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Simulating an adaptive neuro-fuzzy inference system (ANFIS) model of innovation labs for technology-based firms (TBFs) of Iran (case study: Firms in Pardis Technology Park of Tehran) to predict the level of digitalization of the innovation process

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Abstract

This study aims to simulate an adaptive Neuro-Fuzzy inference system model of innovation labs, which is a model to predict the level of digitization of the innovation process in knowledge-based companies. The results of 188 indicators were distributed among 18 experts in this field in the form of a 5-point Likert questionnaire and a two-round Delphi method. The result of the work was 5 components as input to the model, which were sent in the form of a questionnaire to 230 knowledge-based companies in Pardis Technology Park, of which 198 companies completed and resubmitted. From this number of samples, 150 data points were isolated for training data and 48 data as model testing based on a random function. In the last phase, i.e. modelling, the adaptive fuzzy-neural inference method was used for the model. The network separation method or the lookup table (PG) in MATLAB 2023 software was used to evaluate the performance of the model using the root mean square error (RMSE) and relative error(E). This research was able to present the design model of a smart innovation lab with a very low error. As a result, it was able to achieve effective indicators in the degree of digitalization of the innovation process.

Keywords: smart innovation lab, digital innovation, adaptive neuro-fuzzy inference system (ANFIS), digital transformation, technology-based firms (TBFs), ANFIS model design, innovation process, digitalization
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1 Introduction

The ideal form for an innovation process, whether in its general form from the stage of idea formation to entering the market and commercialization, or in each of the parts separately, should be in such a way as to have the highest productivity (combined efficiency and effectiveness) during the process. Moving in this direction will reduce financial, time and human costs. One of the concepts that covers the innovation process from the beginning to the end is

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the innovation laboratory concept. By using these laboratories, organizations, commercial companies, accelerators and growth centers have been able to obtain a comprehensive view of this process, and secondly, by making changes in each part of it, they can adjust the outputs according to the micro goals, and guide their parents. According to Clayton Christensen [32], 95% of product innovation processes fail. According to PWC's 2017 report, 54% of innovative organizations face a major gap in transforming their innovation strategy into a big business strategy [25]. In this regard, as factors of innovation failure, BCG reported in 2016 that 42% of failed innovation projects had a very long development time. 32% did not choose the right idea and 31% did not have a risk-taking culture. 25% lacked the ability to collaborate, 22% did not have good enough ideas, and 20% were lacking in marketing innovations [117]. In the search for ideas, all the efforts of these laboratories are to involve the customer more at the beginning of the innovation process so that they can minimize the possible costs of not welcoming the idea into the market. Another thing is that under the selection process, how to act in screening among the flood of ideas in such a way that the highest chance can be imagined for the commercialization of that idea. Some people consider the use of experts and the opinions of experienced experts to be helpful, but in practice and in the real world, this does not happen due to organizations being locked in their current routines, and in the continuation of innovation, it suffers a systemic failure.

In addition to routines, the limited rationality of humans during the search and selection process can also be mentioned. Another issue is that, after the stage of choosing ideas during the process of implementation and exploitation, the requirement of prototyping, pilot productions and testing the beta form of products are all costly and time-consuming processes. The involvement of human tastes, even in the form of experts, adds to the complexity of this phase and stages of managing innovation projects. Finally, in the last part, i.e. the maximum use of innovation achievements, the limitations of the life cycle of a product or technology, as well as the dependencies of the previous path of an organization, as well as knowledge spillovers due to the human-centeredness of decision-making processes, this can be making the sector face a serious challenge. The consequences of the continuation of this form of decision-making in innovation management increase the probability of failure of the whole process and include the reduction of effectiveness and the achievement of goals, i.e. the successful commercialization of ideas in the market, on the one hand, and on the other hand, the reduction of efficiency, which means the loss of financial resources and Sometimes due to the existence of human decisions, it is affected by limited rationality and the overall productivity of innovation decreases. Among the possible influencing factors in increasing the productivity of an innovation process, it is possible to reduce the time interval from idea generation to entering the market, moving from path dependencies to path creation strategy, lean screening and selection of ideas. Optimally, he pointed out in capturing the opinions of customers along the way and absorbing and adapting their ideas through the strategy of open innovation and optimizing the prototyping phase in the implementation of the project. In all of these solutions, according to the obtained literature, traces of human decisions can be seen both individually and in the form of organizational routines created over time. The main issue in this research is how to digitize the innovation process in the form of designing a model of an innovation laboratory. From a practical point of view, it is to present the model of an innovation laboratory that can solve this gap and systemic failure caused by the human mind in decision-making by using intelligence.

The relevance of innovation to ensure the competitiveness of companies has been confirmed among researchers and professionals [126]. Also, innovation is a risky process that requires resources, competence, culture and attitudes that cannot even be easily promoted and managed [45]. In this regard, most organizations rely on external entities, namely innovation intermediaries, research and development laboratories or innovation centers, to exploit innovation processes [40].

Innovation labs are models of innovation management that aim to foster creative and critical thinking, guide the organization in finding the best ways to produce knowledge and digital culture, introduce technology, digitize operations and implement digital strategies for continuous and digital innovation.

Today, in the digital age, the dynamics of innovation are changing. Even after covid-19, the digital ecosystem is even more dynamic and unpredictable. Global and virtual competition, as well as the rapid development of digital technologies and solutions, raise efficiency standards, speed up market dynamics, and shorten product life cycles [126]. In addition, consumers are evolving into customers whose goal is to participate in co-creation processes of products, services, and experiences. Their needs and habits are also changing.

Therefore, innovation becomes popular quickly and easily and is replaced by new innovative solutions. The result is that the organizations that operate must be flexible, active and able to evolve in the same way that the competitive landscape requires. Therefore, innovation should be frequent and periodic. Continuous innovation is required and must be pursued through holistic engagement by the entire organization, stakeholders, and customers, not just senior management and dedicated facilities. Each actor involved in innovation must be aware of the organization's vision, goals, and strategies in order to effectively contribute and generate value [87, 103].

In addition, innovation is increasingly digital and data-driven, and most organizations must embark on a digital innovation journey without difficulty. The rapid development of digital technologies contributes to the generation of large volumes of data, information and knowledge, which further increase the barriers to innovation and accelerate the pace of change. For effective understanding and management of technology, codification and exploitation of generated knowledge, specialized skills and new governance models are needed [76]. But, even if they are equipped with advanced technological infrastructure and skilled employees, the current actors of innovation, such as research and development laboratories or innovation centers, are no longer able to maintain and improve the innovation capacity of companies [28]. These environments are still thought of as separate entities and are unable to guarantee stakeholder commitment and productive dialogue with the entire organization. Due to the mismatch in digital skills and awareness, employees are not able to understand the reasons and potential of implementing new technology and displacement.

Therefore, the next challenge in the digital ecosystem is to promote and define conditions, roadmaps and management models for implementing digital innovation strategies, for managing digital knowledge and fostering continuous innovation [16, 103].

The research of new management solutions, practices and models that enable the dynamics of continuous innovation and digital exploitation is a current topic of great importance for both researchers and practitioners [51]. Among emerging practices, innovation labs have emerged as a valuable response to organizations' needs to develop a digital culture and continuous innovation attitudes [108].

Changes in businesses, organizational processes and the influential role of customers in all stages of innovation after the fourth industrial revolution have a special acceleration, to the extent that the human mind has the ability to make decisions and adapt to this onslaught of information and data. and does not have cooperation networks. Perhaps this is why artificial intelligence tools are mentioned as the main competitive advantage in this century. A turning point during which intelligent systems came to the aid of humans to, in addition to compensating for human decision-making errors, put an end to problems such as path dependence and human-centered organizational routines. The innovation process equipped with artificial intelligence systems under the title of Intelligent Innovation Laboratory will address this issue. According to the literature and the background of the research obtained, the design of various models of innovation laboratories has been done in recent years, of course, these models also sometimes need to be completed in some parts, but according to the investigation carried out done, there has been no research on the smartening of these laboratories with this mentioned approach. Considering the competitive requirements in the coming century, including the reduction of the lifespan of technologies, their complexity, their difficult testability, and the unwanted overflow of knowledge, more than any other aspect, this research is directed towards intelligentization in order to reduce the time of the innovation process. From creating and acquiring an idea to its successful entry into the market. Of course, this reduction in time does not mean renouncing the efficiency and effectiveness of an innovation process, but rather reaching the highest productivity in the shortest possible time and minimum cost. Among the practical benefits of this research is the use of intelligent laboratories by organizations, knowledge-based companies, research centers and accelerators active in the innovation ecosystem in order to minimize human error along the way. In this research, for the first time, fuzzy neural networks are used to design the model of an innovation laboratory, which, according to the deep learning process that is institutionalized in neural networks, in case of repetition and over time in an innovative organization., has the ability to become a model with a reinforcement learning approach.

2 Research methodology

First, to review the relevant literature and extract components and indicators related to smart innovation labs, systematic review methods, and the use of the Prisma protocol [22], text analysis and scanning were used to evaluate articles and scholarly texts using the Google Scholar search engine. This impression is created in such a way that one sees the connection between these two keywords in the title and abstract of the article. The number of 400 articles (2000-2023) was extracted with the keywords Innovation laboratory, smart innovation laboratory, Digital innovation and digital transformation which formed the main articles after the year 2015 has the best adaptability to the research object. Among them, 290 articles with more than one reference were selected. The content of these 290 articles was studied and finally 149 articles related to the selected topic were used as the material and context of this study. The systematic review results are presented in Table 1.

The theoretical method of saturation sampling was applied at this stage, so no new content was retrieved from the articles as new indicators, and other indicators were common in meaning and concept. After reviewing these 149 articles and specialized texts, 189 indicators related to the topic of Smart Innovation Labs were extracted. Second, these 189 indicators are summarized into 42 new headings based on the degree of overlap and similarity of concepts. These 42 new indicators were shown in table 2.

