Impact of Additive Manufacturing on the Strategic Alignment of Business Processes in the Logistics Industry in Europe

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Abstract

The logistics industry in Europe is under constant scrutiny due to the impact of digitalizing business processes and the globalization of competing markets, especially China and the USA. Therefore, the constant optimization of corporate legacy processes and, subsequently, the reduction of logistics costs play a crucial role. The constant development of innovative solutions keeps the technological edge to stay ahead of the global competition. 3D printing technology, or additive manufacturing, represents a possibility for creating innovative complex geometries, which cannot be realized with conventional subtractive manufacturing processes. Furthermore, additive manufacturing contributes to process optimization and lower logistics costs. With the appropriate strategy, the application of additive manufacturing increases customer satisfaction with new opportunities for expansion into leading business areas with higher margins. The research of the paper examines expert statements in two balanced scorecard strategies, which include (1) corresponding key performance indicators for measurement of target achievement, (2) measurement of the realization of the defined targets, and (3) possible customer applications for 3D printing technologies. These suggestions serve as a point of reference for various organizations in the logistics industry. In addition, additive manufacturing coincides with the advances in Industry 4.0 to achieve optimal results. As the industry continues to develop further, the European logistics industry has all prerequisites to prevail in a competitive global market.

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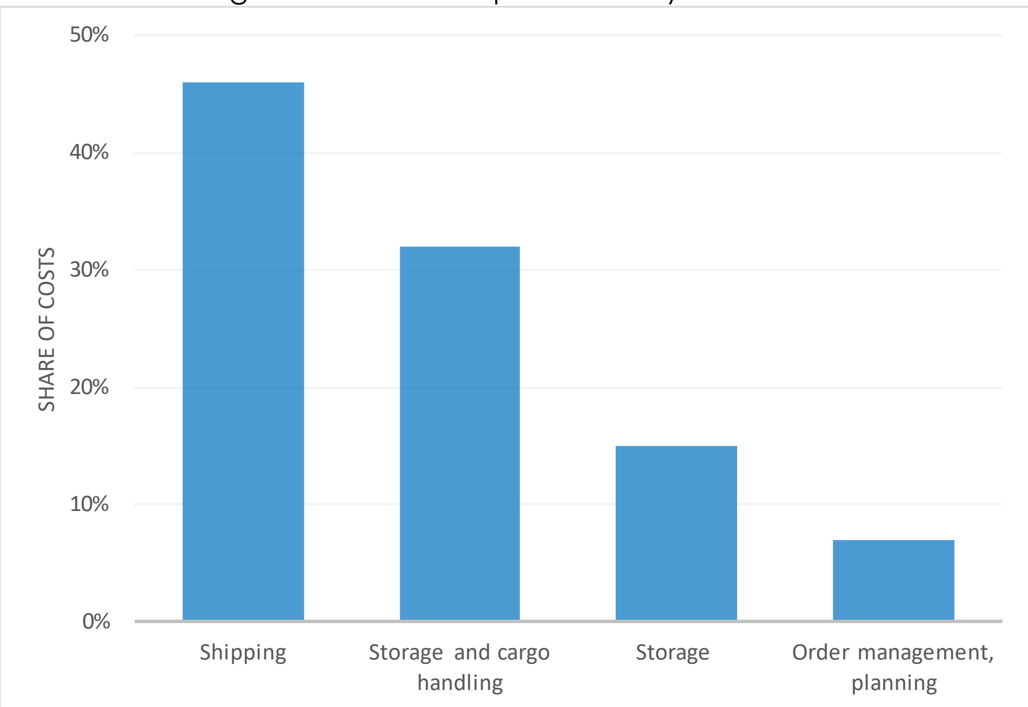
Introduction

The logistics industry in Europe must constantly innovate and adapt its processes to the technologies used by the market to remain competitive. Therefore, the task of the logistics industry is to explore new potential technologies to exploit their benefits for the sake of the industry fully. A high level of experience is required to deploy new technologies to determine the best time for their introduction. Additive manufacturing is a new technology with the potential that can provide many benefits to the logistics industry. Therefore, this topic will be addressed within the scope of this paper.

