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Innovation Management in Manufacturing - A Study on Industrial Application, Deficits and Opportunities

Quirin Gärtner¹, Xuezhou Zhang¹, Fabian Sippel¹

¹*Institute for Machine Tools and Industrial Management, Technical University of Munich, Garching near Munich, Germany*

Abstract

Manufacturing companies are constantly pressured to innovate in an increasingly complex and discontinuous environment. In addition to developing new products and product features, innovation management in manufacturing has become necessary to ensure the competitiveness of technologies and processes in the context of digitalization, human centricity, sustainability and resilience (Industry 5.0). In the study, presented in this paper, companies from various industries participated in an online survey on their approach to incremental and radical innovation in manufacturing and the associated innovation management. In the study, more than 50 participants provide insight into the innovation management of their manufacturing unit and identify specific fields of action as well as challenges in the areas of technology, organization and people. The study results are intended to provide manufacturing innovation managers with an overview of the challenges, deficits and potentials of innovation management in manufacturing and to help them identify and describe challenges in their organization.

Keywords

Manufacturing; Production; Innovation Management; Radical Innovation; Industry 5.0

1. Introduction

In today's dynamic business environment, innovation is critical to the success of manufacturing companies [1]. With the technological advances and the global competition, organizations must constantly seek to innovate and maintain a competitive edge [2]. Innovation, which encompasses the development of new products, processes and business models, has become an essential catalyst to gain competitive advantages, expand into new markets and achieve sustainable growth [3]. In addition to the development and introduction of new products, the competitive, flexible and sustainable manufacture of these products is increasingly important. The manufacturing industry, known to produce tangible goods, has significantly changed recently [4]. Traditional manufacturing practices have focused primarily on efficiency, cost reduction and scale. However, today's landscape demands a shift towards innovation-driven strategies [5]. To maintain the competitiveness of production sites in high-wage countries, it is essential to develop, implement and exploit innovations to gain a technological advantage and secure the prosperity of society. Adopting advanced manufacturing technologies, such as artificial intelligence and the internet of things, can revolutionize manufacturing, enabling greater flexibility, customization and efficiency [6,7]. Despite recognizing the importance of innovation in manufacturing, several challenges remain to be addressed. This study aims to identify these deficits and explore their underlying causes, providing insights into the industry's barriers to effective innovation management. In addition, this study highlights the opportunities to improve innovation management practices. By examining these opportunities, the paper provides practical recommendations and strategies for organizations to effectively leverage innovation management in manufacturing.

2. Study

2.1 Aim of the study

This study aims to identify the current diffusion, operational use, challenges and opportunities of manufacturing innovation management in the industry. To this end, an online survey was created, asking companies on their approach, challenges and the starting points for the further improvement of innovation management in manufacturing.

2.2 Study design and participants

2.2.1 Study design

The study was designed according to the established guidelines and methods of empirical social research [8]. To reach a large number of experts at relatively low costs and to obtain data quickly, the study was conducted as an online survey using Qualtrics. When designing the survey, special attention was paid to reducing response bias by excluding contradictory statements, having few questions with Likert scales and always providing the opportunity to include additional answers. The survey was divided into three parts. First, general information about the participant and his company was collected. Second, general information about the application and the influencing factors of manufacturing innovation management were derived and relevant terms were defined. Third, specific information on challenges and potentials in manufacturing innovation management from the participants' companies was asked for.

2.2.2 Study participants

The data collection for the study took place over three months, with the online survey being completed in December 2022. Company representatives from the extended industrial network of the Institute for Machine Tools and Industrial Management at the Technical University of Munich were surveyed. The aim was to obtain a representative cross-section of the European industrial landscape, but also to include non-European companies. More than 70 experts in the field of manufacturing innovation management were contacted by email and provided with a link for participation.

A total of 55 responded to the online survey and returned the questionnaire. As shown in Figure 1 (a), 59% of the participants consider their role to be in a planning position (e.g., project manager or managing director) and 41% in an operational position (e.g., technical specialist or team leader). In addition to automotive engineering (39%), consulting (17%) and plant and mechanical engineering (14%), representatives of the electronics industry (8%), metalworking (8%), aerospace (4%), energy supply (4%), medicine (4%) and agricultural engineering (2%) could also be interviewed (see Figure 1 (b)).

