMW, Audi, MAN, OSRAM, Wacker, etc.). Generally speaking they have a high level of management, separate and large R&D departments and a high innovation orientation. Regarding the flexibility of their employees most large entities have largely specialized workforce that had similar to the SME staff a very high-quality general education. However, large entities need more flexible employees in the future.			
	Current Status		**Future Needs**	
	Level (1-6)	**Detailed Description**	**Level (1-6)**	**Detailed Description**
Level of innovation orientation of SME	4	• Executives and managers are mostly engineers or with a science background leading to a generally high level of innovation orientation. • Based on the very good economy and the missing time of managers as the book of commissions are full, innovation is not a top priority at the moment.	6	• Besides the process innovation more product and business model innovations are a necessity for being competitive in the future. There exists a need for toolkits and education of managers on business model innovation, product innovation, etc. • Interpretive schemes are strongly rooted in the success of German engineering, this orientation towards the past and the missing focus on software and putting the software at the heart of the products becomes a risk for the innovation of the firms. Typical

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		• Furthermore, SMEs are reluctant to take high risks for their business model. • Some firms have not understood the role of digitalization and its consequences. • Very old and grown interpretive scheme focusing on engineering instead of software programming. • Strong focus on B2b products rather than B2C products		innovators dilemma, the success of yesterday endangers the success of tomorrow. • In SMEs executives miss the staff that has the time to discuss developments with them, know tools for developing innovations and have the capacity to overlook future developments • Networks of SME Executives are important for developing new products.
Presence of R&D dept. in SMEs	2	• Only small number of staffs mostly based in the production or the executives themselves. • SMEs as the result of start-ups, that themselves were the R&D department	1	• No changes, rather less importance as start-up mentality will grow
Presence of managers in SMEs	5	• High professionalization of management in German SMEs and a strong professional background of the employees in German SMEs ("certification culture") • Managers mostly owners and therefore of high importance of SMEs	4	• Less importance of hierarchical systems and more importance of self-leadership. • Parts of coordination function will be replaced by cyberphysical systems and analytics.
Level of flexibility/polyvalence of SME employees	6	• SME employees have generally a high level of flexibility and polyvalence based in their education and the various tasks • SMEs known for their flexible use of employees, less specialisation and development of generalists (interdisciplinarity, complex content of work)	6	• No changes foreseen

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Level of innovation orientation of large entities	5	• High level of innovation orientation in large firms in the greater Munich area. • Munich is a European hotspot for innovation in software, manufacturing, pharmaceutical and chemical productions • Firms have adopted innovation labs, new methods for project management of innovations, etc. • However, most firms are very strong in process innovations rather than product innovations • International networks have changed mindset towards innovations already.	6	• Even more expenditures for innovation are important in the future. • Still a high need for creativity, business model innovation and product innovation.
Presence of R&D dept. in large entities	5	• High and centralized	5	• High, additionally more decentralized innovation structures like innovation labs are needed
Presence of managers in large entities	5	• High with high specialisation and high professionalization	5	• High.
Level of flexibility/polyvalence of large entities' employees	4	• Firms develop their staff to specialist positions limiting their flexibility. • Standard operating procedures, routines, competence models and career paths limit the flexibility of employees in large firms	6	• More talent instead of competence is needed for Industry 4.0 as the content of work will change rapidly. • Flexibility and creativity of employees will become an asset • Needs of interdisciplinarity, mastering complex content of work, exchange with machines and high competencies in solving problems

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Business Model/ Process Management	On an abstract level SMEs in the southern part of Germany are already organized as a network of entrepreneurial firms with a specific problem solving and entrepreneurial mindset. In its sum the multiple small firms form an ecosystem of manufacturing			

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	that enables exchange of knowledge, flexibility and trust between its participants. Furthermore, the ecosystem mostly relies on informal and grown structures of purchasing and developing. Similarly, most SMEs are embedded in deep global value chains as their customers are often large multinational entities. A central problem for the business model and process management is the openness of SMEs to new developments beyond their traditional grown network of suppliers (e.g. other firms from USA, Israel, China, India etc.) as most ties have formed over generations and are informal networks of trust. However, this network of trust mostly focuses on other SMEs as the entrepreneurial mindset allows fast decisions and collaboration on the same level. The diffusion of lean production approaches and business process management systems generally depends on size, industry, production technology and strategy. Small firms often implicitly apply lean production based on their flexibility, scarcity of resources and the mindset of their owners without naming it this way. Larger firms know this approach and apply it. A general problem is the collaboration of small and large entities as this collaboration often is complicated by lawyers and risk management of large firms as well as the mentality differences between managers and owners.	