Globalization has significantly increased the competitive pressure in the market. More and more technologies must be used to simplify workflows and shorten lead times. Every company must deal with capturing price-, economies of scale-, bundling-, time/speed-, and change advantages to achieve a more favourable cost position to survive in the market. The cost pressure increased, and so has the market pressure. Companies must adapt their business processes to these changes due to the great demand for simplified workflows, shorter lead times, and the frequently increasing and demanding customer requirements. Despite all the professional and technical challenges, higher quality is also required in the face of constant cost pressure.

Figure 1
Breakdown of logistics costs in Europe in 2018 by cost center



Source: Fraunhofer SCS - Statista, 2022

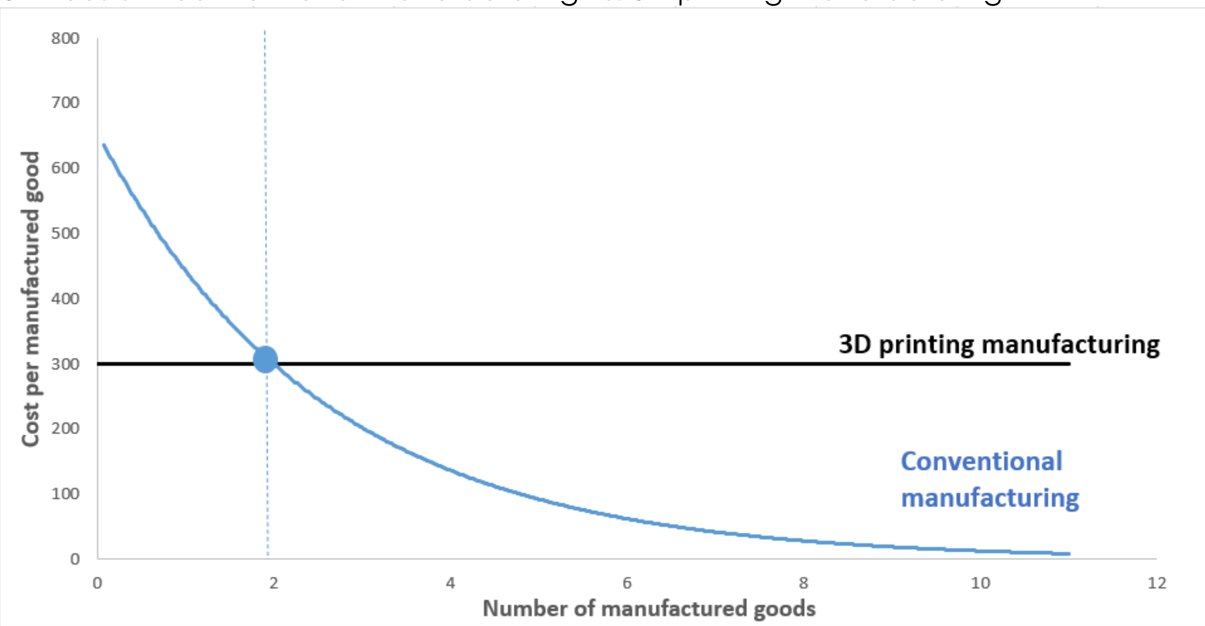
Based on the statistics in Figure 1, transportation accounts for the highest share of logistics costs at 46 percent. Storage and handling generate the second largest expenditure. Therefore, the task of the logistics industry is to reduce transportation and storage costs. One possibility is the use of economies of scale. This involves obtaining volume discounts from the supplier and more favorable transport conditions for larger transport volumes/quantities from the freight forwarder (Pfohl, 2004).