Table 1: Primary components extracted from the literature

NO	The literature of indicators	Indicators	References
1	Digitization refers to the transformation from material scale to digital	Converting physical scales to digital.	[52]
2	Digitization is related to processes, content and topics.	Digitization of processes	[52]
3	The new organizational argument points to a special focus on distributed mass communication networks and therefore can be a great opportunity for digital innovation.	Networking	[155]
4	see productivity as the fundamental mechanism of digital innovation.	Productivity	[155]
5	emphasize the dynamism of their larger digital ecosystems.	to be dynamic	[77]
6	opportunities for innovation by digitizing products and offering digital services.	Digitization of services	[98]
7	Development of digital innovation acknowledge the complexity of material theory performance in digital innovation.	Digital development of the innovation process	[154]
8	Distributed mass communication networks of employees use digital technology to make decisions.	Employee digital networking	[74]
9	challenges for any company require managing innovation and understanding the unique assets of the digital innovation process	Digital assets	[156]
10	One of the reasons that the process of digital innovation to control and prediction is problematic in the production of digital technology	Benefit from digital technologies	[49]
11	It is possible to completely rebuild business around new opportunities and new demands through digital technology.	Business through digital platforms	[10]
12	Digital transformation describes a sometimes-broad change process that may have multiple goals, while innovation focuses on the moment of invention and the implementation of that invention	Digital transformation of the organization	[81]
13	Digital technologies imply data assimilation, editability, reprogramming, distribution and self-reference.	Data assimilation, editability, programmability, distribution and self-referencing	[77]
14	A digital platform can include technical principles (of software and hardware) and related organizational processes and standards as a collector	benefiting from digital standards	[68]
15	Digital platforms are multilateral markets that successfully bring producers and consumers together and support them in creating new forms of value.	Exploiting multi-sided digital markets	[30]
16	Organizational logic in digital innovation is based on non-linear processes.	Taking advantage of non-linear processes	[125]
17	Organizational logic in digital innovation is based on yield control.	Organization efficiency	[24]
18	The organizational logic in digital innovation is based on agility.	Organization agility	[65]
19	Organizational logic in digital innovation is based on communication network.	The organization's digital communication network	[110]
20	Market dynamics in digital innovation is based on a two-way market.	Market dynamic in digital innovation	[139]
21	Market dynamics in digital innovation are based on a multitude of niche markets.	Taking advantage of a multitude of niche markets in digital innovation	[121]
22	Market dynamics in digital innovation are based on shared platforms.	Taking advantage of sharing platforms.	[116]
23	Organizational architecture design in digital innovation is based on functional structures.	Organizational architecture design based on functional structures.	[130]
24	Organizational architecture design in digital innovation is based on business complexity.	Organizational architecture design based on business complexity.	[75]
25	Organizational architecture design in digital innovation is based on reuse of ideas.	Organizational architecture design based on reuse of ideas	[146]
26	Organizational architecture design in digital innovation is based on productive designs.	Organizational architecture design based on productive designs	[82]
27	Organizational architecture design in digital innovation is based on changes in the level of features.	Organizational architecture design based on changes in the level of features	[64]
28	In digital innovation, we mean processes and product innovation that are powered by digital technology and information services and robotics.	Benefiting from robotic technologies	[8]
29	Digital innovation is referred to as new waves of cognitive, technical and organizational innovation that follow the digitization of physical products.	Digitization of physical products	[123]
30	Digital technology is defined by new digital combinations for new production.	Production of new products	[6]
31	consider digital innovation as a product, process or business model that provides some specific changes in the adoption of IT information technology.	Benefiting from the digital business model	[88]
32	Digital innovation is enabled by the new idea, method and understandable subject that digital technology guarantees.	Access to new ideas	[18]
33	Organizations can act as strings between people, practices, tools and other resources and connect them together to create digital solutions.	Solving the problem through the digital platform	[100]

34	Innovation artifacts can be an important tool for individual careers in craft as well as group communication, collaboration, and decision-making while finding digital innovation solutions.	Collaboration and decision-making through a digital platform	[130]
35	Providing IT management is a strategy to deal with the pressures of the commercial competition market, which is actually instead of being predictable, focusing on improving and innovating as much as possible in conceptual spaces, the management strategy for digital innovation is exploratory and its focus is on testing.	The ability to examine markets through the digital platform	[116]
36	Digital innovation means the innovation of products, processes or business models that use the digital technology platform as a means or an end in organizations.	The innovation of products, processes or business models is based on digital technology	[23]
37	The ability of digital technology creates innovation in production	Digital technological capability	[102]
38	Digital technologies have distinct characteristics of digitizing data and subjects.	Capability of Digitizing Data and Topics	[118]
39	Digitization stimulates the development and diffusion of digital technologies.	Development and dissemination of technology from the digital platform	[53]
40	Digitized information can be stored, transformed or transmitted and accessed by any digital device regardless of content.	Ability to store, transform and transfer data	[121]
41	Digital information can be edited through reprogramming. It is possible to build external system digital solutions after deployment.	Ability to edit information	[158]
42	Fundamentally self-referential digital innovation is required to create digital technology.	Self-referentiality of innovation	[99]
43	Digital technology is both the reason and the basis for the expansion of digital innovation, which refers to scalability and reduction of barriers and causes widespread participation and democratic innovation.	Increasing participation and scalability of innovation	[111]
44	Traditionally, innovation is often defined as a discrete, sequential and permanent process with order and results, and the innovation process is divided into search, selection and implementation, and value capture.	The ability to search, choose and execute and capture value in the innovation process	[145]
45	The innovation process described by includes idea generation, defense and testing, commercialization, dissemination and implementation.	Ability to generate ideas and test commercialization, dissemination and implementation	[41]
46	Innovative processes are also necessary conditions for digital innovation; But they alone are not enough to advance the digital innovation capabilities of an organization.	The capability of innovation processes in the digital platform	[92]
47	Capabilities increase if organizations support distributive and hybrid innovations. In order to achieve this goal, companies need to understand and support these practices.	Supporting distributive and hybrid innovations	[122]
48	Companies are actively developing digital innovation and have practices that are their own innovative methods.	Actively expanding digital innovation	[36]
49	Businesses need a dynamic tool to support their digital innovation management efforts.	Having a dynamic tool in the innovation process	[92]
50	Digital products and services should offer high levels of usability and beautiful design and invite employment.	well-designed of digital products and high level of digital services	[71]
51	Digital innovations require architectural value propositions.	The ability to value the architecture of the organization	[120]
52	In recognition of opportunities for innovation, business firms should survey their digital environment, which involves gathering information about new digital devices, channels, and user behavior.	Gathering information and creating new channels with users through the digital platform	[43]
53	As digital innovation benefits, businesses need to acquire new skills internally and externally.	Ability to acquire new internal and external skills by the organization	[55]
54	The flexibility and low cost of digital technologies require higher degrees of innovation.	Having the flexibility and low cost of digital technologies	[104]
55	The relationship between digital innovation and profitability has reportedly increased in the fourth industrial revolution.	High profitability of the organization	[59]
56	The increasing automation and digitization of production shows that adjustment of work performance and labor relations can easily be considered by management with the consequences of technical and neutral mechanisms alike.	The increasing automation and digitization of production	[70]
57	The current wave of technological innovation and its relation to work and production is combined with terms such as the fourth industrial revolution of digital capitalism.	Capability of digital capitalism	[46]
58	The products and technologies developed and produced in collaborative work environments reflect the increasingly blurred boundaries between digital technologies and manufactured products. These activities include the use of digital manufacturing technologies such as 3D printers to make artifacts and IoT-based development that integrates digital technologies into physical products.	Taking advantage of shared workspaces, digital manufacturing technologies such as 3D printers for making artifacts, and IoT-based development	[141]

59	Clustering and sharing of tacit knowledge are very important in an industry.	Ability to cluster and share tacit knowledge in an industry	[150]
60	According to the latest technologies, along with new technologies and new spaces, a new form of network-based innovation model has also emerged - one that is open and based on community and workspace.	Ability to use network-based and open innovation model	[135]
61	One of the first challenges in researching collaborative digital workspaces and their processes is the lack of common understanding or even common terms to describe the phenomenon.	Collaborative digital workspaces	[69]
62	Workspaces based on communities of practice allow people to share and experiment with digital tools and provide experiences of an emerging production method, i.e. peer production.	Workspaces with the ability to share digital tools and test experiences	[101]
63	Claims about networks of innovation and digital manufacturing stem from the “industrialization of the maker movement” at the intersection of digital manufacturing and small-scale manufacturing.	Digital manufacturing capability and small-scale production	[69]
64	Digital fabrication tools make it possible to transform local workspaces and home spaces into small manufacturing labs.	The ability to transform local workspaces and home spaces into small production laboratories	[132]
65	Small-scale producers are emerging and growing in the maker movement as a specialized, local, and networked group.	small-scale, local and networked manufacturing capabilities	[37]
66	Small-scale production potentials may arise from access to a production system model that is ”open and accessible” to potential consumers and entrepreneurs.	Small-scale production capability with access to an open and accessible production model for consumers and entrepreneurs	[29]
67	The inclusion of shared workspaces as part of distributed and consumer-oriented digital manufacturing services has begun.	Inclusion of co-working spaces	[21]
68	Innovation in innovation networks and digital manufacturing is known by different names, including grassroots innovation, citizen-based innovation, and bottom-up innovation.	People’s innovation capability, citizen-based innovation and bottom-up innovation are known.	[131]
69	In many countries, there is a common goal for innovation to address broader socio-economic problems rather than a commercial imperative.	Ability to address socio-economic problems	[2]
70	There are elements of lean innovation with its emphasis on informality and doing. which has been reinterpreted in local and digital contexts.	Ability to benefit from cost-effective innovation	[157]
71	Due to its technology-based origin, which is usually rooted in software development, openness can be described in terms of three basic characteristics: reusability, compatibility, and organizational transparency	Openness of the innovation process with reusability, adaptability, and organizational transparency	[113]
72	The ”paradoxes of openness” in innovation networks and digital manufacturing should be considered.	Openness in innovation networks and digital construction	[129]
73	Social capital is generated through a network where nodes can mediate connections between otherwise disconnected segments.	Benefiting from social capital through a network	[26]
74	The position of the organization in the network (expressed in centrality criteria) affects its innovative performance; Because it enables more access to information.	Organization’s greater access to information	[64]
75	More access to information creates positive effects on learning and organizational reputation.	More accessibility to information	[64]
76	As the industry matures, firms tend to partner at short intervals with cognitively engaged organizations.	Recognizability more than other organizations	[12]
77	The tendency of innovation system actors to participate more with organizations that are cognitively similar.	The willingness of innovation systems actors to be more involved with other organizations	[12]
78	Personal contacts represent an important channel of knowledge diffusion and show how critical ties and organizations with brokerage positions offset the negative effects of network fragmentation.	Benefiting from mediation positions of organizations in networking	[42]
79	Factors that make innovation projects that fail 42% have a very long development time. 32% did not choose the right idea and 31% did not have a risk-taking culture. 25% lacked the ability to collaborate, 22% did not have good enough ideas, and 20% were lacking in marketing innovations	Possessing innovation projects with short-term development, choosing the right idea, having a risk-taking culture, the ability to collaborate, having a good enough idea, lack of defects in marketing innovations	[117]
80	Innovation communication has been confirmed among researchers and professionals to ensure the competitiveness of companies.	Communication of innovation between researchers and professionals	[126]
81	Innovation is a risky process that requires resources, competence, culture and attitudes that cannot even be easily promoted and managed.	Having resources, competence, culture and effective attitudes	[45]
82	Most organizations rely on external entities, namely innovation intermediaries, research and development laboratories or innovation centers, to exploit innovation processes.	Relying on external institutions, i.e. innovation intermediaries, research and development laboratories or innovation centers	[40]

