planned vs. actual data and the intuitively visualization of where material is stored in the warehouse, were mentioned.

CULTURE, PEOPLE and IMPLEMENTATION

In this cluster, the SME's needs to access the financial, informational, digital, physical and educational resources to ensure that Industry 4.0 is fully realized rather than passed by are summarized. The increase of visibility of Industry 4.0 among professionals who might not have been exposed to it otherwise was collected. The requirement of Top Management being aware and supporting Industry 4.0 to avoid missing acceptance throughout the company was mentioned. Moreover, the need of qualified and trained employees to implement and handle Industry 4.0 concepts in daily business was recorded. Here, the participants stated that employees should be specifically trained in software and data collection. For a successful implementation of Industry 4.0 into SMEs the necessity of having an overview of existing Industry 4.0 concepts and tools for logistics and their suitability for SMEs for specific industry sectors was mentioned. Here, the need of a specific distinction of SMEs in countries with high-labor cost and countries with low-labor cost was specified.

3.2. Hypothesis of requirements of intelligent logistics through ICT and CPS

This sub-section focuses on requirements of intelligent SME logistics through ICT and CPS. Thereby, digitalization in logistics was considered as one of the most important ones.

DIGITALIZATION

Digitalization encompasses the visualization of material flow from upstream to downstream companies. This includes the visualization of tools and parts used throughout the supply chain processes. The technology which supports digitalization in the supply chain should be implemented in the entire supply chain to avoid incompatibility. Digitalization could be implemented in order receiving, procurement process as well as in logistical risk warning systems. However, digitalization should limit the accessibility of related stakeholders to obtain optimal data.

REALTIME STATUS AND TRACKING SYSTEMS

Real time status and tracking systems are crucially important for SME logistics processes in terms of supply chain monitoring. This includes the monitoring of shipment status of materials. Real time status can also assist in the predictive maintenance process. The tracking system provides better real time status, for example, inventory tracking, multiple parts tracking through multiple processes to monitor the status of production.

CONNECTIVITY

Intelligent SME logistics requires standardized data interfaces between supply chain partners like suppliers, manufactures and customers. Systems should be synchronized throughout the supply chain to avoid re-work and communication interruptions. Data is required to be integrated to support single database systems. Suppliers are encouraged to use designated barcode or RFID systems that are mutually arranged.

WMS

Warehouse Management Systems (WMS) were mentioned as one of the most significant elements to support smart logistics in SMEs. Requirements like the automated assistance in order and distribution processes based on historical assumptions were mentioned. The provision of data for inventory decision making such as inventory turns and reorder point arrangements to support Economic Order Quantities (EOQ) was mentioned. WMS can also allocate and optimize storage locations and display accurate locations for product pick up.

LEAN AND EASE OF USE

According to the workshop results, the implementation of smart logistics concepts should be lean, understandable and easy to use. For example, the experts proposed that "a supplier list with delivery times should always be available and up to date in order to avoid delays and necessary rescheduling processes with the vendors".

SECURITY AND SAFETY

According to the workshop participants, security and safety issues should be supported along smart logistics in SMEs. Here, specifically the internal traffic optimization for safety and efficiency in the workplace and required ICT to monitor and control safety in driverless transport systems were mentioned. Moreover, the ensuring of data security and intellectual property protection were recorded.

3.3. Hypothesis of requirements of smart and automated logistics systems and vehicles

The third section "automated logistics systems and vehicles for SMEs" was defined as the analysis of existing approaches and technologies for automation in SME Logistics (e.g., autonomous guided vehicles, mobile shuttles, and flexible automated warehouse systems), as well as the definition of the potential of their application in practice and their suitability for SMEs. Based on the analyses from the expert workshops, the research results were aggregated to the clusters "automation", transport and WMS", "Lean" and "digitalization and connectivity".