	Current Status		Future Needs	
	Level (1-6)	Detailed Description	Level (1-6)	Detailed Description
Diffusion of lean production approaches in SMEs	4	• See above. Mostly not systematized.	6	• Lean production will become more important for participating in production networks.
Presence of advanced business process management systems (e.g. management of purchasing, business intelligence) in SMEs	3	• "Gut feeling" of the managers and in the production is the central business management system. • Standard ERP Software is often too expensive • Standard information for external use of partners available • Controlling and Management Accounting are the central source for information supplemented by benchmarking from tax advisors	5	• Need to develop a strong analytics culture and as production becomes automated the introduction of software enabling to optimize shop floors. • Generally, more data driven business decisions are a necessity. • Missing are cheap ERP systems for SME (Standard software) • Often the Management Accountant is simultaneously responsible for bookkeeping and HR, therefore has only a limited capacity for business analytics and data driven optimization

	Current Status		Future Needs	
Level of networking and collaboration among SMEs	2	• Generally, a high level of networking within the local supply chain, only little knowledge about what other firms do in the region. • High trust networks of SMEs when already collaborating • Closed Networks and alliances established over time and therefore sometimes slow in adopting to new circumstance	5	• Joint innovations will become more important. • SMEs will have the necessity to develop new ties with other SMEs in the region for developing new products • Need for platforms and social contacts enabling firms to exchange about their business and products and find new partners • Strategic openness of networks to new partners from the region, but also to international partners is needed but also a question of competencies.
Diffusion of lean production approaches in large entities	5	• High diffusion	6	• High diffusion
Presence of advanced business process management systems (e.g. management of purchasing, business intelligence) in large entities	5	• Firms are using standard and customized ERP systems and all kind of different software for analysis • Generally high importance for business intelligence above and beyond the management accounting department, firms are building up their data analytics capacities through teams and external consultants • Process and knowledge management is driven by software as well as internal specialists	5	• No changes foreseen
Level of networking and collaboration between SMEs and large entities	3	• Smaller firms as part of value chains, yet seen as supplier not as collaboration partner • High degree of formalization and conflict • But for example, creation of an ecosystem in the automotive industry.	5	• Collaboration between small and large entities for innovation will become more important because of the higher division of labour between firms • The establishment of a start-up culture will lead to innovations outside the large firms that then have to be incorporated.

		Current Status		Future Needs
		• Still other industries don't have this high collaboration in Research and development as well as in other areas.		• Industries have to develop closed and simultaneously open and linked ecosystems of partners similar to the automotive industry

Intermediaries and policy makers

Intermediaries and policy makers:

Organisations able to support the diffusion, transfer and implementation of knowledge and practices regarding Industry 4.0 in each PP region; they act as a 'mediator' between researchers and practitioners. Some examples are: Chambers of commerce; Industrial associations; Scientific parks; Innovation agencies; Clusters; Regional public bodies related to industry and innovation (e.g. managers or regional council members, S3 - strategy); Financial institutions, …

Indicate here the sources used to provide information (e.g. reports, publications, SME/industry interviews):

Interviews: 111.21 Dr. Blum (VCI),111.22 Dr. Funk (ZD. B), 111.23 Dr. Kinkeldei (VDMA), 111.24 Group Interview Bavarian Ministry of Economic Affairs and Media, Energy and Technology

Documents:

All the ongoing (last three years) and planned initiatives (next two years) are summarized in the following table.

List the intermediaries in your region that have been supporting SMEs/industry in increasing AVM competences and/or resources and provide the requested information.