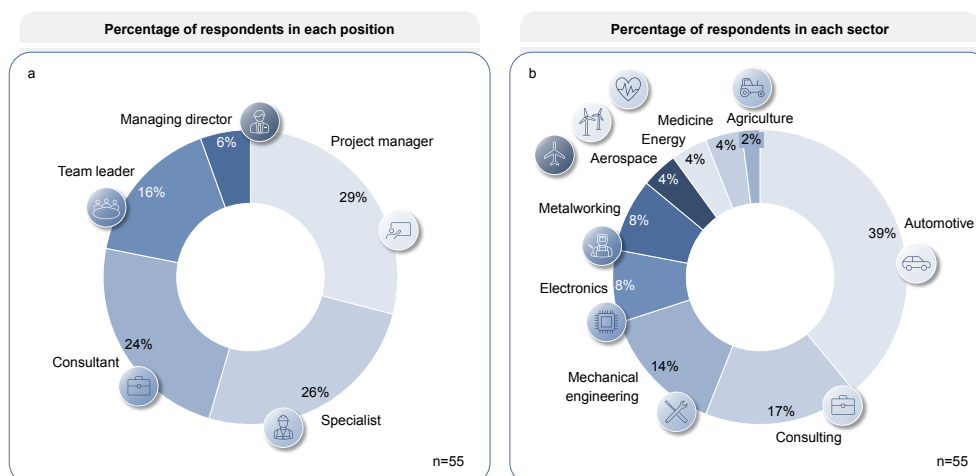


Figure 1: (a) Positions of the study participants; (b) sectors of the study participants

The surveyed experts indicated that their companies operate production facilities in Europe (28%), Asia (26%), North America (18%), Central and South America (15%), as well as Africa (8%) and Oceania (3%) (see Figure 2 (a)). As shown in Figure 2 (b), 40% of the experts represent large companies, 35% medium-sized companies and 25% small and micro companies. In addition, 27% of respondents have more than ten years of professional experience, 37% have between 3 and 10 years, and 36% have less than three years of experience (see Figure 2 (c)).

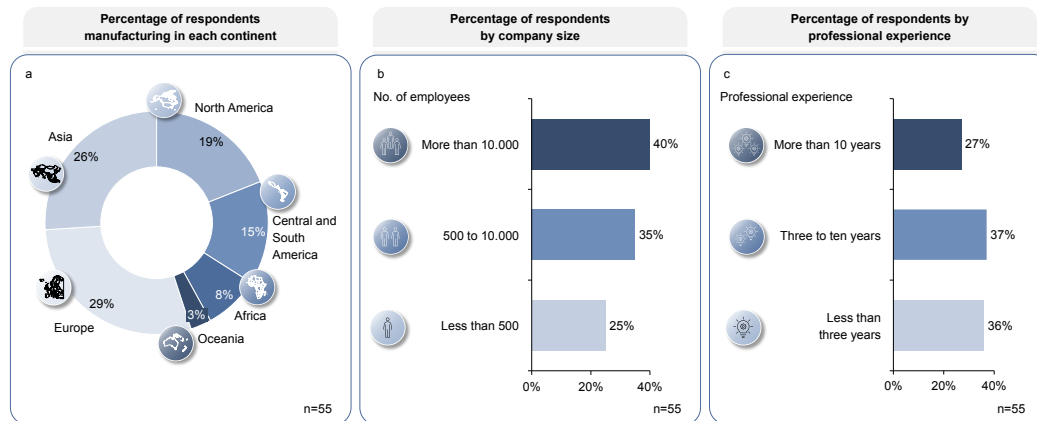


Figure 2: (a) Location of respondents' production sites; (b) Percentage of respondents by company size; (c) Percentage of respondents by professional experience

3. Innovation management in manufacturing

3.1 Terms and definitions

Manufacturing transforms inputs, such as raw materials and resources, into finished goods or services [9]. It involves a series of interrelated activities, which can be divided into value-adding activities, like the production of raw parts and assembly, and non-value-adding activities, like planning, logistics and quality management [10].

Innovation is defined as the generation and successful implementation of new ideas in processes or products that lead to improvements in efficiency, quality or functionality [11]. According to [12], innovation in the context of manufacturing can be defined as the recombination of forces and objects to either produce differently or something different. There are two critical factors in determining an innovation. First, there must be an invention aimed at improving a process. Second, this invention must be followed by a successful implementation in a manufacturing system [13].

