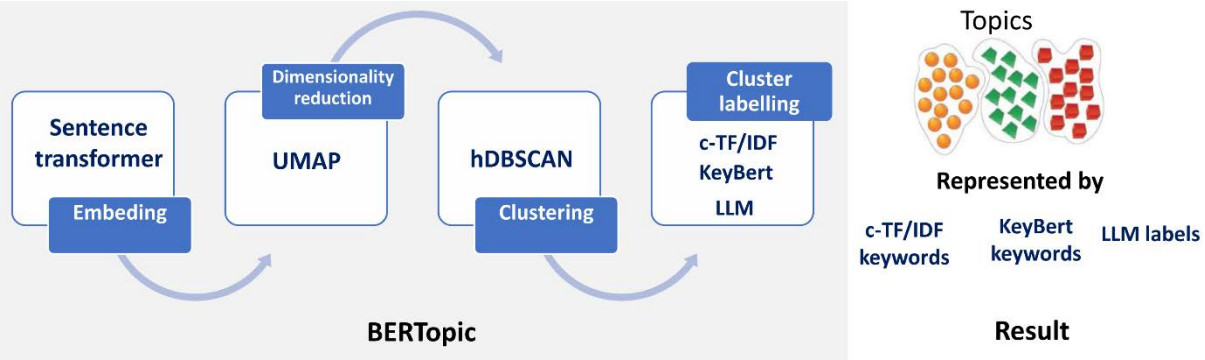
SUPPLEMENTARY MATERIALS

SM1: The applied TM process

Overall, the applied topic modeling process was the following (Source: Authors' work)



First (Embedings), the interview texts were converted using the pre-trained sentence transformer language model "all-MiniLM-L12-v2" to a 384-dimensional vector space.

Second (Dimension reduction), we then decreased these 384 dimensions to optimize the clustering process. We employed the Uniform Manifold Approximation and Projection (UMAP) method, which, based on published research (Grootendorst, 2022; Thompson & Mimno, 2020), better preserves the local and global structure of the corpus than Principal Component Analysis, which is arguably the most widely used technique for dimension reduction. Based on the results of the related literature, in our research, UMAP uses the five nearest neighbours to prefer local structures.

Third (Clustering), the reduced dimensional embeddings were clustered using the Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) algorithm, which defines clusters of different densities. This algorithm allows noise to be modelled as an outlier, preventing unrelated document parts from being assigned to any cluster and improving topic identification. We set the minimum size of clusters to 45.

Fourth (Cluster labelling), we used quantized LLM technology, the KeyBERT extraction technique (Grootendors, 2020; Sammet & Krestel, 2023), and the class-based frequency-inverse document frequency approach (c-TF-IDF[1]) to characterize the resulting clusters/topics[2]. The technique of quantized LLM was initially employed to improve the representation of the topics (Grootendorst, 2022). Quantization is crucial in the utilisation of LLMs. It involves reducing the precision of the model's weights by assigning smaller approximations, such as 4-bit or 8-bit values, instead of the original 32-bit floating points. While there may be a slight reduction in accuracy, this approach effectively reduces the memory requirements of the model. This study utilized the pre-trained language model "OpenHermes-2.5-Mistral-7B-GGUF" and the LlamaCPP representation model (Betlen, 2023). A prompt has been established for LLM to utilize when developing topic labels. These labels are derived via clustering comments pertinent to each topic.

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[1] The c-TF-IDF value of a term x in a given class c $w_{x,c} = \|tf_{x,c}\| \cdot \log\left(1 + \frac{A}{f_x}\right)$, where $tf_{x,c}$ is the frequency of word x in class c; f_x frequency of word x in all classes and A is the average number of words in the classes

[2] As mentioned, the original BERTopic solution proposed by Thompson and Mimno in 2020 was also applied to test reproducibility with a test-test procedure (Potter & Levine-Donnerstein, 1999).

SM2: The 11 topics resulted from the topic modeling. The extracted topic labels (LLM), the 8 most important keywords of KeyBert (KeyBert) and c-TF/IDF. (Source: Authors' work)