Name of the intermediary	Type	Focus (SME or large entity)	Dimension (Technology/HR+Organization/Strategy)	Summary of initiatives in the last three and coming two years (e.g. regional/European funds for training programs or research, support for networking development) and provide a comment
Industrie- und Handelskammer München und Oberbayern (IHK)	Chamber of Commerce	Both (mandatory membership)	HR+Organization, Strategy, Technology	- Generally speaking the IHK offers a broad range of services for SME regarding law, consulting, continuing education and lobbying. - Specifically, for the topic digitalisation, the IHK has several initiatives for its members guiding them through digital transformation "Pack ma's digital": Networking platform, events and continuing education for SMEs, the focus lies on providing information, best practices and contacts in digitalization - Open IHK as an open platform for competitions of ideas, discussion of topics and networking - Handbook and checklist "Industry 4.0": A quick introduction to the topic and checklist for a quick self-diagnosis - First business and law consulting on topics regarding Industry 4.0 - Continuing education in several topics of HR and organisation, business models and strategy and the impact of digitalisation, as well as analytics and cyber security for executives and professionals - Newsletters focusing on digitalisation (Akademie Westerham) - Different documents on general management topics of digitalisation
Handwerkstag Bayern	Chamber of Commerce	Both (mandatory membership)	HR+Organization, Strategy + Technology	- Generally speaking the Chamber of crafts offers a broad range of services for SME regarding law, consulting, continuing education and lobbying. - Part of an Initiative "Handwerk.digital" and competence centres with other chambers of craft. - Competence Centre for "Handwerk.digital" with focus on production technology, digital business models, business processes and information technology

Name of the intermediary	Type	Focus (SME or large entity)	Dimension (Technology/HR+ Organization/Str ategy)	Summary of initiatives in the last three and coming two years (e.g. regional/European funds for training programs or research, support for networking development) and provide a comment
				• Research funding for a project transferring production technology from Industry 4.0 to craftsman firms. • In cooperation with Handwerk.digital: checklists, online tools, events, demonstration of digital technologies and their application in firms, continuing education, development of implementation strategies, organisation of networking events and consulting of firms in projects work
Zentrum Digitalisierung. Bayern	Coordination platform	Both		Central topic is the development of networks between firms, universities and association and the support of • Initiatives for academia: Sponsoring of 20 professorships in Bavarian academia, 10 junior research groups, a central doctoral programme for all universities, 10 innovation labs at universities, establishment of an entrepreneurial ecosystem • Initiatives for the economy: 6 thematic platforms • Platform Digital Production and Engineering: Different working groups on analytics, business models, cyber-physical systems, standards for interoperability, etc. • Platform Cybersecurity with topics for advanced manufacturing, critical infrastructures and others
Cluster Offensive Bayern	Cluster	Both	All three dimensions, but mainly technology	Central topics are events for networking, support of members, continuous education, research and development projects, access to funding possibilities, access to foreign markets. All clusters named here include topics regarding advanced manufacturing: • Bicc.net: A cluster for information technology focuses on cyber security, cyber physical systems, IT services and embedded systems. • Strategische Partnerschaft Sensorik e. V.: A cluster for sensor technology. Specifics are the continuous education to a „Industrietechnologe 4.0"(Advanced Manufacturing Technologist) and Innovation manager

Name of the intermediary	Type	Focus (SME or large entity)	Dimension (Technology/HR+ Organization/Str ategy)	Summary of initiatives in the last three and coming two years (e.g. regional/European funds for training programs or research, support for networking development) and provide a comment
				• Cluster Mechatronik & Automation: network for the exchange of technology and organizational know-how in the mechatronic and automation industry; Competence Centre Industry 4.0 and Mittelstand 4.0 Akademie
VDMA	Industrial Association	Both	All three dimensions	VDMA (Verband Deutscher Maschinen- und Anlagenbau, Mechanical Engineering Industry Association) represents more than 3,200 mostly medium-sized companies in Germany in the capital goods industry, making it the largest industry association in Europe. VDMA Bayern has an Industry 4.0 project sponsored by the Bavarian Ministry for Economics. Topics of the VDMA regarding Industry 4.0 include work groups on: Digitalisation, Business Models, Standardisation, OPCMA, work 4.0, Predictive Maintenance, Services, Block Chain, Ecologies, Industrial Data Space, and Start-ups.
VBW	Industrial association	Both	All three dimensions	The Bavarian Industry Association (vbw—Vereinigung der Bayerischen Wirtschaft e. V.) is the voluntary, cross-industrial, interest group of Bavarian industry. They represent the collective economic, social, and socio-political interests of more than 100 Bavarian employers' and business associations, as well as more than 30 individual companies. • Studies on digitalisation and future studies • Lobbying activities • Continuous education (BBW group)
Bayme vbm	Industrial association	Both	All three dimensions	bayme vbm refers to the Employers' Associations of the Metalworking and Electrical Industries in Bavaria. They represent the joint commercial, social and political interests of more than 2,600 member-companies. Their activities on digitalisation include: • Service Centre "Digitalisation" with Quick Checks, • Digital enabling, work 4.0, IT law and security, as well as other topics • Mostly studies and information