Innovations are differentiated in various ways in the literature and different dimensions are repeatedly addressed [14,15]. Concerning the research topic of this study, it is necessary to explain the distinction between incremental and radical innovation. According to [16], a gradual differentiation of innovations can be translated into dichotomies. The most common dichotomy in the literature is the distinction between incremental and radical innovation. Incremental innovation in manufacturing refers to improvements with a high affinity to the existing process [17], unlocking its underlying potential through comparatively minor changes [18], like the accuracy of a laser cutting process. In contrast, radical innovation describes a leap or fundamental change that leads to a breakthrough toward a new technological process (component), environment or organization [19,20], like the introduction of additive manufacturing technologies.

From a process perspective, innovation management involves the identification, idea generation and evaluation, development, integration, adoption and diffusion [21,22] of novel concepts within an organization, leading to improved performance and market advantage. Internal and external stimuli are used to discover innovation needs and opportunities during the identification process. The subsequent generation

and evaluation of ideas generate possible solutions and select the most promising ones. Thereafter, the chosen solution is developed until it is suitable for serial production. The implementation and the use of the new solution in the existing or new manufacturing system follow the development. In the final diffusion, the results of the previous stages are fed back into the organization and used for further use cases [21].

Integrating innovation into manufacturing gives rise to the concept of manufacturing innovation management. Effective manufacturing innovation management enables organizations to respond to market changes proactively, capitalize on emerging technologies and continuously improve their products and value-adding processes, ultimately leading to sustainable growth and competitive advantage in quality, cost and time [23]. It involves the use of methods for the systematic planning, coordination and control of innovation processes, including the process activities mentioned above [23].

3.2 Industrial application of manufacturing innovation management

To successfully compete in the market, manufacturing companies have several options. In theory, four basic strategies can be distinguished [24,25]. The differentiation strategy aims to differentiate from competitors by offering unique product quality or functionality. The cost leadership strategy seeks to differentiate itself from competitors by offering a product at a lower price. The niche strategy aims to satisfy the specific needs of a particular customer group through specific product qualities or functionalities to gain market share. Finally, the hybrid strategy includes all combinations of the first three competitive strategies.

The respondents were asked to classify the innovation strategy of their manufacturing unit, which follows the company's competitive strategy. It became clear that most manufacturing units pursue quality differentiation (41%) and a hybrid strategy (28%). The competitive strategies of cost leadership (20%) and niche strategy (11%) are followed by only a small proportion of manufacturing units (see Figure 3 (a)).

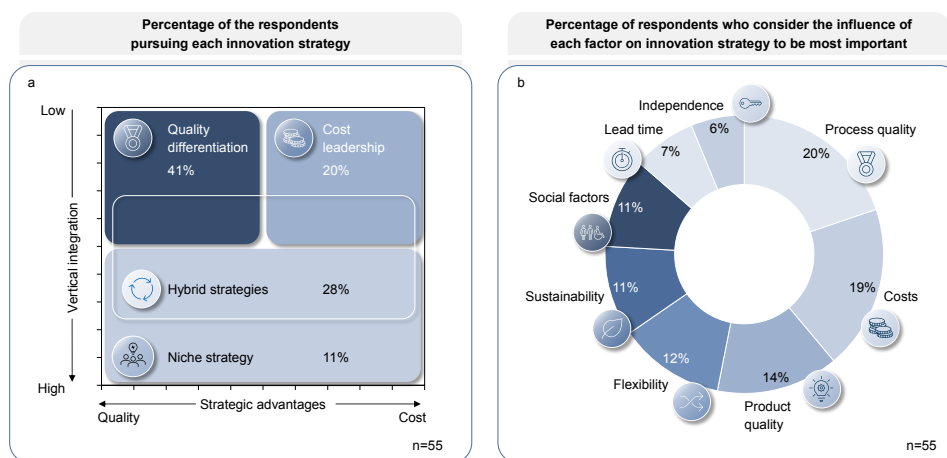


Figure 3: (a) Percentage of the respondents pursuing each innovation strategy; (b) influence factors for the manufacturing innovation strategy

Manufacturing companies strive to continuously align their performance indicators with their competitive strategy through the processes and methods of manufacturing innovation management. Production costs, process and product quality and lead time within the manufacturing process are strongly emphasized to measure this process. These four main objectives are complemented by new strategic orientations in modern manufacturing units, such as flexibility, sustainability, independence or social factors such as employee satisfaction and health. As shown in Figure 3 (b), respondents ranked the influence of these objectives on their manufacturing innovation management according to their perceived importance. It was found that process quality (20%), production costs (19%) and product quality (14%) remain the most critical influencing factors. However, it also became clear that objectives such as flexibility (12%), sustainability (11%) and social factors (11%) are having an impact on the innovation strategy of manufacturing. Lead time (7%) and independence (6%) were rated to have the least influence on the innovation strategy.