83	The rapid development of digital technologies and solutions raises efficiency standards, accelerates market dynamics, and shortens product life cycles.	Rapid development of digital technologies and solutions	[126]
84	Not only senior management and dedicated facilities. Every actor involved in innovation must be aware of the organization's vision, goals, and strategies in order to effectively contribute and generate value.	Awareness of innovation actors Vision, goals and strategies of the organization	[87]
85	To understand and effectively manage technology, codification and exploitation of generated knowledge, specialized skills and new governance models are required.	The ability to code and use the generated knowledge	[76]
86	The current actors of innovation, such as research and development laboratories or innovation centers, are no longer able to maintain and improve the innovation capacity of companies.	Ability to create new innovation actors	[27]
87	Improving and defining conditions, roadmaps and management models for implementing digital innovation strategies, for managing digital knowledge and fostering continuous innovation.	Ability to promote and define conditions, roadmaps and management models for implementing digital innovation strategies, for managing digital knowledge and	[16]
88	New management solutions, practices and models that enable the dynamics of continuous innovation and digital exploitation are a current issue of great importance for both researchers and practitioners.	Benefiting from management solutions, practices and models for digital exploitation	[51]
89	Among emerging practices, innovation labs have emerged as a valuable response to organizations' needs to develop digital culture and continuous innovation attitudes.	Ability to develop digital culture	[108]
90	Still shows the lack of management models based on innovative approaches and methods and addressing current competitive challenges.	The ability to address the organization's current competitive challenges	[108]
91	Innovation labs are defined as a dedicated center that encourages creative behaviors and promotes innovative projects by providing appropriate resources.	The ability to encourage creative behaviors and promote innovative projects.	[93]
92	Emphasize the role of creative spaces to increase innovation.	The ability to create spaces	[91]
93	Innovation Lab is considered as a collaborative ideation space that helps organizations break down the walls of traditional labs and enables different people to participate in creative and innovative activities.	Having a space for collaborative ideation	[19]
94	The basic distinguishing feature of innovation labs is that they are innovative spaces that enable organizations to adopt the paradigm of open innovation, user-centered innovation, and collaborative innovation by overcoming hierarchies and by promoting stakeholder participation in the co-creation of potentially successful innovations	The ability to co-create potentially successful innovations, open innovation paradigm, user-centered innovation and collaborative innovation	[94]
95	Innovation Lab is a dedicated center for encouraging creative behavior and supporting innovative projects, which supports innovative scientific activities by providing appropriate resources and model building facilities for new projects.	The ability to encourage creative behaviors and support innovative projects	[86]
96	Innovation Lab is an environment with dedicated facilities and shared workspaces where groups and teams of employees can interact with each other, discover and expand their creative thinking beyond normal boundaries.	The ability to create shared workspaces	[91]
97	Innovation Lab is a dedicated physical environment where appropriate tools and methods are used to help the idea creation process with innovation development.	The ability to help the idea creation process by developing innovation	[54]
98	An innovation lab is an ideal physical or virtual co-working environment where companies can develop, test and promote innovations.	The ability to create an ideal physical or virtual collaborative work environment for developing, testing and promoting innovation	[95]
99	Innovation Lab is a common intersection with a dual purpose: stimulating business model innovation and developing a systematic approach to innovation processes where the three components of environment, technology and facilitating mechanisms are used to make it appropriate.	The ability to stimulate business model innovation and develop a systematic approach to innovation processes	[143]
100	Innovation Lab is a collaborative and location-independent ideation space that requires three interrelated components, technological environment and facilitating mechanisms, to be suitable for ideation and innovation activities.	Benefiting from a common and location-independent ideation space with three interrelated components, i.e. technological environment and facilitating mechanisms	[67]
101	Innovation Lab is a physical space for testing innovative ideas, business models, new economic practices or flexible structures.	Having a physical space to test innovative ideas, business models, new economic practices or flexible structures	[127]
102	An innovation laboratory is a physical structure or dedicated stimulus that mediates the innovation process and enables the effective development of innovations through the provision of shared services and necessary resources.	Having a physical structure for the effective development of innovations through the provision of joint services and necessary resources	[94]

103	The Innovation Lab should primarily be a management initiative to influence organizational initiatives with a focus on developing capacity behavior in terms of propensity to innovate.	Benefiting from organizational initiatives with a focus on innovation development	[159]
104	The activities of innovation labs should be aligned with the vision and strategic goals of the organization and should be inspired by innovative methods and approaches that enhance stakeholder participation and satisfaction.	Alignment with the vision and strategic goals of the organization	[149]
105	Innovation labs are innovation management models that aim to foster creative and critical thinking, guide the organization in finding the best ways to produce knowledge and digital culture, introduce technologies, digitize operations and implement digital strategies for continuous and sustainable innovation paths.	The ability to cultivate creative and critical thinking, guide the organization in finding the best ways to produce knowledge and digital culture, introduce technologies, digitize operations and implement digital strategies for continuous and sustainable innovation paths.	[124]
106	Most organizations rely on a wide range of external institutions to exploit innovation processes, including technology zones, innovation intermediaries, research and development laboratories or innovation centers.	Relying on external institutions, such as technology zones, innovation intermediaries, research and development laboratories or innovation centers	[89]
107	Global and virtual competition, as well as the rapid development of digital technologies and solutions, increase efficiency standards, speed up market dynamics, and shorten product life cycles.	The ability to participate in global and virtual competition as well as the rapid development of digital technologies and solutions	[103]
108	Every actor involved in innovation processes must be aware of the vision, goals and strategies of the organization in order to contribute effectively and generate value.	Knowledge of the vision, goals and strategies of the organization	[87]
109	To understand and effectively manage digital technology, codification and exploitation of generated knowledge, specialized skills and new governance models are required.	The ability to code and use the generated knowledge	[76]
110	Current innovation laboratories, in the traditional form of research and development laboratories and innovation centers, are not always able to maintain and improve the innovation capacity of companies.	Ability to maintain and improve innovation capacity	[27]
111	Digital innovation, in fact, is not only about technological innovation. It is more about innovation of knowledge and cultural attitude.	Capability in knowledge innovation and cultural attitude	[142]
112	Improving and defining conditions, roadmaps and management models for implementing digital innovation strategies in order to manage digital knowledge and strengthen continuous innovation.	Ability to manage digital knowledge	[16]
113	The Innovation Lab model has emerged as a specific solution that enables continuous innovation dynamism and digital exploitation for private and public organizations interested in achieving sustainable advantage and increasing performance and services.	Ability to achieve sustainable advantage and increase performance and services	[51]
114	There is a lack of management models to implement digital innovation strategies to manage digital knowledge, foster continuous innovation based on innovative approaches and methods, as well as the ability to address current competitive challenges.	Ability to manage digital knowledge, address current competitive challenges	[108]
115	Innovation labs may act as an innovation broker to provide opportunities for building communities and partnerships with different stakeholders.	Ability to mediate innovation	[95]
116	Innovation labs should provide services such as mentoring, coaching or facilitating meetings with end users to obtain feedback and control the risk of failure.	Ability to provide services such as mentoring, coaching or facilitating meetings with end users	[136]
117	Coding of learned knowledge; or improving routines. In addition, the innovation lab may play a strategic role in building bridges between companies and markets.	Coding of learned knowledge	[51]
118	Evaluation for strategic learning requires a process of action, evaluation and re-action. It is a continuous cycle of reflection and action.	Capability in strategic learning including the process of action, evaluation and re-action	[148]
119	Evaluation of joint creation processes and interdisciplinary knowledge production which is the basis of laboratory strategy.	The ability to evaluate joint creation processes and interdisciplinary knowledge production	[112]
120	There is a reciprocal relationship between strategy and evaluation. When both elements are understood and implemented in this way, the organization is better prepared to learn, grow, adapt, and continuously change in meaningful and effective ways.	Ability to evaluate innovation strategy	[114]
121	Systemic learning must assess whether the current and relatively stable set of social structures is being challenged, and what new knowledge and practices are emerging.	System learning capability	[50]
122	Although for a long-time instrumental evaluation and learning were considered as opposite approaches, recently diverse approaches have been considered.	Competence in instrumental evaluation and learning	[9]