Name of the intermediary	Type	Focus (SME or large entity)	Dimension (Technology/HR+ Organization/Strategy)	Summary of initiatives in the last three and coming two years (e.g. regional/European funds for training programs or research, support for networking development) and provide a comment
VBCI/VCI	Industrial association	Both	All three dimensions	VBCI/VCI are the industrial association of the Bavarian pharmaceutical and chemical companies. Their activities on digitalisation include: • Study on Chemistry 4.0
ZVEI	Industrial association	Both	All three dimensions	German Electrical and Electronic Manufacturers' Association The ZVEI is one of the most important manufacturers' associations in Germany. It represents the interests of a high-tech branch with a very widely varied and extremely dynamic product portfolio. It is represented by an office in Munich • Studies, continuous education and lobbying on topics of digitalisation, smart factories and cybersecurity • Development of the Reference Architectural Model Industrie 4.0 (RAMI 4.0) • Platform Industry 4.0 (Work groups, best practices, industry 4.0 landscape)
Bavarian Ministry of Economic Affairs and Media, Energy and Technology	Policy maker/Public body	All	All	• Coordination of various programs for digitalisation and industry 4.0 • Financing digital infrastructure, modern IT and cyber security in SMEs (DigitalBonus) • Establishing digital founder centres in all Bavarian regions • Continuous education of all levels in SME focusing on topics of Business model innovation, process optimization, developing of programming knowledge • Establishment of a cybersecurity cluster at the Bundeswehr University Munich • Further development of artificial intelligence competencies by developing Fortiss to a Bavarian AI centre, development of a Bavarian network on AI based on the Fraunhofer Institutes, Development of a Centre for Analytics Data Application • Development of a worldwide leading robotic competence centre with the TUM and the German Aerospace Centre

Name of the intermediary	Type	Focus (SME or large entity)	Dimension (Technology/HR+ Organization/Str ategy)	Summary of initiatives in the last three and coming two years (e.g. regional/European funds for training programs or research, support for networking development) and provide a comment
				- Maker labs for additive manufacturing (Initiative Industrial applications of Additive manufacturing) - Financial aids for developing of intelligent components of electronics, e.g. Big Data applications. - Further investments in the ZD. B - Baystartup initiative, founder centres
Bayerische Forschungs- und Innovationsagentur	Public body	Both	Technology	Bavarian agency for research and innovation: The State Ministries' and partners' shared goal is to ensure close, trustful cooperation between all parties involved and successful coordination of all activities so that The overall technology transfer system in Bavaria becomes more efficient and more transparent for scientists and businesses It can provide comprehensive information about the funding available in the EU, Germany and the Free State of Bavaria Bavarian applicants with little experience in the field of national and international cooperation and/or public research and innovation funding have access to an extensive range of advisory and support services It can further develop its portfolio of qualified advisory services in the field of technology funding, in order to make sure that more innovations from Bavarian companies – particularly SMEs – make it onto the market Bavarian organisations, especially universities and SMEs, have significantly better access to EU funding, particularly through the formation of consortia from the worlds of science and business with a higher chance of receiving funding from the EU. Usable findings / research results from Bavarian universities can be identified and quickly and effectively converted into applications: Specifically, they work on: - Financial aids for technology-oriented research and development in different stages, - Knowledge and technology transfer