Manufacturing companies face external challenges forcing them to rethink their manufacturing operations, including processes, working methods, technologies and organizational structures. Respondents highlighted rising costs (16%), digitalization and artificial intelligence (16%), sustainability (16%), skills shortages (14%) and unstable supply chains (14%) as the most critical challenges to their competitive position. By contrast, demographic change (8%), cyber security (7%), individualization (5%) and the shift in global economic power (4%) are currently of secondary importance to the companies surveyed (see Figure 4 (a)).

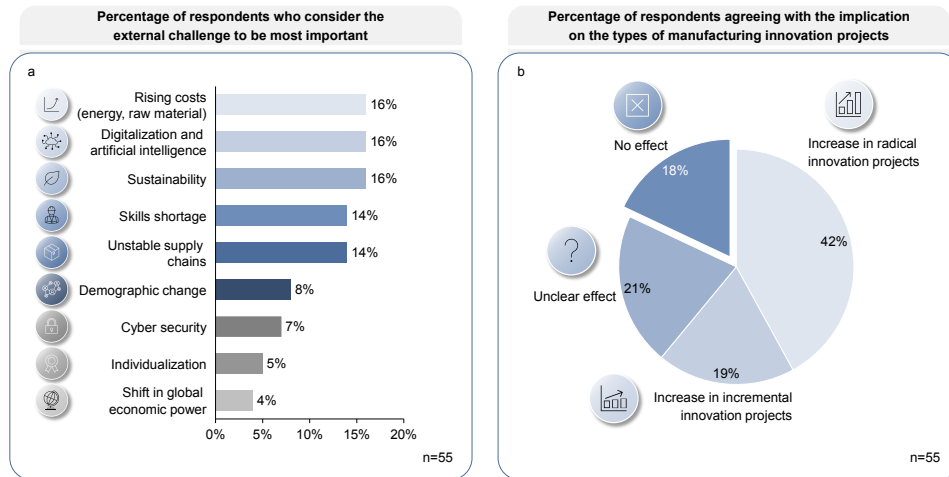


Figure 4: (a) External challenges for manufacturing; (b) implications for manufacturing innovation projects

According to respondents, these external influences affect manufacturing companies' innovation strategy and the types of innovation projects (82%). As Figure 4 (b) shows, most respondents (42%) state that the proportion of radical innovation projects has increased. In contrast, 19% of respondents see an increase in incremental innovation projects or an unclear effect (21%). This suggests that the challenges ahead are so significant that manufacturing units need to address them through radical innovation projects.

3.3 Challenges and deficits of manufacturing innovation management

However, when carrying out innovation projects in manufacturing unplanned complexity is created by challenges. As shown in Figure 5 (a), respondents state that the execution of radical innovation projects is rather complex, while the complexity of incremental innovation projects is rated to be rather moderate.