Consequently, higher inventories are created, and warehousing and storage costs increase. Current approaches such as Just-In-Time, Logistics 4.0, and Lean Production also reduce warehousing costs, focusing on optimizing internal workflows but not transport. This means that although transportation costs can be decreased for long-haul distances through technological developments in shipping and air transport (cf. Baumgartner et al., 2008), companies find themselves in a dilemma because the sum of logistics costs cannot be reduced to any great extent. The use of additive manufacturing makes it possible to set limits to this hopeless situation. The reason is the fact that this technology has many advantages, including efficient use of raw materials, good geometric accuracy, reduction of process steps, shortening of lead times, minimization of transportation costs, reduction of storage costs, accurate production time specifications, and individuality. (Gibson et al., 2015)

Explanation of the research topic

So far, additive manufacturing (AM) is mainly used in product development, as the quality of printed products is improving rapidly, and prices are falling dramatically. The evolution of the current frontiers of this technology is critical to determining if and when 3D printing will play a role in mass production and trigger the much-heralded industrial revolution. These current limitations and risks must be taken into business model developments early and are described below (cf. Feldmann et al., 2017). The production of larger series using additive manufacturing takes longer than conventional manufacturing processes. Therefore, this technology is currently not suitable for mass production. The production time for 3D printing is determined by the time it takes to cure each layer until the next layer is applied. This means that the more real the object is, the more passes are required and the longer it will take to produce the component/product/workpiece. Conventional processes are, therefore, better suited to produce larger lot sizes quickly, as they are much faster once the set-up is performed.

Figure 2
Unit costs in conventional manufacturing vs. 3D printing manufacturing



Source: Bitkom e. V., 2017, p. 1

As seen in Figure 2, the unit costs for conventional manufacturing decrease as the number of units increases, while these remain constant for manufacturing with 3D printing. This means that additive manufacturing appears uneconomical at larger lot sizes than conventional manufacturing. Both processes overlap at a point where the cost per manufactured good is the same. Up to this quantity, the use of additive manufacturing makes sense. For mass production, 3D printing technology is currently not suitable from an economic point of view. (cf. Bitkom e. V., 2017, p. 11)

Research objective

Therefore, all the factors - market, costs, and customer requirements - must be considered to ensure high quality and to remain competitive. To achieve a more cost-efficient position in the logistics industry, it is first important to look at the logistics costs, which refer to the regular, operational consumption of resources, valued in monetary units, that results from handling logistics processes and providing the necessary capacities. These include, for example, freight-, fuel-, packaging-, storage- and transportation costs. (Pfohl, 1998) Furthermore, logistics costs can be divided into two categories system and process costs (cf. Muchna et al., 2018):

- System costs: result from the design, planning, and control of logistics structures. This includes, for example, the costs of logistics control.
- Process costs: result from the execution of all logistics processes. These include production factors, capital commitment costs (warehouse and storage costs), packaging costs, transport costs, and control costs for scheduling and order processing.

Research question

The main objective of this scientific research work is to determine the impact of additive manufacturing on the business processes of the logistics industry in Europe. Thereby, possible applications of additive manufacturing along the supply chain are investigated to reduce logistics costs. In addition, the impact of additive manufacturing on the strategic direction of the logistics industry in Europe is illustrated by creating balanced scorecards (BSC) based on statements from logistics and additive manufacturing specialists/experts. For this purpose, correlations between the five perspectives (process, customers, potential, finance, and suppliers) are examined, and a corresponding strategy is derived. To this end, the following research question is formulated as objective: *What is the impact of additive manufacturing on the strategic direction of the logistics industry in Europe?*