Topic	LLM	KeyBert	c-TF/IDF
0	Manufacturing firms profit and automation	['suppliers', 'manufacturing company', 'industry', 'manufacturing', 'companies', 'make profit', 'revenue', 'company']	['manufacturing', 'automotive', 'company', 'production', 'companies', 'example', 'car', 'also']
1	Information technology in companies	['informationtechnology manager', 'informationtechnology roles', 'informationtechnology', 'informationtechnology education', 'informationtechnology system']	['informationtechnology', 'need', 'company', 'even', 'good', 'people', 'manager', 'managers']
2	Human aspects of business processes	['give example', 'example', 'like evidence', 'sure', 'let', 'give', 'picture realist', 'see']	['let', 'people', 'see', 'way', 'example', 'give example', 'sure', 'think', 'let give', 'yellow']
3	Industry 4 0 Definition and Implementation	['industry four', 'industry industry', 'industry', 'industry development', 'industry example', 'industry digitalisation', 'want industry', 'industry systems']	['industry', 'would', 'companies', 'industry would', 'could', 'machine', 'data', 'want']
4	Data collection analysis sensors time series databases	['data information', 'data data', 'data', 'information data', 'data everyone', 'big data', 'lot data', 'collect data']	['data', 'sensors', 'information', 'collect', 'time', 'collect data', 'also', 'database']
5	Regulating Depth Standards in Systems	['constraints', 'rules', 'regulation', 'entitlement', 'standards', 'principle must', 'exceptions', 'rules game']	['standard', 'rules', 'regulation', 'handle', 'regulated', 'depth', 'standards', 'know']
6	Data Security Cybersecurity	['cybersecurity also', 'cybersecurity issues', 'cybersecurity', 'security cybersecurity', 'information security', 'security', 'cybersecurity course', 'data security']	['cybersecurity', 'security', 'data', 'virus', 'vulnerability', 'attack', 'network', 'secure']
7	ERP System Implementation	['erp systems', 'erp system', 'systems erp', 'company erp', 'use erp', 'erp implementation', 'implemented erp', 'enterprise management']	['erp', 'erp system', 'system', 'erp systems', 'systems', 'company', 'erp implementation', 'enterprise']
8	Process Improvement	['process', 'processes need', 'process analysis', 'process obviously', 'process lives', 'processes job', 'processes aware']	['process', 'processes', 'comes', 'end', 'lack', 'written', 'going', 'prepared']

9	Supplier issues and procurement	['delivery note', 'receipt', 'delivery', 'receive', 'arrive', 'received', 'delivered', 'invoice']	['supplier', 'order', 'invoice', 'delivery', 'note', 'procurement', 'deliver', 'delivery note']
10	Digital Transition of SMEs	['small companies', 'small company', 'companies also', 'companies', 'group companies', 'multinationals companies', 'marketing companies', 'within company']	['companies', 'company', 'small', 'group', 'small companies', 'medium', 'group companies', 'within']

SM3: Operationalization of the process management maturity model

The process management maturity reference model builds on CMMI. A detailed description of how it conceptualizes and operationalizes process maturity can be found in the literature (ISO 2015a, 2015b, 2015c; CMMI Product Team, 2010; Chrissis et al., 2011). Only a focused summary is provided here. CMMI has three complex abilities with the following measurement attributes:

- **The ability to understand, map, and control processes: This captures how control of business areas can be systematically** developed. It moves forward from ad hoc to a consciously controlled operation relying on documented processes designed by company-wide, uniform principles, with regular reviews and redesigns. A further important feature of progress is the ongoing extension of processes with a high-level process control ability.
- **The systemic process improvement ability** starts with a complete lack of process improvement efforts and moves toward a performance-oriented, data-driven analysis, and feedback-based improvement of individual business areas. Gradual extension of this ability is important too.
- **The ability to integrate improvement efforts and align them with strategy:** It captures characteristics of an enterprise-wide, integrated process improvement ability used to harmonize ongoing efforts and align them with strategy and the overall logic of the company's value creation. In the first development stage, neither performance relationships among individual processes nor strategic alignment are present. At a higher level of development, performance interdependence and trade-offs are considered for more and more processes. In addition, strategic alignment becomes important to integrate improvement efforts further.

Figure SM3: The operationalization of process management maturity model of CMMI (Source: Authors' work based on the literature referred to above)

<table>
<tr><th colspan="3">Process Control</th><th colspan="2">Process Improvement</th><th colspan="2">Process Improvement Integration</th><th rowspan="2">Maturity levels</th></tr>
<tr><th>No or ad-hoc process control</th><th>Extent of process control</th><th>Process documentation practices</th><th>Measuring process performance</th><th>Data-driven improvement efforts</th><th>Analysing interrelationships among process performances</th><th>System-level alignment of process improvement efforts</th></tr>
<tr><td rowspan="3">Not ad-hoc</td><td>Large-scale</td><td rowspan="2">Highly developed</td><td rowspan="2">Large-scale</td><td rowspan="2">Large-scale</td><td rowspan="2">Large-scale</td><td>Completely aligned</td><td>Optimizing</td></tr>
<tr><td rowspan="2">Medium-scale</td><td rowspan="3">Partially aligned</td><td>Quantitatively managed</td></tr>
<tr><td>Moderately developed</td><td>Medium-scale</td><td>Medium-scale</td><td>Medium-scale</td><td>Defined</td></tr>
<tr><td rowspan="2">Ad-hoc</td><td rowspan="2">Small-scale</td><td rowspan="2">Underdeveloped</td><td rowspan="2">None or small scale</td><td rowspan="2">None or small scale</td><td rowspan="2">None or small scale</td><td rowspan="2">Not aligned</td><td>Managed</td></tr>
<tr><td>Initial</td></tr>
</table>