Name of the intermediary	Type	Focus (SME or large entity)	Dimension (Technology/HR+ Organization/Strategy)	Summary of initiatives in the last three and coming two years (e.g. regional/European funds for training programs or research, support for networking development) and provide a comment
				- networking, - technology, licenses and patents - other support services
Fortiss	Technological institute/Public body	Both, but focus on SME	Technology	Fortiss is spin-off of the Technical University Munich and the Fraunhofer Gesellschaft working on digital technologies: - Various technological research projects in the area of industry 4.0, e.g. basic system for Industry 4.0, others - Research transfer to SMEs by research projects, digitalization quick checks, cooperation with industrial associations, integration in federal and European research funding. - On behalf of the Association of the Bavarian Economy (Bayme / VBM), Fortiss carries out so-called "digitization" quick checks to
Münchner Kreis	Private network	All	All	The Munich circle provides events, publications and studies on digital transformation and is a network of scientists, managers, public administrators working on issues of digital transformation. Topics are - digital working world, - cyber security - transformation of manufacturing - and others
Innovationszirkel Industrie im Mittelstand	Private network	SME	All three	The Innovation circle industry 4.0 is an initiative of SMEs working on topics about industry 4.0 and aims at - Networking of SMEs in order to generate projects - Increasing the transparency of solution - Supporting the innovation culture in SME and supporting competitiveness - Developing business models - Supporting cooperation and establish a network of trust They provide events and a platform for projects.

Academia

Definition of Academia

·Universities with a technical department

Business schools or Universities with a management department

Research institutions (e.g. CNR, Fraunhofer)

Indicate here the sources used to provide information (e.g. reports, publications, SME/industry interviews):

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Documents:

	Current Status		Future Needs	
	Level (1-6)	**Detailed Description**	**Level (1-6)**	**Detailed Description**
Technologies		The general level of research in technologies relevant for advanced manufacturing is high and covers all relevant topics. However, a specific weakness is research in artificial intelligence. Central for research on technology are the Technical University Munich (TUM), the Ludwig-Maximilians-University (LMU), Bundeswehr Unviersity Munich (UniBwM) the Fraunhofer Gesellschaft (Headquarter in Munich, Institute for Embedded Systems and Communication technologies ESK, Institute for Applied and Integrated Security, AISEC), the German Aerospace Center (DLR) in Oberpfaffenhofen (Institute of Robotics and Mechatronics). The campus automation and digitalization are a cooperation of LMU,TUM, Fraunhofer, Siemens and the German Institute for Artificial Intelligence promoting research on topics related to Advanced Manufacturing. Further (applied) research on AVM related topics can be found at the Universities of Applied Science in Rosenheim, Ingolstadt and Munich. Regarding the courses on advanced manufacturing there is a high level of integration of advanced manufacturing topics in different study programmes at the Munich Universities, especially at the Technical University Munich, e.g. there is a French-German cooperation with more than 30 research groups offering summer schools, micro masters and massive open online courses on topics relating to Industry 4.0. Furthermore, the Fraunhofer Institute offers several courses on "university4industry" (https://www.university4industry.com/) on topics regarding industry 4.0. The UniBwM offers a specialized master on cybersecurity.		

	Current Status		Future Needs	
	Level (1-6)	**Detailed Description**	**Level (1-6)**	**Detailed Description**
Internet of Things	5	• Several research groups work on topics regarding the internet of things [e.g. Institute of Automation and Information Systems (TUM), Chair for Mobile and Distributed Systems (LMU), Institute for Materials Handling, Material Flow, Logistics (TUM), Professorship of Embedded Systems and Internet of Things (TUM), Professorship for Internet services and Internet	6	• Still a high need for those topics; more professorships are planned based on the ZD. B • Missing is research on human factors ("work") in Industry 4.0 and in cyber-physical systems, legal aspects as well as other business-oriented aspects. • Semantics for Industry 4.0 and ethernet and Ip-based communication infrastructure for factories. • Powerline modems for communication of industry 4.0 data.

	Current Status		Future Needs	
		Business (LMU), Institute for Machine Tools and Industrial Management (TUM)], Chair for embedded systems (UniBwM) and Cahir for distributed systems (UniBwM)] • Topics include secure intermachine communication, human factors, hardware software co-design, changeable materiality flows, among others, intelligent cyber physical systems, hybrid blockchain architectures for production among others		
Cloud computing	4	• Several research groups work on topics regarding software architecture for cloud computing as well as on the role (e.g. the cluster for computer and communication architecture of the department for information systems (TUM)) • Topics include: Fog Computing, Edge Computing, Cloudlets	5	• Still a high need for topics on software and data architectures • Topics including fog, edge and cloud computing • Vertical Social Software for Contextual Computing is missing • Research on real time service-oriented architecture
Cybersecurity	6	• Munich is a central hotspot for cybersecurity research in Germany. • UniBw has a cybersecurity cluster as a research centre with more than 11 professorships for cyber security (mobile computing, malware analysis, forensic), • The Fraunhofer Aisec is located in Garching researching on Cybersecurity: Embedded security,	6	• Cybersecurity will be still an important topic in the future. • Cryptographic, security solution for internet of things, certifications and evaluations of secure machines, cloud security, cognitive security systems, product verification, among others • Identity and access management