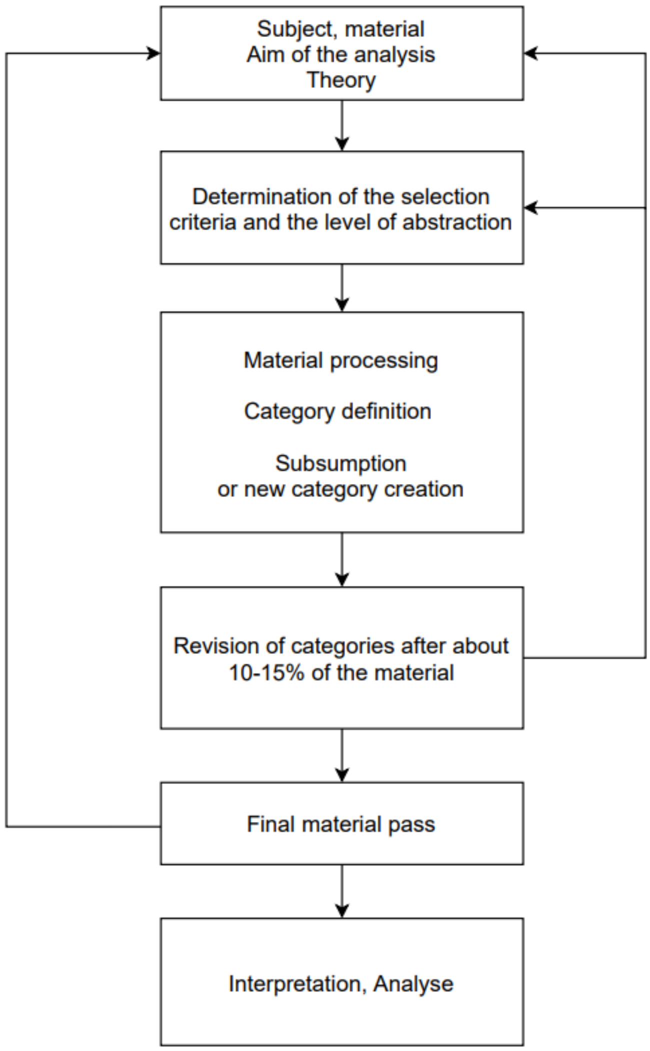
The objectives of this paper do not include a detailed description of the additive manufacturing technology for each process, an explanation of all possible applications of additive manufacturing in the logistics industry, or a description of all existing additive manufacturing processes, but an exploration expressed in the research question.

Methodology

To achieve this objective, the basics of additive manufacturing were first examined thoroughly by literature research to build a fundamental understanding of the topic. Secondly, qualitative interviews were conducted with thirteen experts from the field of additive manufacturing and logistics, which were evaluated using qualitative text analysis according to Mayring (2015), reaching qualitative saturation. The results of the interviews were used to create a balanced scorecard from the perspective of logistics and additive manufacturing. Furthermore, BSCs were made to structure the findings from a logistics point of view. In the scope of this research paper, only the

Balanced Scorecard from the logistics point of view is addressed/shown/illustrated. This is followed by an interpretation and discussion of the results. Figure 3 illustrates the methodology used to answer the research question.