SM4: The coding scheme of the process management maturity benchmark model (Source: Authors' work)

***Abilities*, main features along which process management maturity is evaluated in the reference model**	***Measurement attributes* of abilities, along which their development can be measured**	***Keywords and expressions looked* for in the relevant topics when coding**
Process control	Does process control exist or not? Are processes mapped? Is the process control ad-hoc? Is the process control conscious? Has process control unified guidelines? The extent of the conscious process control? Are process control documents regularly reviewed? Are changes in process control documents traceable? Can changes in process documents be retrospectively verified?	Process control/governance, conscious, ad-hoc, understand /know the process, define the process, write down the process, process map, process mapping, unified guidelines, documentation, process document, process instruction, process standardization, process review, process changes, traceable
Process improvement	Is the performance of operational areas/functions/processes measured? The extent of this performance measurement? Are the performance data used for process improvement initiatives?	Performance, process performance, measured performance, process analysis/assessment, process improvement/development/reorganization, data-driven initiatives, extent of these initiatives
Integration of improvement efforts	Are relationships among the performance of individual processes considered when initiating improvement projects? Is the system-level performance and the overall value creation of the firm analyzed when deciding on improvement projects? Are improvement projects aligned with strategic objectives?	Trade-offs in performance, interdependences among performance, system-level (systemic) performance, overall value creation logic, effort integration, strategic objectives, strategic considerations

SM5: The IT management maturity reference model

As indicated in Section 3.2.2, the IT management maturity reference model is based on SIMMI (Leyh et al., 2016) and the L&K model (Leem & Kim, 2004; Leem et al., 2008). The reference model integrated the human-based organizational aspects of the L&K model with the technological evaluation dimensions of SIMMI. The benchmark model includes the following evaluation dimensions and associated attributes:

(1) The **level of integration** within the firm and along its value chain (vertical and horizontal integration). Elements capturing this have been taken over from the L&K model (investments, IT education, surveys on IT requirements, and business area support) but complemented from SIMMI by a key I4.0 readiness factor, the method of data aggregation, storage, and communication since this is also considered as an important mean of integration. Specifically, the ability of IT integration includes the following attributes:
   a. *Investment rate of IT assets* (from L&K): Since the capacity of physical IT assets has been proved by the L&K model to be proportional to the level of investments in the company's IT infrastructure.
   b. *Periodic requirement survey* (from L&K): Surveys of whether companies regularly conduct needs assessments of IT end-users for IT purchases, renewals, and upgrades are used to assess the appropriateness of IT usage.
   c. *IT education regularity* (from L&K): IT training within the firms is critical for the actual realization of IT usage.
   d. *Target levels of IT education* (from L&K): It is essential that training is provided to all employees, including managers.
   e. *Method of data storage* (from both L&K, SIMMI): It shows the level of data storage in the context of integration. While the focus on process management capability is on integrated management of enterprise processes, the accompanying storage of the generated data in different databases and sometimes in different formats often limits this integration. In different storage and different formats; in different storage but in compatible format; in shared database; in different database with interface; SOA platform.
   f. *Support of business* parts (from both L&K and SIMMI): for the functional areas of the organization, consider whether IT support is available.

(2) **Digital continuity**, especially in production and product development.
   a. *Digital production support* (from SIMMI), whether and to what extent manufacturing is digitally supported.
   b. *Collecting customer data on product usage* (from SIMMI), whether data collection from customers on products is ensured.
   c. *Using these data for product development* (from SIMMI).

(3) **Cross-sectional technology criteria** including the development of the IT platform at the company, application of service-oriented applications, and business analytics and IT security.[3]
   a. *IT platform* (from SIMMI): The technological maturity of a company is well characterized by the IT platform on which it operates. Isolated system, PC; client/server solution; vertically integrated system; platform enabling vertical-horizontal integration; SOA, cloud.