123	Assessment of learning in complex systems includes reflection and measurement of non-linear processes of change with feedback loops and intertwined influence factors.	Ability to assess learning in complex systems	[15]
124	Dynamic capabilities (i.e., "organizational and strategic routines by which firms achieve new resource configurations as markets emerge, encounter, segment, evolve") are largely defined by how managers make judgments about the organization and its future.	Dynamic capabilities	[148]
125	A key advantage of the lab is its contribution to double loop learning.	Double loop learning ability	[35]
126	Physical environments can facilitate organizational and marketing goals.	Capability in facilitating organizational goals and marketing	[153]
127	Policy labs are dedicated teams, structures, or institutions that focus on designing public policy through unconventional methods, involving all stakeholders in the design process.	Ability to involve all stakeholders in the design process	[93]
128	Specifically, co-design is linked to policy and public service development as a joint explanation of options between actors.	Capability in joint design	[152]
129	What unites and distinguishes policy laboratories "is that they all adopt empirical methods to deal with social and public problems."	Benefiting from experimental methods to deal with social and public issues	[13]
130	This process includes discovering user needs, defining the challenge, developing and testing prototypes, and providing a solution approved by users, and is an approach that includes elements of top-down and bottom-up public governance.	Ability to discover user needs, define challenges, develop and test prototypes, and provide solutions approved by users	[149]
131	Policy knowledge transfer can be facilitated by involving governmental and non-governmental actors, often using network and network theories and intermediaries between researchers and policy actors.	Networking ability between governmental and non-governmental actors	[83]
132	Testing activities are embedded in the main policy cycle because they often originate in the smaller loop of design testing compliance.	Capability in design testing	[107]
133	Laboratories can provide evidence to policy makers that a particular issue is ready to be placed on the policy agenda.	Capability in providing information to policy makers	[3]
134	Because labs promote open government and evidence-based criteria, they can encourage governments to become more transparent and participatory during policymaking.	The ability to cooperate in formulating policies	[17]
135	Design culture is essential for transforming an organization through human design, co-creation, and, in general, increasing the value of the public sector.	Ability to create culture	[80]
136	Policy labs should be understood within a broader policy work ecosystem.	Ability to create a broader policy work ecosystem	[48]
137	on the contribution of policy impact labs to local government innovation capacity, showing that they improve innovation capacity by contributing to aspects such as idea generation and knowledge management.	The ability to increase the innovation capacity of the local government	[138]
138	Policy labs act as "technology" or "tools" to improve policy-making processes. One of the promising methods of research is to imagine the policy laboratory as a source of diffusion of innovation.	The ability to improve policy processes as a source of innovation diffusion	[140]
139	Process improvement is central to the nature of business and is consistently focused on hard facts and business value, embodied in total quality management (TQM).	Capability in process improvement in the nature of business	[149]
140	Integrated AIS is a generalized class of information technology systems that emerged from a new generation of ERP-based systems.	Benefiting from integrated information technology systems	[96]
141	Innovation Mediation is an exploratory approach to study integrated business process modeling in a controlled environment, embodied in the Process Innovation Lab.	Ability to integrate business process modeling in a controlled environment	[97]
142	The basic idea is the system view in the business process, that is, the business process should be seen as a work system and the business process modeling should be seen as a system development process.	Having a systemic perspective in the business process	[7]
143	Living labs are considered as innovation tools and innovation mediators capable of bridging the gap between research and market introduction.	Ability to fill the gap between research and introduction to the market	[44]
144	Living labs are considered as complex phenomena in which three levels of analysis can be distinguished: the organizational level, the project level, and the level of individual interactions with the user.	The ability to be analyzed at three organizational levels, the project level, and the level of individual interactions with the user	[144]
145	Management of value capture and value creation processes in living laboratory organizations is very important for their sustainability.	Ability to manage value absorption and value creation processes	[11]
146	Living labs are defined as organizing open innovation processes with a focus on co-creating innovations in real-world contexts by involving multiple stakeholders with the goal of production.	The ability to organize open innovation processes with a focus on co-creating innovations	[14]
147	Most living laboratories do not yet have standardized instruments, but use custom-made instruments, which indicates the immaturity of these living laboratories in terms of performance.	Using custom-made tools	[84]

148	consider living labs to be an excellent tool to explore and define the value proposition of innovations in a lab.	Ability to review and define the value proposition of innovations	[151]
149	Living labs, focusing on providing specific services to foreign customers, play the role of innovation intermediary between entrepreneurs and end users.	The ability to mediate innovation between entrepreneurs and end users	[133]
150	Artificial intelligence refers to human-like intelligent activities that are programmed to perform specific tasks.	Having intelligent processes (based on artificial intelligence)	[57]
151	Artificial intelligence has the ability to think like humans and can be used to perform certain roles and tasks that were originally performed by people in public places and social life.	The ability to analyze the system and solve problems and make decisions in an intelligent way	[38]
152	Artificial intelligence refers to systems with human characteristics, such as learning, speaking, and other cognitive functions.	Having intelligent systems with human characteristics, such as learning, speaking and other cognitive functions	[119]
153	Artificial intelligence includes a series of technologies including machine learning, deep learning, natural language processing, robots, etc., which can be defined as advanced technologies.	Benefiting from a series of technologies including machine learning, deep learning, natural language processing, robots etc.	[4]
154	Artificial intelligence is a cognitive science that integrates image processing, natural language processing, robotics, machine learning and other technologies. Combining artificial intelligence with emerging technologies such as the Industrial Internet of Things, big data analytics, and cloud computing applied to industrial manufacturing can help produce flexible, efficient, and green operating methods while providing solutions for industrial applications.	Capability of image processing, natural language processing, robotics, machine learning and industrial internet of things, big data analysis and cloud computing	[56]
155	Artificial intelligence is technology that can perform complex tasks that originally required human involvement.	The ability to decrease the need for human participation	[1]
156	Artificial intelligence has the ability to achieve specific tasks by flexible learning of output data.	Ability to achieve flexible learning output data	[34]
157	Artificial intelligence mainly includes two aspects, computational intelligence and perceptual intelligence.	Benefiting from computational intelligence and perceptual intelligence.	[60]
158	that artificial intelligence is the use of machine learning, deep learning, computer vision and other technologies to achieve imitation of human capabilities through algorithmic programming and processing. Artificial intelligence has the ability to learn, reason, perceive and make independent decisions. It can replace part of human and mental work and provide users with efficient auxiliary functions such as data processing and technical analysis, which can greatly improve work efficiency and production.	Benefiting from machine learning, deep learning, computer vision and other technologies to achieve imitation of human capabilities through algorithmic programming and processing and the ability to learn, reason, perceive and make independent decisions	[33]
159	Innovation is a process that involves generating, developing and implementing new ideas or behaviors.	Ability to produce, develop and implement new ideas or behaviors	[90]
160	Innovation is a change in a product, service, process or, more broadly, an organization.	Innovation capability is a change in a product, service, process or more broadly, an organization	[117]
161	Innovation is something new (new, original, or improved) that creates value, where "something" can be a process, product, or service that starts as an idea.	Ability to create value in the organization	[109]
162	Gaining a competitive advantage in the market is the main goal of promoting innovation.	The ability to gain a competitive advantage in the	[39]
163	Technological innovation is an essential factor for manufacturing companies to maintain stability.	The ability to maintain stability in border organizations,	[34]
164	Innovation in products or services, management operations or production processes underlies any competitive advantage as a fundamental guiding principle.	The ability to innovate about products or services, management operations or production processes	[117]
165	Similar to the formation of food webs in ecosystems by different species, complex and dependent networks are formed between technological innovations.	The ability to create complex interdependent networks between technological innovations	[58]
166	Each technological innovation is not independent, each innovation is based on the behavior of other technological innovations, and each innovation depends on other innovations to achieve joint evolution through interaction.	Ability to interact with other innovations	[39]
167	Technological innovation is not independent and depends on other innovations and evolves through interaction with other innovative activities.	Ability to interact with other innovative activities	[39]
168	Artificial intelligence is a universal technology that can support other innovations.	Ability to support other innovations	[33]
169	Knowledge is the core of technological innovation. To effectively create new knowledge, it is the basis for technological innovation.	Ability to effectively create new knowledge	[58]

170	Intelligent machines or algorithms, such as machine learning, deep learning, etc., perform tasks, but new forms of human-machine interaction can produce more efficient knowledge retrieval and data processing.	The ability to retrieve knowledge and process data efficiently with machines or intelligent algorithms, such as machine learning, deep learning, etc.	[33]
171	Learning by artificial intelligence is a process from collecting and structuring huge data into information to creating knowledge.	It is the ability to collect and structure huge data into information to create knowledge.	[106]
172	The development of artificial intelligence promotes the generality and use of the Internet and communication methods of platform economies, removes the boundaries of knowledge within and between companies, and accelerates the dissemination of knowledge and the process of creating new knowledge through the exchange and integration of knowledge. This goal, in turn, strongly influences the development of artificial intelligence.	The ability to exchange and integrate knowledge	[67]
173	When the distance between the source of knowledge (a research institute) and the users increases, the effect of knowledge and technology transfer decreases.	The ability to reduce the distance between the source of knowledge and the users	[82]
174	Absorptive capacity is widely recognized as an effective tool for gaining and maintaining competitive advantage.	The ability to increase the organization's absorptive capacity	[66]
175	The development of artificial intelligence has actually improved the learning and recruiting capabilities of companies. For example, technologies such as deep learning, intelligent image recognition, etc., can help industrial robots make independent judgments and take appropriate actions.	Ability to develop learning and absorption	[47]
176	The purpose of having internal research and development (R&D), if possible, is to help the company to achieve production, exploitation and transformation of knowledge, which has been recently created either inside or outside the country, into new products or processes.	The ability to transform knowledge, which is newly created either internally or externally, into new products or processes.	[79]
177	The purpose of having internal research and development (R&D), if possible, is to help the company to acquire, integrate, transform and exploit new technologies.	Ability to acquire, integrate, transform and exploit new technologies	[117]
178	The purpose of having internal research and development (R&D), if possible, is to attract cooperative partners.	Ability to attract partners	[61]
179	The purpose of having in-house research and development (R&D) is, if possible, to create new technological configurations that are very costly and particularly difficult or even impossible to obtain from competitors.	Ability to create new technology settings	[134]
180	When a firm grows to a certain scale of power, it will naturally have R&D capabilities as described above.	Possessing research and development capabilities	[62]
181	Internal R&D is widely accepted as an important determinant of innovation.	Benefiting from internal research and development	[105]
182	Artificial intelligence uses various technologies such as machine learning, deep learning, computer vision, and algorithmic programming and processing to mimic human abilities. It is difficult to measure artificial intelligence with a single variable. A number of industrial robots are being used as an alternative to artificial intelligence based on training.	Benefiting from various technologies such as machine learning, deep learning, computer vision and algorithmic programming and processing to imitate human abilities	[90]
183	Research and development investment intensity is one of the main ways to improve technological innovation.	Ability to increase research and development investment	[63]
184	The high dependence of domestic investment companies on foreign direct investment is created and the enthusiasm for technological innovation decreases, which leads to the reduction of technological innovation capabilities.	Reducing the organization's dependence on foreign direct investment	[147]
185	uses the total output value ratio of foreign-invested enterprises in different industries (Sino-foreign joint ventures, Sino-foreign cooperative ventures, and wholly foreign enterprises).	The ability to increase the total output value ratio of companies	[85]
186	Ownership structure is one of the known factors affecting technological innovation. The proportional relationship between state-owned enterprises and the private sector has strongly influenced the allocation efficiency and technology efficiency.	Benefiting from a suitable ownership structure	[128]
187	Technical imitation plays an important role in manufacturing sectors with little or no technical innovation and is one of the important tools to achieve rapid technological progress.	Ability in technical imitation	[5]
188	Treating projects as experiments, working dynamically, and systematically documenting the learning process proves valuable because it challenges traditional forms of operation and sets the stage for other possibilities.	Ability to experiment, work dynamically, and systematically document the learning process	[108]