Figure 3
The process model of inductive category formation, according to Mayring



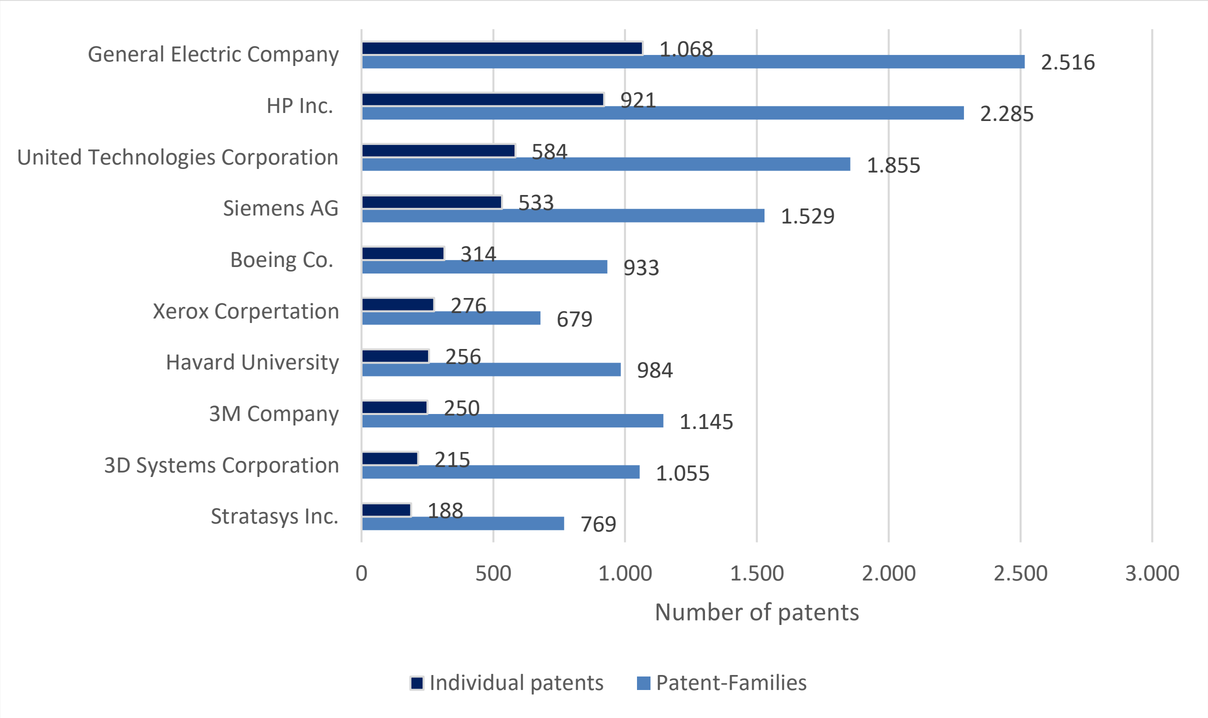
Source: Mayring, 2015, p. 86

Figure 3 demonstrates the process for creating new categories from the studied material, according to Mayring (2015). After defining the main categories and subcategories, the paraphrased text passages are reduced to strategic goals for each category. The summarizing technique, according to Mayring, is applied. After transcribing the interviews, the selected qualitative content analysis technique was used to create the balanced scorecards. The software MAXQDA was used, which facilitated the creation of the category system with the help of color codes to provide a better overview.

Results

The thoroughly conducted literature review unveiled that according to a study published by the European Patent Office in 2020, the rate of increase in 3D patent applications in Austria between 2014 and 2017 was found to be 1,300%. Between 2015 and 2018, the average annual rate of AM applications grew by 36%, which is ten times faster than the average for all other patent applications (3.5%) over the same period. Basic AM research at Austrian universities is increasingly contributing to this success. Europe is responsible for 47% of AM patent applications, overtaking the U.S., which accounts for 35 %. Applicants include individuals, companies of various sizes and industries, and universities with various research interests. (cf. Korner, 2020)

Figure 4
Companies with the most 3D printing patents worldwide



Source: Statista Research Department, 2019

Figure 4 shows the companies with the most patents in 3D printing worldwide in 2019. Based on these statistics, Siemens AG, as the first European company, already had 1,529 individual patents in 3D printing in 2019, according to a study conducted by Statista Research Department (2019).

Using Mayring's qualitative content analysis, the balanced scorecard from the logistics point of view was developed. The interview material elaborated on the vision of Realizing every product idea through innovation and cutting-edge technologies. For this purpose, the strategies 'Expanding business areas with an opportunity-oriented approach' and 'Expanding customer satisfaction' were identified using appropriate techniques, according to Mayring. For each literature-related perspective, the strategic objectives were summarized from the material according to the strategy. In addition, possible key performance indicators (KPIs), metrics, and measures to achieve the strategic objectives were added to the balanced scorecard.