[3] We mention here that the capability level of the IT management process itself is also crucial for a company. The evaluation of this IT management process is covered, however by our process management model (CMMI).

b. *Service-oriented cloud applications* (from SIMMI): The use of modern technology is characterized by whether they have service-oriented cloud applications.
c. *Applications for business analytics* (from SIMMI): To decide whether a company is state-of-the-art, it is important to know whether business intelligence applications are used.
d. *IT security* (from SIMMI): a high level of IT security is essential to meet the technological criteria, ensuring the risk-free flow of data and information. The operation of a company in Industry 4.0 is heavily dependent on the use of the Internet, which enables the daily transfer of data from machines that are in operation. Due to the continuous internet-based operations, ensuring IT security is a major challenge in using various IT systems. IT security involves ensuring that all electronically accessible information is properly protected. In addition, it is essential to ensure that IT systems and their services are always available to users and that they function properly.[4]

[4] We note that the degree of a firm's overall IT management maturity along the reference model fits well with the levels of the process management maturity reference model. See the scope or the integration levels defined there (e.g., ad hoc process - isolated systems; optimized, managed, cross-enterprise process system - SOA platform).

Figure SM5: The operationalization of the IT management maturity reference model based on SIMMI and the L&K model (Source: Authors' work based on the literature referred to above)

Organizational/ Strategical Aspects				Enterprise Systems		Digital Production and Product Development			Cross-sectional Technology Criteria				Maturity levels
Investment rate of IT assets	IT education regularity	Target levels for IT education	Periodic requirements survey	Method of data storage	Support of business parts	Digital production support	Collecting customer data on product usage	Using data for product development	IT platform	Service-oriented cloud applications	Applications for business analytics	IT security	
1% or more	Regular and planned	For leaders and employees	Regular and consciously organized	Internal SOA-architecture	All areas (5)	Product development data is processed digitally both within and outside the company	Data collected	Yes	External SOA integration	Successfully implemented	Successfully implemented	IT security compliant with ISO standards or stronger (e.g., token-based authentication - 2FA). Adapts promptly to new risks, and any security issues that arise are immediately resolved. Encryption is optimized across value networks	**Optimized full digitization**
Between 0.2% and 1%				In different databases with an interface	All relevant areas (4-5)	The product development process is digitally supported					Under implementation	Compliant with ISO standards. Secure access to data. Inter-enterprise data encryption and authentication for global access	**Full digitization**
	Occasional	For leaders or employees	Occasional	In shared database		Product development information is digitally transmitted between the steps of the process		No	Integrated internal SOA platform	Under implementation	Under planning	It is based on an accepted methodology (e.g., COBIT). They employ an advanced security system, ensuring continuous protection of data access, and encrypted data transmission within the enterprise	**Horizontal and vertical digitization**
				In different storage but in compatible format	All relevant areas (3)		Not collected		Client – server environment	Under planning	None	Part of the organization's internal governance and control system. They are working on the development of initial IT security models	**Cross-departmental digitization**
Under 0.2%	None	None	None	In different storage and different format	Some areas (1-3)	Product development is not digitally supported			Isolated IT systems	None		Confidentiality, availability, and integrity are not guaranteed	**Basic digitization**

SM6: The coding scheme for the IT management benchmark model (Source: Authors' work)

***Abilities*, main features along which IT management maturity is evaluated in the reference model**	***Measurement attributes* of abilities, along which their development can be measured**	***Keywords and expressions looked* for in the relevant topics when coding**
Organizational, strategic aspects	Investment rate of IT assets.	increasing capacity of IT, expanding the IT asset, IT investments, investment rate
	Do periodic requirement surveys exit?	IT requirements, IT surveys, periodic surveys, regular surveys
	How regular IT education is?	IT education, IT training
	What are the target levels of IT education?	training/education of end-users, training/education of employees, training/education of management
Enterprise systems	What is the method of data storage?	mode/way of data storage, place of data storage, format of databases, compatible format of storage, shared database, interface between databases, integrated database, integrated data storage, SOA
	How different business areas are supported?	support of business, IT support of functions / operational areas
Digital production and product development	Is production digitally supported?	digital manufacturing, digital support of manufacturing, digital support of production/operation, PLM, manufacturing/production digitalization
	Are customer data on product usage collected?	customer data, collecting customer data /information, data on product usage
	Are the above data used for product development?	product usage analysis, product development
Cross-sectional technology criteria	What IT platform does the firm use?	IT platform, integrated platform, isolates IT system, PC, client-server solution, integrated system, ERP, SOA
	Are service-oriented cloud applications used?	cloud, using cloud, service-oriented cloud, SOA
	Are business analytics applied?	state-of-the-art analytics, business analytics, business intelligence, BI
	What is the level of IT security?	data/information security, IT security, cybersecurity, IT risk, data/information protection, basic security (password), privacy, privilege entitlement, eligibility, ISO, virus protection, firewall, COBIT