		Current Status		Future Needs
		mobile security, industrial security, testing, among others. • Several chairs at the LMU and the TUM are focusing on these topics as well		
Big data and analytics	5	• Several institutes are researching in the area of big data and analytics: Quantitative and computational systems science centre (LMU); Cluster Data Analytics and Engineering (TUM) • Several Chairs for Business Intelligence exist at the three universities. • Topics include data engineering, data analytics, machine learning and data science • Business schools have chairs for analytics in production and optimization (TUM, UniBw) as well as other analytics topics in other areas like Customer or People Analytics (LMU, TUM, UniBw)	6	• Will remain important in the future • Missing is research focusing on intelligent analytics based on artificial intelligence though IBM and Microsoft offer both artificial intelligence centres for firms in Munich. • Missing is research on industry and business analytics beyond the single production site and within business networks.
Advanced manufacturing solutions	6	• Several institutes are researching in the area of advanced manufacturing solutions. • Institute for Machine Tools and Industrial Management (TUM): intelligent tools, optimization of industrial practice, cyberphysical assembly systems, industrial robotics • Cluster for Robotics (TUM): Human machine interaction, seeing of machines, autonomous navigation, artificial intelligence for planning and	6	• Will remain important in the future

		Current Status		Future Needs
		perception, software architecture of robots, etc. • Institute for Human factors: Social Robotics, telematics robotics • Research project ("ForRobotics") of several Bavarian universities, Fraunhofers and firms on mobile, ad-hoc cooperating robotics • Robolaw project at the LMU		
Additive manufacturing	3	• Institute for Machine Tools and Industrial Management (TUM): process development, process observation and simulation • Chair of carbon composites (TUM): Process technology and tools	6	• Institute for Additive manufacturing planned at the TUM, • Ludwik Bölkow Campus plans a model factory for additive manufacturing in aerospace industry. • More institutes working on additive manufacturing needed
Augmented reality	3	• Chair for Computer Aided Medical Procedures & Augmented Reality (TUM): Sensing, Ubiquitous Tracking (Sensor Fusion), 3D Information Presentation, System Architectures for Ubiquitous Augmented Reality, Industrial Augmented Reality: • Institute of Human-Machine Communication (TUM): Interfaces, Data Visualization and Automotive User Design • Work Groups Media Informatics and Human-Computer Interaction (LMU): secure software services, human centred organizational designs	6	• Only few researches on augmented reality in the factory and the potential for support and learning. • No research integrating
Simulation tools	3	• Chair of Computational Modelling and Simulation (TUM): 3 & 4D simulations of buildings	5	• Will be important in the future.

	Current Status		Future Needs	
		• Chair for Computation in Engineering (TUM)		
Presence of courses regarding AVM/digital technologies	4	• High level of courses relating to AVM & digital technologies at the LMU und TUM (both have an informatics department, several specialist's master's degrees), TUM has several master's degrees for engineers with elements of AVM technologies, furthermore several courses in data science, embedded systems, cyber security, additive manufacturing LMU has an Analytics research centre offering a Data scientist master's degree, • Cyber Security is a specialised master's degree at the UniBwM • Some courses for continuous education	6	• Missing is a master course combining mechatronics and embedded systems • Missing is a master's degree on "additive manufacturing" • Missing are specific courses for continuing education on topics related to AVM
Level of collaborations/contracts with SMEs/Industry	4	• All universities have high levels of cooperation with the industry (third party funding, practice lectures, others), Fraunhofer has a high number of collaborations • Collaborations with SMEs are not high	6	• Missing are forms of cooperation with SMEs, most collaboration partners are large entities
Level of financed projects on AVM technologies		• High, especially Siemens has established a high level of third-party funding (Campus Digitalization and Automation), Fraunhofer has a high level of financed projects, furthermore, the Bavarian research foundation, the German research foundation and the BMBF (Federal		• Specifically, third party funded research by SMEs is still expandable