Table 1
Financial perspective from the point of view of logistics experts

Perspective	Vision	Strategy	Strategic objectives	Possible key performance indicator (KPI)	Possible measured variable	Possible action
FINANCES	Realization of any product idea through innovation and the use of cutting-edge technologies	Expansion of business segments with an opportunity-oriented approach	Increase sales	Cashflow	P&L + revenues - expenses	Reduction of logistics costs by using 3D printing
Company success				sales	Sales / Customer / Year	Development of a marketing measurement strategy for the acquisition of new customers
				Return on sales	P&L / Sales	Defining higher sales prices for 3D-printed products
			Reduce logistics costs in development and spare parts procurement	All logistics relevant costs	Percentage of logistics costs in the total costs of the company	Acceleration of development time due to the use of 3D printing
						Production of spare parts using 3D printing
			Reduce manpower costs in development and spare parts procurement	Number of employees	Number of employees per department	Reduction of manpower costs in the administrative area of spare parts procurement due to the use of 3D printing
						Reduce the number of employees and staff in spare parts warehousing through the use of 3D printing
		Expand customer satisfaction	Plan expansion investment	Return on assets	Profit / Equity capital	Increase efficiency by creating an investment plan for new equipment, infrastructure and manpower for the use of 3D printing technology
						Development of a trial plan for the use of 3D printing technology to improve market position
				Error cost prevention	Failure costs / customer	Accelerate development by using 3D printing to rapidly create prototypes and avoid potential failure costs
						Meticulous evaluation of the feedback surveys

Source: Own presentation

Table 1 depicts the financial perspective from the viewpoint of the logistics experts. The vision relates to a two-dimensional strategy with clearly stated strategic objectives, corresponding key performance indicators, measured variables, and eleven possible actions recommended to meet the strategic objectives, respectively, the vision.

Table 2
Customer perspective from the point of view of logistics experts

Perspective	Vision	Strategy	Strategic objectives	Possible key performance indicator (KPI)	Possible measured variable	Possible action
CUSTOMERS	Realization of any product idea through innovation and the use of cutting-edge technologies	Expansion of business segments with an opportunity-oriented approach	Acquisition of new customers	New customer acquisition	New customer ratio	Targeted marketing of 3D printing technology and increasing risk awareness among customers
Fulfillment of customer requirements			Strengthen customer loyalty	Customer loyalty	Percentage of purchase volume from repeat customers	Informing customers about the benefits of 3D printing technology and the opportunities to identify risks at an early stage of development and the resulting cost savings throughout the product lifecycle
				Customer retention rate	((existing customers at the end - new customers) / existing customers at the beginning) *100	Planning and implementation of further measures to increase customer loyalty, e.g. improvement of services and communication
		Expand customer satisfaction	Flexible response to individual customer requirements using 3D printing	Customer satisfaction	Customer satisfaction index	Customer survey regarding their expectations
			Rapid response to change requests	Satisfaction with customer service	Percentage of recommendations	Customer survey

Source: Own presentation

Table 2 depicts the customer perspective from the viewpoint of the logistics experts. The vision relates to a two-dimensional strategy with clearly stated strategic objectives, corresponding key performance indicators, the measured variables, and five possible actions recommended to meet the strategic objectives, respectively, the vision.

Table 3
Supplier perspective from the point of view of logistics experts

Perspective	Vision	Strategy	Strategic objectives	Possible key performance indicator (KPI)	Possible measured variable	Possible action
SUPPLIERS	**Realization of any product idea through innovation and the use of cutting-edge technologies**	**Expansion of business segments with an opportunity-oriented approach**	Reduce supplier dependency	Number of suppliers	Number of suppliers / quarter	Manufacturing of components by using 3D printing in own company
Cooperation with suppliers		**Expand customer satisfaction**	Intensify exchange of information	Number of common data	Frequency and number of records exchanged / quarter	Optimization of interfaces and standardization of master data
						Improve collaboration with suppliers through mutual exchange of know-how and definition of common goals for projects
				Number of common systems	Number of integrated partner systems	Integration of partner systems
			Increase supplier confidence and satisfaction	Delivery reliability	Number of orders delivered on time	Establishing and maintaining a relationship of trust with suppliers
						Contractual agreement of penalties for delayed deliveries and incentives for early deliveries
						Reduction of delivery times due to short development time and early transmission of designs to the supplier for calculation and set-up of the production process
					Number of orders delivered in the right quality	Contractual agreement of the missing legal aspects for the regulation of liability issues
				Supplier satisfaction	Indices for satisfaction	Supplier survey

Source: Own presentation

Table 3 depicts the supplier perspective from the viewpoint of the logistics experts. The vision relates to a two-dimensional strategy with clearly stated strategic objectives, corresponding key performance indicators, the measured variables, and nine possible actions recommended to meet the strategic objectives, respectively, the vision.