AUTOMATION

The cluster automation includes requirements for decreasing the manual workload in logistics systems. Thereby the experts mainly focused on the automated labeling of products, automatic picking and delivery, automated storage systems for materials and transport containers and the automated removal of scape in the course of the production process. Moreover, the participants were interested in cause-effect analyses aiming at the impact of automation approaches on business success.

TRANSPORTATION AND WMS

This cluster contains the automated material transport by using driverless transport systems (AGVs) including all related activates (e.g., loading, transport, unloading, safety issues) aiming at a fast and cost-efficient distribution of materials. Moreover, the cluster includes the automation of warehouses by using warehouse management systems (WMS), automated inventory monitoring, and automated systems for the ongoing operation and maintenance of warehouse systems.

LEAN

This cluster mainly includes strategies to increase the material efficiency in automated logistics systems. Thereby, the reduction of buffer stocks, raw material, WIP and finished parts were recorded. Moreover, the usage of advanced planning techniques was mentioned as a further requirement.
Additionally, the reduction of buffer stocks at the workplace, preventive "rhythms" (delivery, preparation, etc.), grouping complimentary suppliers (trucking routes), efficient storage and removal systems for the holding of raw material, WIP, finished parts, parts produced and packaged at machines and moved to shipping were mentioned.

DIGITALIZATION AND CONNECTIVITY

This sub-section comprises the automation of information flow activities in logistics systems. Thereby, the requirements included the automated tracking of prices, the automation of processes (e.g. the generation of bill of materials) and the automated communication between different systems.
Moreover, the workshop participants mentioned the sharing of transport capacities, the flexibility regarding the scalability of logistics systems and the predictive maintenance of logistics systems as further requirements.

3.4. Outline of the questionnaire

From the workshop results, the requirement analysis of three sub-sections are summarized and used to develop a questionnaire to conduct a field study by using a questionaire in a next stage. The questionnaire was designed based on a Likert 1-4 scale to avoid neutral responses. Level 4 indicates the most important while Level 1 indicates the least important one (Table 1).

Table 1. Outline of questionnaire to validate hypothesis for requirements

First hypothesis of requirements	Level of Importance			
	1	2	3	4
A) Smart and Lean x-to-order Supply Chains				
A1) LEAN AND AGILITY				
(1) The identification and avoidance of material flow breaks throughout the supply chain.				
(2) A production on-demand and delivery of products just in time to the customer.				
(3) A mechanism for self-assembly of data/information flows of smart logistics systems.				
A2) REAL TIME STATUS				
(4) The availability of data in real-time about the status of production, storage and shipping throughout the supply chain (at suppliers and customers)				
A3) DIGITIZATION, CONNECTIVITY and NETWORK				
(5) The digital connection of customers and suppliers to gain the ability to communicate and/or share information, capacity, materials and infrastructure.				
(6) The geographical visualization of transport routes for the analysis of inefficiencies in delivery routes.				
A4) TRACKING, PPC and WMS				
(7) A digitally tracking and locating of products throughout the supply chain.				
(8) Advanced Production Planning and Control (PPC) tools that allow forecasting rapidly demand changes by interacting with internal and external systems for planning, control and logistics.				
(9) Transparency of inventory levels and storage locations as well as an automated stock refill in warehouses.				
A5) CULTURE, PEOPLE and IMPLEMENTATION				
(10) Top Management is aware and supports Industry 4.0 for a successful implementation.				
(11) The qualification and training of employees in software and data collection tools.				
(12) SMEs have knowledge about existing and suitable Industry 4.0 concepts and tools for logistics management.				
B) Intelligent Logistics through ICT and CPS				
B1) DIGITALIZATION				
(13) The visibility of material flow along supply chains from upstream to downstream companies.				
(14) The tools and parts visualization within the supply chain.				
(15) The digitalization of the overall procurement process.				
(16) Limitation of data accessibility to different stakeholders in the supply chain.				
B2) REALTIME STATUS AND TRACKING SYSTEM				
(17) Real time tracking in material shipment status (from supplier to focal company).				
(18) Real time tracking about order production.				
(19) Real time tracking in product shipment (from company to customers).				