	Current Status		Future Needs
		Ministry of Education and Research) provide third party funding in this area	
Publications (academic + pract. journals)		• Very high numbers (LMU, TUM, UniBw, Fraunhofer, Hochschule München)	• Transfer activities could be enforced.
Conferences, Events organized by institution		• Various at the TUM, LMU, UNIBw, Hochschule München, Fraunhofer	• Integrating Conference of researchers in areas of AVM is missing.
Techn.Transfer activities (academia --> SME)		• High (Fortiss, Bölkow Campus, Fraunhofer, etc.)	• Will be needed in future
Dedicated departments in the topic		• None in the sense of AVM. • Various at the different universities on engineering, informatics, electronics and information technique, aerospace technique, mathematics and statistics	• Rather missing are single chairs supplementing the existing research landscape in some areas (see Initiatives of the ZD. B)

	Current Status		Future needs	
	Level (1-6)	**Detailed Description**	**Level (1-6)**	**Detailed Description**
Human Resource Management / Organisation		The general level of research on HRM/ORG is high, all three universities have a management department with dedicated Chairs for HRM/Organization and related topics. All three management departments of the three universities have a research focus on digital transformation, with the respective chairs having research projects in this area. The ISF e.V. researches work and organizational sociology regarding digitalization. Further (applied) research on HRM/organization relating to AVM related topics can be found at the Universities of Applied Science in Rosenheim, Ingolstadt and Munich. Regarding the presence of AVM related courses, the topics are rather embedded in thesis and seminars than in lectures, though a ring lecture on industry 4.0 at the TUM exists. However, lectures are focusing more generally on strategic organizational design, technology and innovation in capital intensive industries, topics in HRM and leadership, strategic human resource management, applied leadership, people analytics, organizational change, organization of family firms, organization of multinational entities, etc. exist.		

	Current Status		Future needs	
	Level (1-6)	**Detailed Description**	**Level (1-6)**	**Detailed Description**
Presence of courses regarding AVM related HR topics	3	• General presence of HR topics in bachelor and master's degrees very high. • No specific AVM related HR topic course integrated in the curricula • Generally, speaking various continuous courses on organizational development, organizational design, HRM related topics at all Munich universities. • HR Analytics courses already present • Missing are coursed dealing explicitly with 1. datafication, technical integration, sensors as influencing HR	3	• Integration of explicitly AVM related topics to HRM • Continuous education form HRM practitioners on topics related to advanced manufacturing and their implication for HR work. • Courses on HRM innovation and human factors in cyberphysical systems • Courses on organisation of digital factories, value creating networks of firms, change towards industry 4.0.

		Current Status		Future needs
		technologies. 2. Productivity gains, information bases and acceleration of HR Work (real-time HRM), 3. Changing role of HRM, HRM competencies in the Industry 4.0 • No specific courses on organization in relation with AVM technologies. • But general courses on organization and innovation, Management of digital technologies, digital firm, digital transformation, strategic organizational design, strategy in network industries, etc.		
Level of collaborations/contracts with SMEs/Industry	4	• All departments have third party funding from industry, practice lectures, etc. • Applied research mostly in form of consulting projects and at the university of applied sciences	4	• More third-party funding specifically focusing on HR/Organization challenges of SME
Level of financed projects on AVM related HR/organisation topics	4	• Generally, high level of financed projects in the area of digitalization (e.g. competence centre Industry 4.0 at the TUM Business School, Digitrain at the UniBw, Munich Centre for Internet Research (MCIR), Internet Business Cluster (IBC) e.V.	6	• More funded research on the transformation of HRM and organisation is needed.
Publications (academic + pract. journals)	3	• Still in its infancy, but already some publications regarding the AVM topics in HRM/Organisations	6	• Publications with high impact factor still scarce • More research on these topics and dissemination
Conferences, Events organized by institution	3	• Various conferences on topics related to digitalization are organized in cooperation with the professorships for HRM/organization	3	• Still high need as dissemination events

	Current Status		Future needs	
Know-how Transfer activities (academia --> SME)	3	• In the frame of the know-how transfer of the respective university. • A lot of presentations of the professors at industry events • Universities of applied sciences (Hochschule München)	3	• More engagement in the third mission is needed, however, all universities are offering continuous education, consulting, etc.
Dedicated departments in the topic	3	• Competence centre industry 4.0 at the TUM; Cluster Digitalization and Analytics at the UniBw, Cluster Technology and Innovation as well as HRM and Leadership at the LMU.	4	• More clustering of already existing competencies on HRM/organisation related to AVM is needed. • High level of opaqueness about research topics on AVM related implication of AVM.