Table 4
Potential perspective from the point of view of logistics experts

Perspective	Vision	Strategy	Strategic objectives	Possible key performance indicator (KPI)	Possible measured variable	Possible action
POTENTIAL	**Realization of any product idea through innovation and the use of cutting-edge technologies**	**Expansion of business segments with an opportunity-oriented approach**	Increas employee motivation	Employee satisfaction	Satisfaction assessment by employee surveys	Increasing the motivation of employees through quick realization of ideas and feasibility of the created products
Learning and development perspective						Survey of employees
				Employee loyalty	Quit rate per year	Revision of the recruitment process
					Willingness to work unpaid overtime	Improvement of the work atmosphere in the company
		Expand customer satisfaction	Increase employee productivity	Continuous improvement	Rate of improvement proposals per employee	Encouraging employees to develop their skills so that they can implement new technology and help shape new trends
				Vision knowledge	Number of employees who are aware of the company's vision / Number of employees in the company	Internal communication of the corporate vision
				advanced training	Advanced training rate per employee	Provide internal and external training for employees in the area of 3D printing technology

Source: Own presentation

Table 4 depicts the business-potential perspective from the viewpoint of the logistics experts. The vision relates to a two-dimensional strategy with clearly stated strategic objectives, corresponding key performance indicators, the measured variables, and seven possible actions recommended to meet the strategic objectives, respectively, the vision.

Table 5
Process perspective from the point of view of logistics experts

Perspective	Vision	Strategy	Strategic objectives	Possible key performance indicator (KPI)	Possible measured variable	Possible action
PROCESSES	Realization of any product idea through innovation and the use of cutting-edge technologies	Expansion of business segments with an opportunity-oriented approach	Optimize procurement process	Procurement costs	Procurement costs per quarter	Simplify procurement process in spare parts procurement and product sampling
Quality and performance of the processes				Process costs in the administrative area	Number of suppliers per quarter	Reduction in the number of suppliers due to the use of 3D printing
			Relocation of production back to Europe	Reshoring	Production costs	Shifting production on premises by using 3D printing technology
			Optimize production process	Product portfolio	Number of new products / year	Manufacturing of new and complex products using 3D printing technology
				Effectiveness	Achieved process goal / defined process goal	Recruitment of experts and professionals in the area of 3D printing with an understanding of the company's strategy
						Increasing the risk awareness of employees through internal trainings
				Efficiency	Output / Input	Avoid waste
						Reduction of resource consumption due to the use of 3D printing
			Reduce waste	Process waste	Waste ratio per process	Use of 3D printing to reduce process waste
		Expand customer satisfaction	Produce complex and individual products	Customer requirements	Implementation level of identified customer requirements	Fulfillment of individual customer requirements through the use of 3D printing technology, considering its limitations
						Campaign planning for customer management
			Reduce process lead time	Process lead time	Lead time in days from order placement to delivery	Reduction of preparation time (retooling) through the use of 3D printing
						Shortening the development time through the use of 3D printing
				Failure rate	Defects per 100 products	Recruitment of experts and professionals in the area of 3D printing
					Percentage of valid drawings	Recruitment of design experts for the creation of 3D designs
						Outsourcing of 3D design creation

Source: Own presentation

Table 5 depicts the business-process perspective from the viewpoint of the logistics experts. The vision relates to a two-dimensional strategy with clearly stated strategic objectives, corresponding key performance indicators, the measured variables, and 16 possible actions recommended to meet the strategic objectives, respectively, the vision.