(20) Real time tracking on machine maintenance to assist accurate predictive maintenance.				
B3) CONNECTIVITY				
(21) Standardized data interface between supply chain partners.				
(22) Single database system along the supply chain.				
(23) Using mutually designated barcode or RFID systems among suppliers.				
B4) WAREHOUSE MANAGEMENT SYSTEM (WMS)				
(24) Automatic ordering system managed by vendors.				
(25) Product location optimization to support put away and pick up processes.				
(26) Automated distributing parts to points of use.				
(27) Inventory decision support data through WMS.				
B5) LEAN AND EASE OF USE				
(28) Specific work instructions by using ICT along the supply chain.				
(29) Intuitive software for SMEs.				
(30) Digital-Assist-System for SME user.				
B6) SECURITY AND SAFETY				
(31) Internal traffic optimization software to increase safety in workplace.				
(32) Data security and IP Protection in intelligent SME logistics.				
C) Smart and automated Logistics Systems and Vehicles				
C1) AUTOMATION				
(33) Automated storage of material.				
(34) Automation of material flow processes.				
C2) TRANSPORT AND WMS				
(35) Material transport using driverless transport systems.				
C3) LEAN				
(36) Lean strategies for increasing the material efficiency in logistics systems.				
C4) DIGITALIZATION AND CONNECTIVITY				
(37) Automated information flow in logistics systems.				

4. Triangulated validation by using a field study approach

In the first step of the systematic investigation of requirements for smart logistics in SMEs, the research team conducted expert workshops based on a qualitative content analysis. Thereby, the expert statements were systematically recorded, clustered and analyzed based on the pre-defined sub-sections “smart and lean x-to-order supply chains”, “intelligent logistics through ICT and CPS”, “smart and automated logistics systems and vehicles” and “main barriers and difficulties for SMEs”.

In addition to this exploratory-based research approach, the authors propose to conduct a field study for further investigation. In this second step, the field study will be used as confirmative research method to ensure a higher level of external validity, transferability, and generalizability of the preliminary research results (Bortz and Schuster 2010). This mixed method design is supported by a multitude of studies in logistics management (e.g., Soni and Kodali (2012), Golicic and Davis (2012), Boyer and Swink (2008)) and will be used to create fruitful insights for the holistic understanding of the requirements of smart logistics in SMEs. In addition, the causal mechanisms between the requirements and logistics key performance indicators will be investigated by applying structural equation modelling procedures (SEM).

5. Conclusions and outlook

SMEs will only benefit from Industry 4.0 by following customized implementation strategies, approaches, concepts and technological solutions. Otherwise, the current effort for publication and sensitization of Industry 4.0 will not show the expected results. The paper presents an explorative set of hypothesis of requirements for the application of Industry 4.0 concepts in logistics processes based on expert workshops with SMEs. The expert workshops were conducted by the Free University of Bolzano (Italy), the University of Leoben (Austria), the Worcester Polytechnic

Institute (USA) and the Chiang Mai University (Thailand). The hypothesis were elaborated according to three main research directions of the project SME4.0: 1) smart and lean x-to-order supply chains, 2) intelligent logistics through ICT and CPS and 3) smart and automated logistics systems and vehicles for SMEs. From the workshops different elements emerged to be important for the definition of requirements like lean and ease of use, agility, real time status, tracking, connectivity, WMS, automation, transportation, security and safety. The second part of the paper presents the outline of a questionnaire that will be used in a next step to confirmatively validate the set of hypothesis for the requirements of smart logistics by using a large-scale sample. It will be used as explanatory research method to ensure a higher level of external validity, transferability, and generalizability of the preliminary research results. Furthermore, the causal mechanisms between the requirements and logistics key performance indicators will be investigated by applying structural equation modelling procedures (SEM).

Acknowledgements

The project "SME 4.0 – Industry 4.0 for SMEs" has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No. 734713.

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