Then, to further increase the richness of the research, we collected these 42 key and performance indicators, which were provided to 32 experts, professors and entrepreneurs according to the Delphi method and divided into two rounds, in the form of a 5-point Likert scale questionnaire. (very high, high, average, low, very low) and were asked through

Table 2: Indicators and Component after Expert Judgement

NO	Indicators	components
1	The ability to digitize physical products	Technological
2	Benefiting from digital manufacturing technologies	
3	Benefiting from Internet of Things technology	
4	Capability in joint design in the digital platform	
5	Ability to solve problems and make decisions in an intelligent way	
6	Benefiting from the abilities of intelligent cognitive sciences	
7	Benefiting from artificial intelligence technologies	
8	Benefiting from computational intelligence and perceptual intelligence	
9	Intelligent programming capabilities	
10	Benefiting from robotic technologies	
11	Benefit from digital standards	
12	The ability to digitize physical products	
13	Benefiting from digital organizational architecture	Structural
14	Benefiting from the digital business model	
15	Benefiting from shared digital workspaces	
16	Ability to support other innovations	
17	Ability to maintain and improve innovation capacity	
18	Ability to share tacit knowledge	
19	Ability to learn and evaluate it in the digital platform	Learning
20	Smart learning capabilities (using smart algorithms)	
21	Ability to create, exchange and integrate new knowledge	
22	Ability to increase the absorption capacity of digital technologies	
23	Capabilities in research and development of digital technologies	
24	Networking capabilities in the digital platform	
25	Ability to digitize data	Data and information
26	Ability to generate ideas in the digital platform	
27	Ability to generate ideas in the digital platform	
28	The ability to collect information on a digital platform	
29	Networking capabilities with digital markets	Networking
30	The ability to carry out popular and citizenship-based innovations	
31	Ability to discover and develop the needs of users in the digital platform	
32	Benefit from automation production	Manufacturing
33	Ability to produce and test prototypes	
34	Benefiting from digital processes	Processes
35	Benefiting from intelligent processes (based on artificial intelligence)	
36	Ability to develop the innovation process in the digital platform of development	Development
37	The ability to develop and spread technology in the digital platform	
38	Financial digital investment capabilities	Financial
39	Ability to increase investment in research and development of digital technologies	
40	Development capabilities of digital culture	Cultural
41	Benefit from digital services	Services
42	Alignment of the digital strategy with the organization's	Strategy

an electronic questionnaire, and 18 of them responded and responded. After reviewing the experts' opinions, it was found that they reached consensus on all indicators with an average score above 4. The lowest average answer was related to the impact of self-regulation. automation to the innovation process with an average score of 4 and the highest score related to the profit index of smart business models with an average score of 4.9.

The validity of the questionnaire was confirmed in terms of content validity based on expert opinion, and the dynamic of the questionnaire was calculated using the Cronbach's alpha method in Excel and SPSS software, which is 0, 98 and in very good condition. Therefore, the validity and dynamics of the questionnaire in this study were in excellent condition. 5 new components, i.e. digital technology, digital structure and architecture, capability in digital networking, digital learning and benefiting from digital processes, the second-round questionnaire was prepared and provided to 18 previous experts, and in parallel, the link to the previous answers It was made available to everyone (on the Press Line website). For the second round, everyone's score for these 5 components was set to the highest number, 5, and they reached a consensus with the highest percentage. The validity of the second questionnaire was also confirmed by the content validity method and its dynamics was also confirmed through Cronbach's alpha with a value of 0.99, which is excellent and acceptable.

As a result, the output of the questionnaire including 5 components (main variable) to enter the adaptive neural inference fuzzy system model is as follows:

1. The innovation laboratory benefit from digital technologies (based on artificial intelligence) (IN1)
2. The benefit of innovation laboratory from digital structure and architecture (IN2)

3. Capability of innovation laboratory in smart networking in digital platform (IN3)
4. The innovation laboratory's ability to create and maintain knowledge and smart learning in the digital platform (IN4)
5. Benefiting the innovation laboratory from digital processes (based on artificial intelligence) (IN5)

The output in this model is the digital level of the innovation process centered on artificial intelligence in an innovation laboratory. (OT)

Now, these 5 components in the form of a 5-point Likert questionnaire with a range of very high, high, medium, low and very low, were provided to the statistical sample of the research, including 250 knowledge-based companies in the campus technology park and its branches, and 198 questionnaires were answered and has been sent.

The content validity of this questionnaire was confirmed by relying on the opinion of professors and expert experts in this field, and the dynamics of the questionnaire was obtained in SPSS software by calculating Cronbach's alpha of 0.73, which was acceptable and the questionnaire can be considered as having good reliability.

At first, the data were trained and a multivariate regression function was drawn between the data and the output. This function helps to better understand the relationship between the 5 inputs and the output and the degree of deviation from the predicted model.

In the fourth phase, i.e. modeling, the adaptive fuzzy-neural inference method was used for the model. In adaptive neural fuzzy inference, network separation method or lookup table (PG) was used in MATLAB 2023 software. In this method, the number of membership functions is 5, representing very low, low, medium, high and very high. The type of input membership function can be selected, and in this research, a bell was chosen (it gave less error than other types of function) and considering that we had 5 inputs and 1 output, this method is suitable for determining the model [72, 73].

The conceptual model of research will be shown in Figure 1.

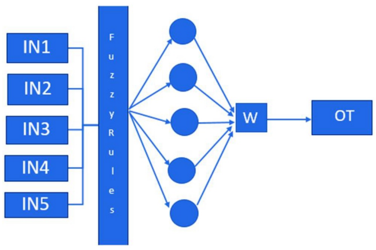

Figure 1: Research conceptual model for fuzzy-neural adaptive inference calculation

Firstly, 150 data were randomly selected as training data and 48 data were selected as test data. Using MATLAB software, 150 data were first trained to be prepared for entering the designed fuzzy inference system (to design the best fuzzy inference system, 13 systems were designed and implemented with the data, and the last model with the least error was selected). The fuzzy inference system (FIS) designed in MATLAB has the following characteristics:

- Each entry has 5 membership functions as follows:

  (mf1=very low) (mf2=low) (mf3=moderate) (mf4=high) (mf5=very high)

- The output has 3125 membership functions (because 3125 of our rules were selected). The membership functions for all 5 inputs were selected in the form of a bell (with the lowest error compared to the rest of the functions that were tested)

- The number of rules of 3125 numbers were selected by default by the software, which have "and" relations and have the most exploitation meaning. Then they got the approval of two of the professors of this field.

- The weight of each function was set to 1, which means that the impact of each function in the model is equal.

- In this model, the Takagi-Sugeno-Kang (TSK) fuzzification method was used for the inputs. Before the selection, it was tested with the Mamdani model, and the Sugeno method had less error and more overlap of the membership functions, and it was approved by two professors.

- In this model, the dephasing method of the average maximum output values (wtaver) was used, first tested and then confirmed due to less error.
- The range of functions between 0 and 1 were selected, which were normalized and had the most accuracy.
- The number of nodes in the model was calculated to be 6308.
- The number of linear parameters was 3125 and the number of nonlinear parameters was 75 in the model.
- The number of repetitions of the test was chosen 40 times, which was also tested with the number of 100 times, and no noticeable change in the model error was observed.

To evaluate the performance of the model, the parameters of the root mean square error (RMSE), the value of which is 0.1 and less is excellent, the percentage of relative error (E), the lower the better, has been used [78, 115].

3 Results

The output results obtained in MATLAB software for modeling are presented in order according to the shape of each section.

At first, the data were trained and a multivariate regression function was drawn between the data and the output. This function helps to better understand the relationship between the 5 inputs and the output and the degree of deviation from the predicted model. The next two figures, figure 2 and figure 3, show this topic. According to these two figures, an acceptable amount of overlap between the inputs and outputs between the prediction model and the actual model obtained is observed, and the findings will be discussed in the fifth chapter.

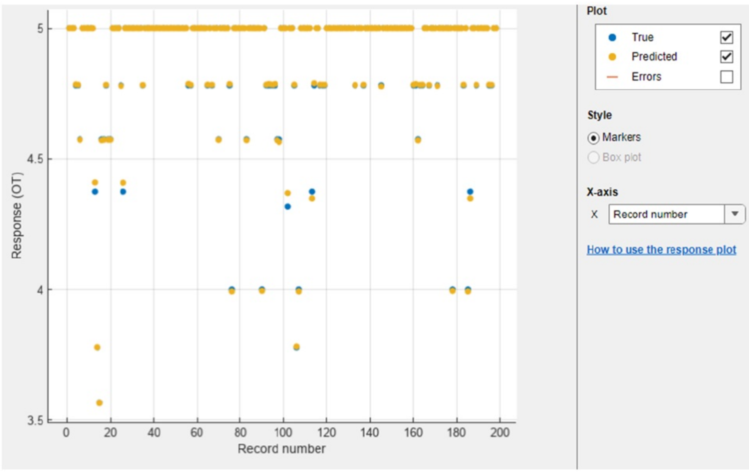

Figure 2: The degree of matching of the outputs between the two predicted and realized states

In the following, an output of the general structure of the model is shown according to Figure 4. As shown in the figure, the model has 5 inputs, 5 membership functions for each input, 3125 inference rules, 3125 membership functions for the output, and one output. The rules of blue color mean to use the conjunction "and" between the clauses.