As shown in Tables 1 to 5, the logistics experts believe that the logistics industry sees an opportunity in 3D printing technology and should regard the resulting costs as secondary. This is the only way to exploit the benefits of this technology fully. In the long term, its use will pay off later through the optimization of processes, the reduction of logistics costs, customer satisfaction, and the acquisition of new customers combined with an increase in market share.

Discussion

Based on the balanced scorecard results, the experts surveyed merely the benefits and opportunities of 3D printing technology with examples of potential applications along the supply chain from their experience. They are also aware of the possible risks, but they believe that any new technology involves certain risks and that these must be accepted to take full advantage of the opportunities offered by the technology and achieve a better position on the market. Likewise, they believe that investments must be made to create the necessary framework conditions for introducing 3D printing technology so that it can be successfully established within the company. They are also keen to clarify that the design is the main competence of this technology and should therefore be the focus. They also state that in addition to the production process, the procurement, distribution, and quality assurance processes must also be taken into account to deliver the appropriate quality. This means that the technology is technically advanced, but investments must be made to create the necessary conditions. In each case, it is necessary to consider what the company wants to achieve with additive manufacturing and develop its strategy for this purpose, as each company has different goals. Thus, if the company's goal is to 'optimize business areas', this technology can certainly be used for this purpose, regardless of whether the company takes full advantage. Therefore, it is first necessary to analyze what added value the logistics industry intends to derive from this technology and in which areas it should be used to achieve the set goals. The balanced scorecard created based on expert testimony shows that using additive processes creates new opportunities to meet ever-increasing customer requirements while considering technological restrictions. The balanced scorecard is merely a rough guide to illustrate the possible strategies that can be implemented using 3D printing technology. Considering the various perspectives can elicit ideas for one's strategies and objectives. 3D printing technology can also be combined with widespread technologies, such as Logistics 4.0. This involves physical mapping processes in digital models that constantly interact with each other.

In this way, the entire infrastructure is networked centrally. As a result, the individual system components can also communicate directly with each other, detect problems, and rectify them independently. In addition, data can be collected automatically, enabling real-time response. (cf. Benimetskaia, 2018) Finally, it should be mentioned that digitalization plays an important role in the market, so it is advisable to consider introducing additive processes to improve one's market position in terms of future competitiveness. This is because 3D printing technology is widespread outside Europe, especially in America and China, and globalization will significantly intensify competitive pressure in the market.

Conclusion

The logistics industry is under constant competitive pressure due to globalization and must constantly develop and optimize its business areas to maintain and improve its market position. Digitization and innovation, therefore, play a decisive role in the sustainable success of companies. Additive manufacturing represents one approach to driving digitization forward. It also enables the production of complex geometries that cannot be realized using conventional processes. The logistics industry can use these processes to open up new markets, increase customer satisfaction, attract new clientele and improve their margins, thus positioning themselves better on the market. Therefore, before adopting this technology, it is important to consider what it is intended to achieve and in what areas it will be used to achieve the desired goals. 3D printing technology has many advantages that can be fully exploited if implemented appropriately. However, investments must be made to create the necessary framework to establish this technology effectively. As with any other technology, certain risks associated with additive processes must be accepted to take advantage of its opportunities. In addition, 3D printing technology can optimize business areas and reduce logistics costs, especially in prototyping, spare parts storage, and production. It reduces storage and transportation costs, administration costs in procurement, material costs in production, and disposal costs. Additive processes can lead to the development of new customer orders and, thus, to improved margins. They can also simplify the production process by reducing the number of process steps and enabling individual parts to be combined to form assemblies. They help minimize waste and thus relieve the burden on disposal logistics.

Furthermore, they significantly shorten development time and enable comprehensive testing of prototypes, as changes can be made easily and quickly. As a result, costs for troubleshooting can be avoided, and recalls can be prevented.

This technology thus significantly contributes to reducing logistics costs and enables new business areas to be opened thanks to the freedom of design and the possibility of producing complex geometries. In further research, the necessary investments can be calculated in individual cases based on mathematical models to determine the economic viability of using this technology.

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