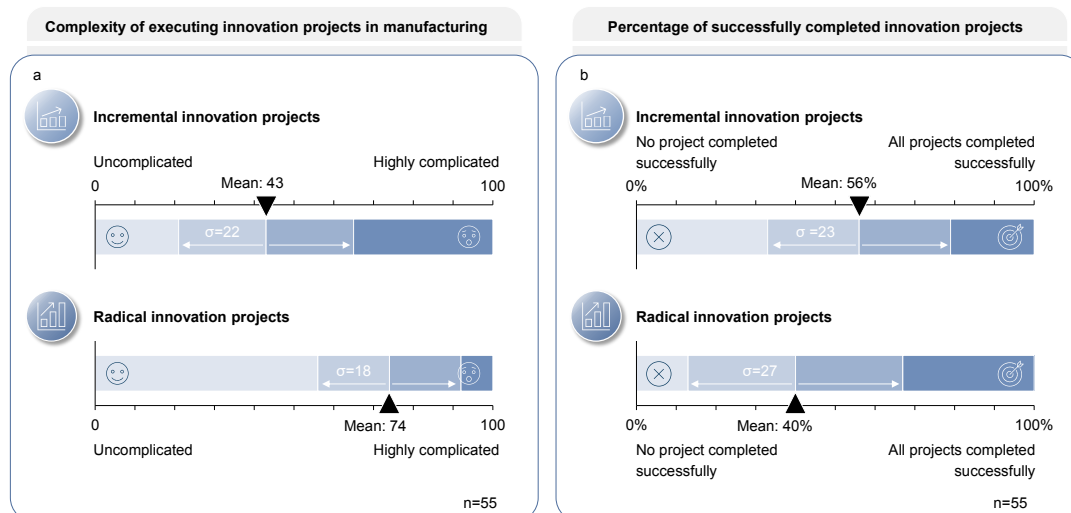


Figure 5: (a) Complexity of innovation projects; (b) Percentage of successfully completed innovation projects

The complexity of radical manufacturing innovation projects becomes even more apparent when comparing the two types of projects (radical and incremental) regarding the percentage of successfully completed

projects. Figure 5 (b) shows that, respondents indicate that only 40% of initiated radical manufacturing innovation projects are completed. For incremental innovation projects, this proportion is 56%.

Subsequently, the participants were asked at which stage of the innovation process the challenges occurred most frequently and in which area the challenge originated. The challenge areas were based on [26], dividing the elements of a manufacturing unit into the main categories of technology, organization and people. Participants were then asked to choose which of these three areas presented the most challenges.

Figure 6 shows that, the development (22.5%) and integration (36.3%) phases are where most of the challenges in the manufacturing innovation process occur. The phases of idea generation, evaluation and selection (12.7%) and exploitation (16.7%) are the second most challenging. Demand identification (5.9%) and dissemination (5.9%) are considered by the participants to be relatively unproblematic.

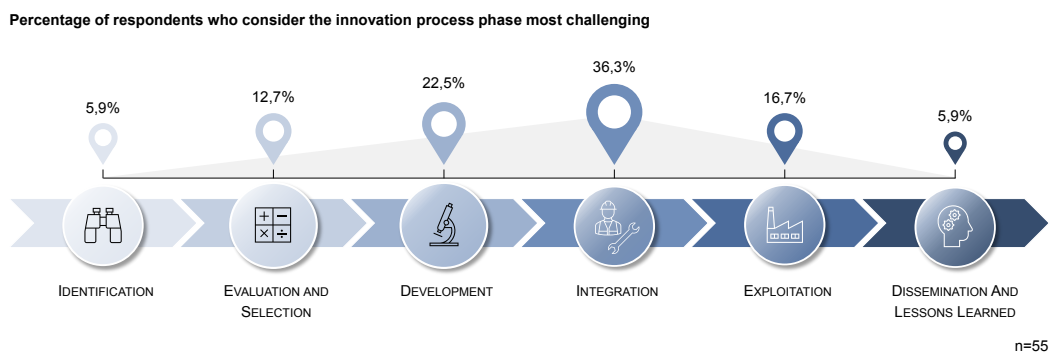


Figure 6: Occurrence of challenges in the manufacturing innovation process

Looking at the areas where challenges arise, it became surprisingly clear that there was not one area where problems occurred most frequently (see Figure 7). The areas of technology (35%), organization (32.5%) and people (32.5%) were rated equally by participants when asked about the causes of challenges.

The study then sought to gain a deeper understanding of the specific challenges in each area. In the area of technology, three key challenges were highlighted by respondents. Firstly, in the context of technological innovation management in manufacturing, challenges are seen in providing appropriate resources for technology development (e.g., facilities, environments, software) as these are often unavailable or difficult to obtain. Secondly, the lack of technological knowledge in the organization to implement technology projects in a targeted and successful way was emphasized. Thirdly, it was stressed that implementation often fails because the integration into the existing manufacturing system is too complex or the technical equipment is insufficient (e.g., IT system, infrastructure).