In this section, Figure 5 shows the fuzzy inference system (FIS) designed for this model. This inference system was chosen among 13 other designed systems because it had the lowest output error. Among the other specific cases in the figure, we can mention the method of dephasing the output, which used the average of the highest output value for this model and gave a better response. For the "and" method in conditional statements, the method (prod) or the array result of each member is used. This inference system uses Sugeno fuzzing method and has 5 inputs and one output.

In the following, 150 randomly selected data were trained and the result is displayed as shown in Figure 6. The output for 150 data varies between 3.5 and 5, and the amount of dispersion of each can be recognized.

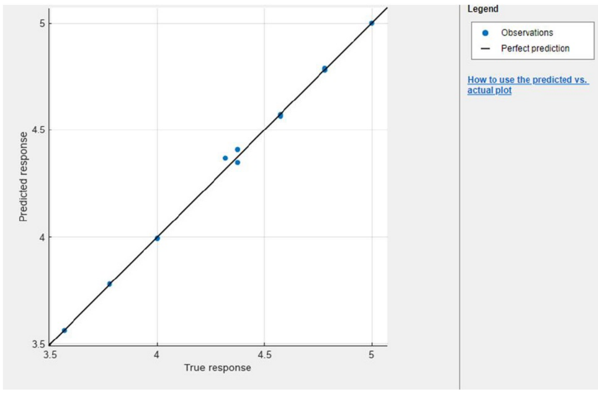

Figure 3: The degree of deviation of the observed data from the predicted amount

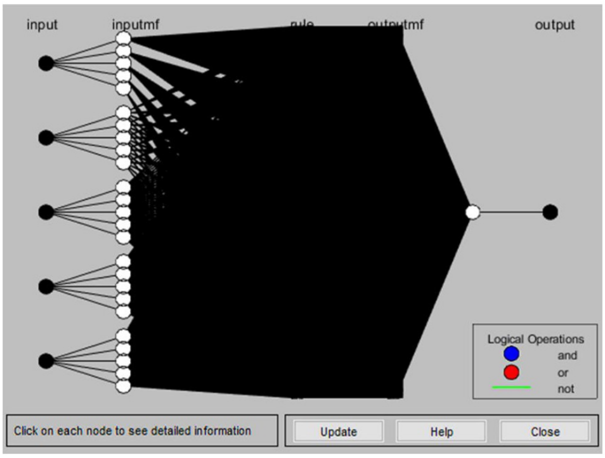

Figure 4: output of the general structure of the model

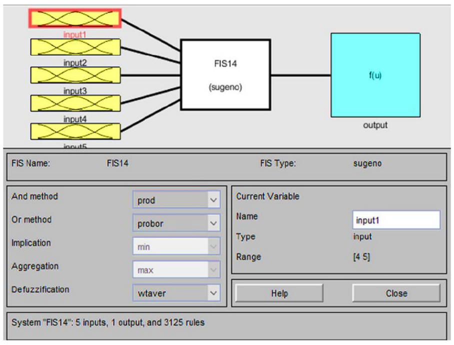

Figure 5: Fuzzy research inference system based on Sugeno method

Figure 7 shows the training error of 150 data, which is equal to 0.010097 for 40 repetitions (due to the absence of system error, it was done 20 times separately) and is very acceptable. A hybrid method was used to train the fuzzy inference system, which performed better than other methods.

In Figure 8, a comparison was made between the trained data and the output of the fuzzy inference system, the data is shown in the form of blue circles and the target output of the fuzzy inference system is shown in the form of a star and in red. As it is clear, the results overlapped in a very acceptable way and it was confirmed with the average test error of 0.100585, which is very acceptable.

In this step, the designed fuzzy inference system is evaluated by the test data and entered into the model in the form of a neural network as the training data. As shown in Figure 9, the number of 48 data randomly selected from the total data, as input, measures the performance of the model. The test data output shows a numerical output

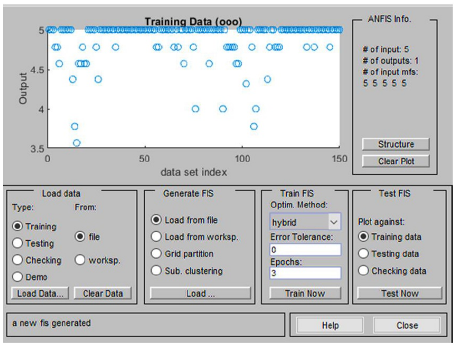

Figure 6: Model output based on training data

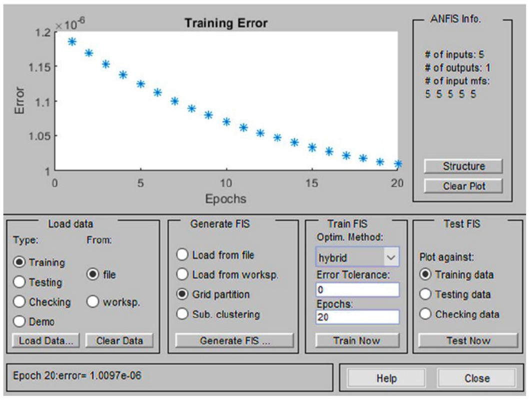

Figure 7: Model training data error

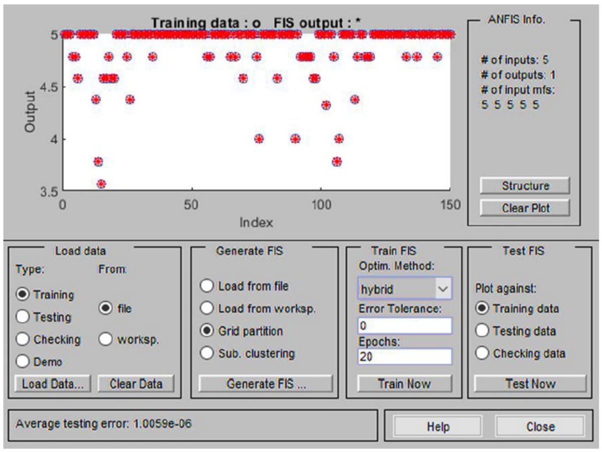

Figure 8: Overlapping training data with the output of the fuzzy inference system

between 4 and 5.

In Figure 10, a comparison is made between the test data and the target output of the fuzzy inference system. The test data are shown as blue dots and the target output of the fuzzy inference system is shown as red stars. As shown in the figure, excellent overlap with less error than the overlap of the training data and the target output of the fuzzy inference system was obtained. The value of this error was less and equal to 0.0079291. This problem indicates the correct performance of the model in the design of the fuzzy system, which is well trained and can be used as an approved model.

Figure 11 shows the fuzzy inference system for each of the inputs including their membership functions. By using this section and by changing each of the inputs, it is possible to include how the result changes. This section helped to add more richness to this research and access to the analysis of the results from more angles, which will be mentioned

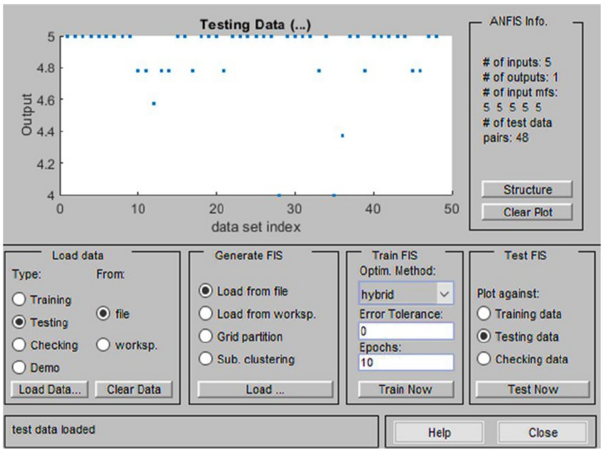

Figure 9: Model test data output

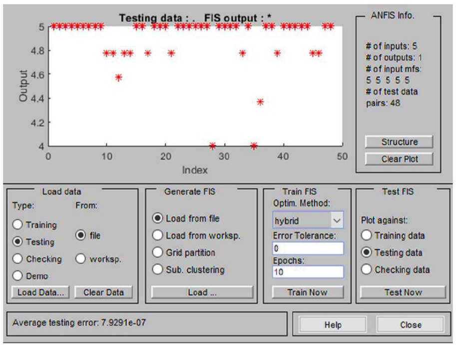

Figure 10: Overlay test data with fuzzy inference output

in the fifth chapter.

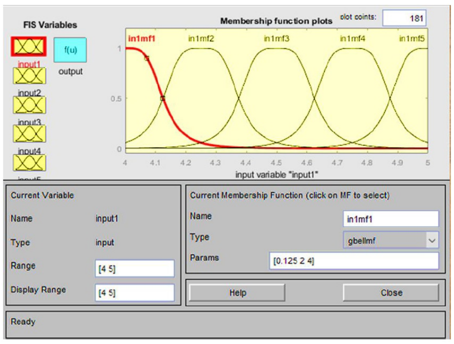

Figure 11: Membership functions of inputs and outputs based on the bell model

In the following figures, the surface diagrams between both inputs and their relationship with the output are shown separately. These figures have provided the basis for further analysis on the level of sensitivity of inputs in a pairwise comparison with each other.