	Current Status		Future needs	
	Level (1-6)	Detailed Description	Level (1-6)	Detailed Description
Business Model Innovation/Process Management		The general level of research on Business Models and Process Management is high. All management departments have research on innovation and entrepreneurship as well as research on Business process management, furthermore all departments have a chair for strategy. Further (applied) research on strategy, business model innovation and process management relating to AVM related topics can be found at the Universities of Applied Science in Rosenheim, Ingolstadt and Munich. Regarding the presence of AVM related courses, the topics are rather embedded in lectures than as specific courses. A central topic is digitalization. The STrategsch Centre for entrepreneurship offers courses.		

	Current Status		Future needs	
	Level (1-6)	Detailed Description	Level (1-6)	Detailed Description
Presence of courses regarding AVM related Business model strategy and process management	3	• General presence of these topics in bachelor and master's degrees very high. • No specific AVM related topic course integrated in the curricula • Several general courses on TiM, Entrepreneurship, Process and Operations management, open innovation, etc. courses on digitalization of process, strategies and business models mostly in services and media. • All three universities have several chairs for management information systems research offering general courses on process management and digital work. • CDTM (cooperation between TUM and LMU) educates on Technology	4	• Need for courses focusing on industrial digitalization rather than services and media. • Missing are courses on role on cluster and ecology management • Integration of AVM related topics in the courses on strategy, innovation, entrepreneurship • Furthermore, a centre similar to the CDTM is needed for Industry 4.0 topics educating the top students and delivering related research. • Missing integration of informatics, cyberphysical systems etc.

		Current Status		Future needs	
		Management. CDTM focuses on three main topics: Innovation, Product development, Entrepreneurship. CDTM closely cooperates with renowned partners from industry as well as with start-ups and medium-sized companies. Research at the CDTM focuses on new technologies of high economic relevance that are expected to be ready for the market in five to ten years.			
Level of collaborations/contracts with SMEs/Industry	3	• General modest level regarding strategy, business model innovation, no specific research centres (except the industry 4.0 competence centres) exist. • However, there exists a craftsman's institute collaborating with the TUM. • Furthermore, the STrategsch Center as well as the Entrepreneurship Centres of LMU/TUMare funded by industry		4	• There is a need to coordinate efforts on digital transformation of intermediaries and universities. • Need of SMEs and Industry for a stronger focus on the business administration aspects of industry 4.0 •
Level of financed projects on AVM related business strategies + process management	4	• High level of financed research by different institutions (e.g. Munich Center for Internet Research, BMBF, DFG, multinational firms) • Focus on information systems research (processes rather than business models) • Several endowed chairs on Technology Management (Theo Schöller, ISTO)		3	• Need for more funding of projects regarding the strategic and process management aspects of advanced manufacturing by technology companies like Siemens, BMW, etc. though already at a high level • Funding of a competence centre of the Munich universities regarding strategic aspects of AVM.

	Current Status		Future needs	
Publications (academic + pract. journals)	4	• High number of publications on strategy, technology, innovation, entrepreneurship and process management		• More research on these topics and dissemination needed • Missing are the differences resulting from AVM in strategic and process aspects.
Conferences, Events organized by institution	4	• Various conferences on topics related to strategy and business model innovations are organized at specific universities	4	• Still high need as dissemination events
Know-how Transfer activities (academia --> SME)	3	• In the frame of the know-how transfer of the respective university. • Important role of universities of applied science (Hochschule München) • A lot of presentations of the professors at industry events	4	• More engagement in the third mission is needed, however, all universities are offering continuous education, consulting, etc.
Dedicated departments in the topic	3	• Competence centre industry 4.0 at the TUM; Cluster Digitalization and Analytics at the UniBw, Cluster Technology and Innovation as well as Strategy at the LMU. • Several chairs for research in management information systems	4	• More clustering of already existing competencies on strategy and business model transformation related to AVM is needed. • High level of opaqueness about research topics on AVM related implications • Missing are chairs focusing on industrial management