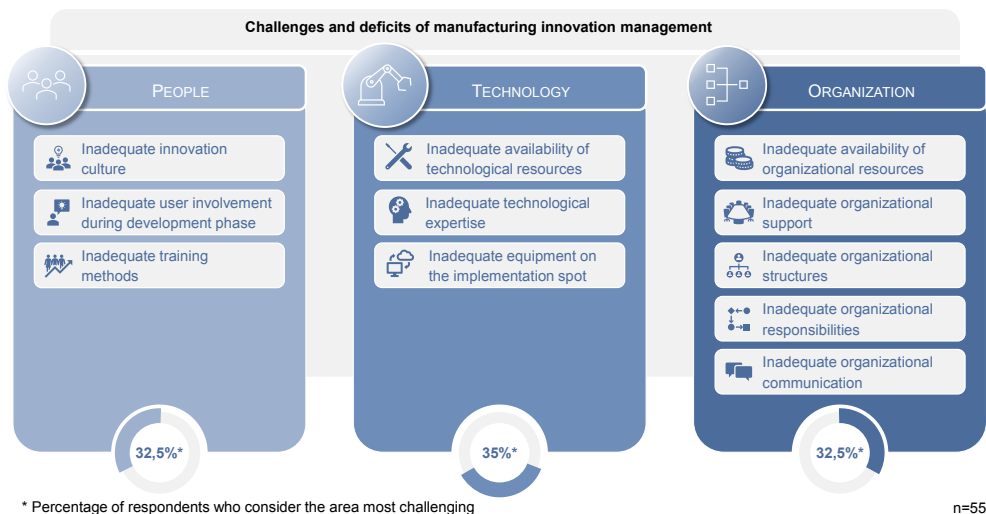


Figure 7: Challenges in manufacturing innovation management

In the area of organization, participants identified five root causes of organizational challenges in manufacturing innovation management. Firstly, a lack of organizational resources (e.g., time and people) was emphasized. Secondly, a lack of organizational support from management or the innovation culture and philosophy of the organization was identified by the participants. Thirdly, inappropriate organizational structures (e.g., hierarchical project structures) were emphasized. Fourthly, unclear managerial responsibilities (e.g., decision rights and process structures) were highlighted. Fifthly, insufficient internal scaling due to a lack of dissemination (communication) or organizational strategy was mentioned.

In the area of people, three critical challenges for innovation management in manufacturing were identified. Firstly, a lack of acceptance of new solutions and willingness to change was emphasized by the participants. Secondly, a lack of user involvement during the innovation development to enable ergonomic application in manufacturing was highlighted. Thirdly, a lack of solutions and methods to familiarize users with new technologies or processes in a targeted, application-oriented and economical way was stated.

3.4 Opportunities for manufacturing innovation management

In addition, the participants were asked about their ideas and opportunities for innovation management in manufacturing. Since most participants stated that the proportion of radical innovation projects in manufacturing is increasing, the opportunities also relate to the implementation of radical projects.

Surprisingly, only under half of the respondents indicated that a distinction is made between incremental and radical innovation projects in their manufacturing unit. However, the vast majority of respondents (91%) indicated that the planning and implementation of radical innovation projects in manufacturing should be handled different from that of incremental innovation projects. Based on the responses, several potential areas for innovation management in manufacturing could be identified (see Figure 8).