4 Conclusion

According to what was stated in the literature, the innovation process, in its common form, was defined as steps including finding new ideas, selecting and sifting ideas, implementing and acquiring values. This definition is taken from the point of view of Joe Tidd [137]. The opinions of other researchers and experts in the field of innovation, although they may differ in the use of words, but in the general sense, it is not outside of these steps. Even the concept

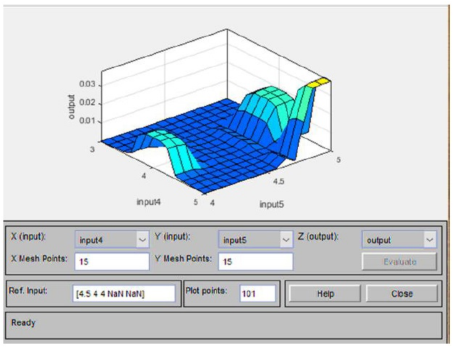

Figure 12: Relationship between entry level 4 and entry level 5

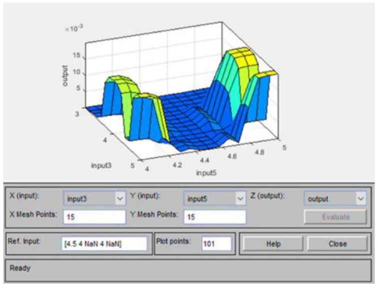

Figure 13: Relationship between entry level 3 and entry level 5

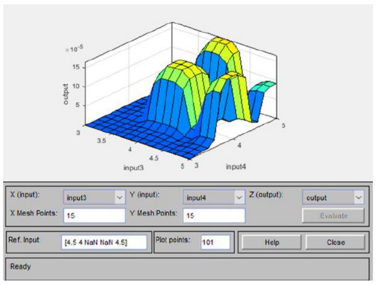

Figure 14: Relationship between entry level 3 and entry level 4

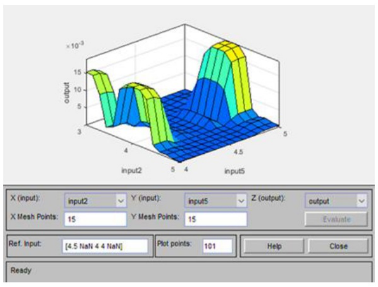

Figure 15: Relationship between entry level 2 and entry level 5

of open innovation is proposed by Bogers et al., in the same stages but in a different paradigm [20]. Another thing is that different industries have been tied to a concept called research and development as the heart of their organization's innovation over the years after the industrial revolution and with the increasing progress of new technologies and the emergence of new indicators for production. In fact, it is the control room of innovations and relevant processes in this sector. Now, it has been looked at either structurally in the organization or conceptually in the framework of organizational strategy.

Considering these general questions and following them more questions that deal with details in this field, the

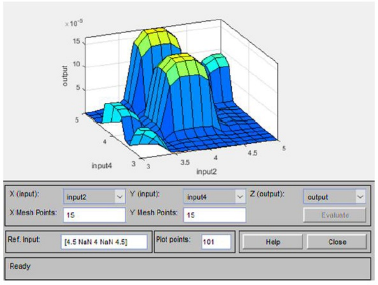

Figure 16: Relationship between entry level 4 and entry level 2

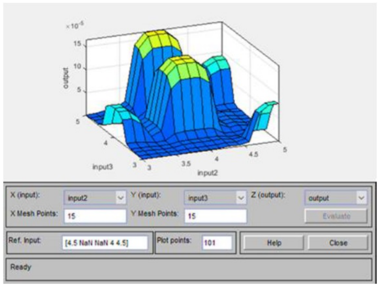

Figure 17: Relationship between entry level 2 and entry level 3

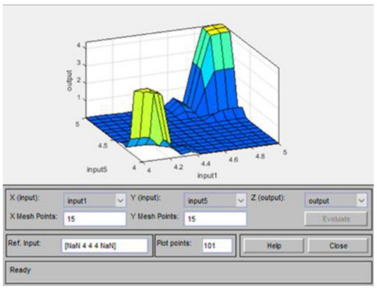

Figure 18: Relationship between entry level 1 and entry level 5

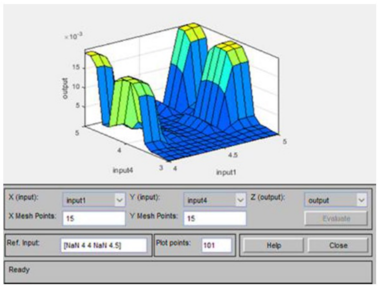

Figure 19: Relationship between entry level 4 and entry level 1

researchers of this research started to review the existing literature to find answers to these questions. Among various library and sometimes field searches abroad, they came across the concept of innovation laboratory. By further examining the related literature and field research of several case studies, the researchers found that this concept has more potential. By referring to the website of some world-renowned organizations and visiting some of them in person, the researchers realized that even in terms of naming, the tendency of organizations to use the word innovation laboratory is more than that of research and development center, and also the historical course of the literature shows that day by day, innovation laboratory has found a more prominent place in the structure of organizations. With more accuracy in the literature and case studies, it seemed that this concept can answer the questions of this research. Therefore, literature, theoretical foundations and innovation labs in different organizations were reviewed in a very

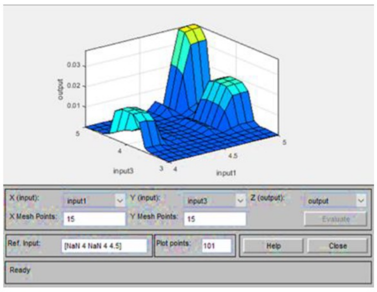

Figure 20: Relationship between entry level 1 and entry level 3

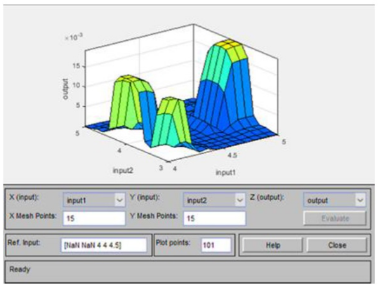

Figure 21: Relationship between entry level 1 and entry level 2

extensive way and over a period of about two years.

Therefore, it can be said that the major part of the literature review examined the innovation process in the digital platform and the digital innovation laboratory centered on artificial intelligence. This study went so far that as an output, a model was designed for a smart innovation laboratory, a model that, in the theoretical dimension, expresses the characteristics of an innovation laboratory suitable for the digital age, and in the practical dimension, as a reference for industries and organizations, in Using these laboratories as much as possible and culturizing the innovation process is compatible with the digital age. In fact, researchers have given importance to the theoretical and practical implications of this research.

To measure the degree of digitalization of the innovation process in laboratories, a method was needed to predict the level of digitalization, so that by having inputs in the model, the degree of digitalization of the innovation process can be predicted. In the practical dimension, in the sense that, in order to implement and implement their innovation processes through innovation laboratories, industries need to check the measure of how much they have been able to digitize the innovation process in their organization. This model is an answer to the question that if there are input indicators of this model, it can be predicted to what extent they have succeeded in digitizing the innovation process. Then by changing the inputs, whether in terms of financial and time investment on input indicators or in terms of process design and other indicators, they can increase the level of their organization's achievement of digitizing their innovation process. As it was said, the centrality of being digital in this research is with artificial intelligence. So that in addition to digitizing the innovation process in general, the advantages of artificial intelligence technology can also be used in innovation processes. In order to find answers to the mentioned research questions, a research methodology was designed. At first, the objectives of the research were determined separately, then the optimal method was designed for each of them separately.

In fact, the general goal and main question of this research, which was the modeling of a digital innovation laboratory centered on artificial intelligence, was successfully carried out with a very low model error during testing. In fact, by determining the effective indicators and components for the design of a digital innovation laboratory centered on artificial intelligence, a model with this theme was obtained to be able to predict the digital level of the innovation process. The more an organization has been able to digitize the innovation process according to the inputs given to the model, the more successful it has been in doing this important thing, i.e. designing a digital innovation laboratory. The indicators (inputs) of this model are determined in such a way that they implicitly form the components of an innovation laboratory, so the output of the model is the degree of digitalization of the innovation process, in fact, the degree of digitalization (based on artificial intelligence) of a laboratory It shows innovation. For modeling in this research, the adaptive neural fuzzy inference system method was used, which is based on deep learning and neural networks and the clustering performed by it as one of the subsets of unsupervised artificial intelligence. It can be acknowledged that in this research, an intelligent model for the design of a digital innovation laboratory (centered on artificial intelligence) has been presented.

In addition to the main goal and the special goals of the research, which was realized through the presentation of the model, by examining the relationships obtained as shown in the surface diagrams, it is possible to determine the sensitivity and impact of each of the components (variables) in the output, i.e. the amount the digitality of the innovation process was analyzed in innovation laboratories. According to the findings, it can be stated:

- The level of sensitivity and impact of input 1, i.e. the benefit of digital technologies based on artificial intelligence, has more than the other 4 inputs on the degree of digitalization of the innovation process, in the sense that having these technologies is the main focus of the output, and if there is no in a laboratory, they practically benefit from other components, it is less effective.
- The lowest sensitivities and impact on the output in the model belonging to the 3rd and 4th components, i.e. networking and smart learning, were identified next to the component of benefiting from technologies, and this could mean that in the conditions of benefiting from digital technologies in an implicit way, networking and learning and preserving knowledge also happen in the digital platform.
- Another thing that was observed, even in the case of having a less digital organizational structure, i.e. component number 2, we will still see a high level of digital innovation in the output (in the case of having 4 other inputs), so the impact of this second input is also in the digital level of innovation laboratory was observed to be low.

Innovation labs are models of innovation management that aim to foster creative and critical thinking, guide the organization in finding the best ways to produce knowledge and digital culture, introduce technology, digitize operations and implement digital strategies for continuous and digital innovation.

5 Discussion

As discussed, the ideal form for an innovation process, whether in its general form from the stage of idea formation to entering the market and commercialization, or in each of the parts separately, should be in such a way that the highest Gain productivity (efficiency and effectiveness) during the process. One of the latest concepts that covers the innovation process from the beginning to the end is the innovation laboratory concept. In addition, customers are evolving with the goal of participating in co-creation processes of products, services and experiences. Their needs and habits, as well as the ways and speed of using goods, are changing. Therefore, the dynamics of innovation is more and more repeated, cyclical and characterized by a high rate of substitution of new and newer products, services and solutions.

The applications of artificial intelligence in the innovation laboratory can affect the process of creating knowledge and the ability to learn and absorb it. The subsequent impact on technological innovation is mainly created in the following ways. This means that artificial intelligence promotes technological innovation by:

- Accelerating the creation of knowledge.
- Acceleration of knowledge and technology.
- Improving the ability to learn and absorb
- Increasing investment in research and development and talents.

In line with knowledge creation, as described above, the development of artificial intelligence supports the collection of data to reveal entirely new ways of looking at existing knowledge, supports the rapid pace of testing different ways of integrating knowledge, and provides discovery for It provides new knowledge. That is: the development of artificial intelligence creates new knowledge.