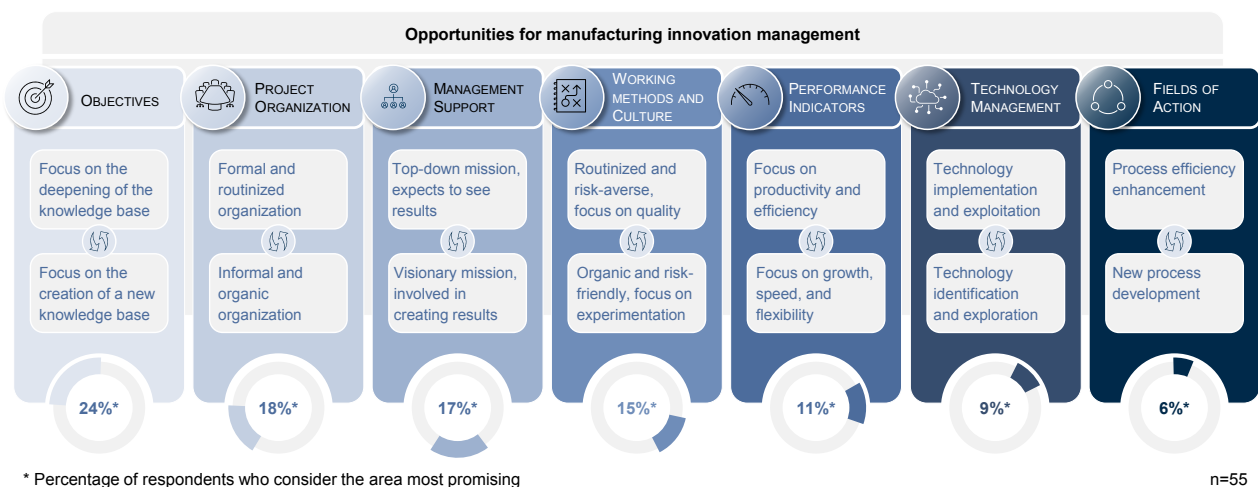


Figure 8: Opportunities for manufacturing innovation management

Differentiation in project objectives (24%) was the most frequently mentioned potential. The objectives of radical innovation projects should focus on creating new knowledge and not on deepening knowledge to reach objectives like quality, costs and lead time in the short run. Secondly, project organization (18%) was seen as another significant potential in differentiation. In line with the challenges identified, respondents highlighted a need for informal and organic organizational structures and process organizations in radical innovation projects in manufacturing. The third potential area concerns the type of management support (17%). According to the respondents, radical innovation projects in manufacturing require a visionary and supportive management to be successfully implemented. The fourth potential area relates to working methods and culture (15%). Respondents emphasize new methods and a risk-friendly culture to implement radical innovation projects in manufacturing. Fifth, the respondents state that measuring the performance of radical innovation projects requires indicators related to growth and speed rather than productivity and

efficiency. Concluding, the least potential is seen in technology management (9%) and general fields of action (6%) of innovation projects in manufacturing to differentiate. According to the respondents, the technology management activities for incremental and radical innovation projects can be identical. The same applies to the relevant fields of action.

4. Summary and outlook

In summary, this contribution explores the concept of innovation management in manufacturing, examines its industrial application, identifies shortcomings and uncovers opportunities. Contributing to the existing body of knowledge on innovation management, it provides valuable insights for manufacturing companies navigating the complexities of the modern innovation management.

This study shows that the differentiation through quality and cost remains the most critical innovation strategy in manufacturing. However, it also shows that flexibility, sustainability and social factors increasingly influence these innovation strategies. It became clear that external challenges, like rising material and energy costs, digitalization and artificial intelligence or sustainability, are significantly impacting the innovation activities of manufacturing companies. Further, it was found that these external challenges strongly influence the type of innovation activity, leading to an extreme increase in radical innovation projects in manufacturing. The challenge, however, is that implementing radical innovation projects in manufacturing is almost twice as complex as implementing incremental innovation projects. This complexity occurs mainly during the phases of development and integration. However, it is surprising that the challenges are evenly distributed across the areas of technology, people and organization. On the other hand, opportunities and potentials for innovation management in manufacturing were identified. The study showed that the most significant potential and opportunities lie in defining the objectives, informal project organization, visionary management support, appropriate working methods and suitable performance indicators to enable knowledge generation and short-cycle innovation development.

Looking forward, modern manufacturing units must focus on managing radical innovation projects on a regular basis. Therefore, manufacturing units must learn to adapt their organizational and project structure to radical innovation projects. Second, manufacturing units need to identify and apply the right technologies and methods for these projects in short cycles. Third, manufacturing units and innovation managers need to involve their employees even more, promote active and inclusive communication and create and foster an innovative culture. In all three areas, the scientific and industrial community must develop concepts and methods to strengthen the radical innovation capacity of European manufacturing companies, maintain their technological leadership and thus ensure the prosperity of society.

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Biography



Quirin Gärtner (*1994) holds a M.Sc. degree in Mechanical Engineering and Management from the Technical University of Munich. Since 2020 he is a doctoral fellow at the Institute for Machine Tools and Industrial Management (*iwb*) at the University of Munich, Germany. His research areas are Innovation and Technology Management.



Xuezhou Zhang (*1994) holds a B.Sc. degree in Mechanical Engineering from the University of Kassel, Germany. He currently pursues a M.Sc. degree in Automotive Engineering at the Technical University of Munich, Germany. His research areas are Innovation and Technology Management and Automotive engineering.



Fabian Sippl (*1993) holds a M.Sc. degree in Mechanical Engineering from the Technical University of Munich. Since 2018 he is a doctoral fellow at the Institute for Machine Tools and Industrial Management (*iwb*) at the University of Munich, Germany. Since 2021 he is part of the management board of the *iwb* and head of the department for production management and logistics. His research area is Manufacturing Change Management.