In particular, AI technology has clearly helped business enterprises to increase their data collection capabilities, which has led to the rapid development of various tools to deal with big data. Not only do intelligent machines or algorithms, such as machine learning, deep learning, etc., perform tasks, but new forms of human-machine interaction can produce more efficient knowledge retrieval and data processing. This in turn speeds up data collection and improves the accuracy and reliability of the resulting understanding and knowledge. Due to the development of artificial intelligence, such advanced methods of analysis have been introduced. For example, deep learning and computer vision technologies can process large amounts of information faster than ever before. This helps to create new knowledge and new computational schemes faster than before to accelerate the process of regrouping knowledge. In other words, what accelerates this concept is the process of collecting and structuring huge data into information to create knowledge.

Research limitation

One of the limitations of the research that was out of the hands of the researchers was the fact that many knowledge-based companies were unfamiliar with the concept of the innovation laboratory, and because of the name of the laboratory, many made mistakes in completing the questionnaire in the first place. The researchers spent a lot of time to justify the respondents and introduce them to the concept of innovation laboratory in written form at the beginning of the questionnaire and even in person.

Another thing is that the digital innovation laboratory was not observed in the country, so the researchers needed to spend more time to refer to samples from abroad to examine case studies in this field.

Future studies

According to the findings of the research, it is suggested to design the innovation laboratory model in different industries and for each industry separately for future researches. In the literature, researchers encountered a wide range of innovation laboratories, such as banking, schools and higher education institutions, health, etc.

The second suggestion is that future researches can design a separate model for each of the input components in such a way that the input component of this research is placed in the output position and the indicators determined in this research are used as their inputs. It is possible to design 5 other models according to the five components of this research, and connecting these models to develop a final and macro model can bring new achievements.

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References

[1] D. Acemoglu and P. Restrepo, *Artificial intelligence, automation, and work*, A. Agrawal, J. Gans and A. Goldfarb (Eds.), The economics of artificial intelligence: An agenda, University of Chicago Press, 2018, pp. 197–236.

[2] African Union, *The digital transformation strategy for Africa (2020-30)*, www.au.int, 2020.

[3] M. Agbali, C. Trillo, I.A. Ibrahim, Y. Arayici, and T. Fernando, *Are smart innovation ecosystems really seeking to meet citizens' needs? Insights from the stakeholders' vision on smart city strategy implementation*, Smart Cities **2** (2019), no. 2, 307–327.

[4] P. Agrawal, *Artificial intelligence in drug discovery and development*, J. Pharmaco. 6 (2018), no. 02.

[5] M. Al-Amin, T. Hossain, and J. Islam, *The technology development and management of smart manufacturing system: A review on theoretical and technological perspectives*, Eur. Sci. J. **17** (2021), no. 43, 170–193.

[6] S. Albukhitan, *Developing digital transformation strategy for manufacturing*, Proc. Comput. Sci. **170** (2020), 664–671.

[7] S. Alter, *The Work System Method: Connecting People, Processes, and IT for Business Results*, Work System Method, 2006.

[8] W.A. Ansari, P. Diya, S. Patil, and S. Patil, *A review on robotic process automation-the future of business organizations*, 2nd Int. Conf. Adv. Sci. Technol., 2019.

[9] M. Arkesteijn, B. Van Mierlo and C. Leeuwis, *The need for reflexive evaluation approaches in development cooperation*, Evaluation **21** (2015), no. 1, 99–115.

[10] A. Asadullah, I. Faik, and A. Kankanhalli, *Digital platforms: A review and future directions*, 22nd Pacific Asia Conf. Inf. Syst. (PACIS 2018), Yokohama, Japan, Assoc. Inf. Syst., 2018, no. 248.

[11] J. Åström, W. Reim, and V. Parida, *Value creation and value capture for AI business model innovation: A three-phase process framework*, Rev. Manag. Sci. **16** (2022), no. 7, 2111–2133.

[12] P.-A. Balland, R. Boschma, and K. Frenken, *Proximity and innovation networks: An evolutionary approach*, Re-framing Regional Development, Routledge, 2013, pp. 186–200.

[13] C. Bason and A. Schneider, *Global Trends in Design*, C. Bason, (ed.) Design for policy, Farnham: Gower Ashgate, 2014.

[14] C. Beaudoin, S. Joncoux, J.-F. Jasmin, A. Berberi, C. McPhee, R.S. Schillo, and V.M. Nguyen, *A research agenda for evaluating living labs as an open innovation model for environmental and agricultural sustainability*, Envir. Challeng. **7** (2022), p. 100505.

[15] G.B. Benitez, N.F. Ayala, and A.G. Frank, *Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation*, Int. J. Prod. Econ. **228** (2020), 107735.

[16] A. Bharadwaj, O.A. El Sawy, P.A. Pavlou, and N.V. Venkatraman, *Digital business strategy: toward a next generation of insights*, MIS Quart. **37** (2013), no. 2, 471–482.

[17] S.E. Bibri and J. Krogstie, *The emerging data–driven Smart City and its innovative applied solutions for sustainability: The cases of London and Barcelona*, Energy Inf. **3** (2020), 1–42.

[18] P.M. Bican and A. Brem, *Digital business model, digital transformation, digital entrepreneurship: Is there a sustainable "digital"?*, Sustainability **12** (2020), no. 13, p. 5239.

[19] L. Bloom and R. Faulkner, *Innovation spaces: lessons from the United Nations*, Third World Quart. **37** (2016), no. 8, 1371–1387.

[20] M. Bogers, H. Chesbrough, and C. Moedas, *Open innovation: Research, practices, and policies*, California Manag. Rev. **60** (2018), no. 2, 5–16.

[21] M. Bogers, R. Hadar, and A. Bilberg, *Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing*, Technol. Forecast. Soc. Change **102** (2016), 225–239.

[22] A. Booth, M. Clarke, D. Ghersi, D. Moher, M. Petticrew, and L. Stewart, *An international registry of systematic-review protocols*, Lancet **377** (2011), no. 9760, 108–109.

[23] R.B. Bouncken, S. Kraus, and N. Roig-Tierno, *Knowledge-and innovation-based business models for future growth: Digitalized business models and portfolio considerations*, Rev. Manag. Sci. **15** (2021), no. 1, 1–14.

[24] H. Brdesee, *A divergent view of the impact of digital transformation on academic organizational and spending efficiency: A review and analytical study on a university E-service*, Sustainability **13** (2021), no. 13, p. 7048.

[25] J. Brown, T. Gosling, B. Sethi, B. Sheppard, C. Stubbings, J. Sviokla, J. Williams, D. Zarubina, and L. Fisher, *Workforce of the Future: The Competing Forces Shaping 2030*, London, PWC, 2017.

[26] R.S. Burt, *Bridge decay*, Soc. Networks **24** (2002), no. 4, 333–363.

[27] J. Buvat, B. Gilchriest, E. Turkington, S. KVJ, and A. Ghosh, *The Discipline of Innovation: Making Sure Your Innovation Center Aktually Makes Your Organization More Innovative*, Digital Transformation Institute, 2017.

[28] Capgemini Digital Transformation Institute, *The Digital Talent Gap: Are Companies Doing Enough?*, Capgemini and LinkedIn, 2017.

[29] C. Cautela, P. Pisano, and M. Pironti, *The emergence of new networked business models from technology innovation: An analysis of 3-D printing design enterprises*, Int. Entrepr. Manag. J. **10** (2014), 487–501.

[30] C. Cennamo, *Competing in digital markets: A platform-based perspective*, Acad. Manag. Persp. **35** (2021), no. 2, 265–291.

[31] M. Chen, *Education Nation: Six Leading Edges of Innovation in our Schools*, John Wiley & Sons, 2010.

[32] C.M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Harvard Business Review Press, 2015.

[33] G. Christian, *Predictive coding: Adopting and adapting artificial intelligence in civil litigation*, Can. B. Rev. **97** (2019), 486.

[34] F. Ciampi, R. Rialti, and G. Marzi, *Artificial intelligence, big data, strategic flexibility, agility, and organizational resilience: A conceptual framework based on existing literature*, Int. Conf. WWW/Internet 2018 Appl. Comput., 2018.

[35] M.V. Ciasullo, M. Calabrese, and A. La Sala, *Surfing across industrial revolutions: a resilient sensemaking perspective on innovation*, Glob. Bus. Org. Excell. **43** (2024), no. 2, 27–42.

[36] R.F. Ciriello, A. Richter, and G. Schwabe, *Digital innovation*, Bus. Inf. Syst. Eng. **60** (2018), 563–569.

[37] J. Clark, *Manufacturing by design: the rise of regional intermediaries and the re-emergence of collective action*, Cambridge J. Reg. Econ. Soc. **7** (2014), no. 3, 433–448.

[38] M. Coccia, *Artificial intelligence technology in cancer imaging: Clinical challenges for detection of lung and breast cancer*, J. Soc. Admin. Sci. **6** (2019), no. 2, 82–98.

[39] M. Coccia, *Technological innovation*, Innovations **11** (2021), I12.

[40] A. Corre and G. Mischke, *The Innovation Game: A New Approach to Innovation Management and R&D*, Springer Science & Business Media, 2005.

[41] A. Coskun-Setirek and Z. Tanrikulu, *Digital innovations-driven business model regeneration: A process model*, Technol. Soc. **64** (2021), 101461.

[42] M.S. Dahl and C.Ø. Pedersen, *Knowledge flows through informal contacts in industrial clusters: myth or reality?*, Res. Policy **33** (2004), no. 10, 1673–1686.

[43] V. Desai and B. Vidyapeeth, *Digital marketing: A review*, Int. J. Trend Sci. Res. Dev. **5** (2019), no. 5, 196–200.

[44] M. De Silva and M. Wright, *Entrepreneurial co-creation: societal impact through open innovation*, R&D Manag. **49** (2019), no. 3, 318–342.

[45] P. D'Este, S. Iammarino, M. Savona and N. Von Tunzelmann, *What hampers innovation? Revealed barriers versus deterring barriers*, Res. Policy **41** (2012), no. 2, 482–488.

[46] R. Dorschel, *Discovering needs for digital capitalism: The hybrid profession of data science*, Big Data Soc. **8** (2021), no. 2, 20539517211040760.

[47] N.D. Du Preez and L. Louw, *A framework for managing the innovation process*, PICMET'08-2008 Portland Int. Conf. Manag. Engin. Technol., IEEE, 2008, pp. 546–558.

[48] B. Evans and S.M. Cheng, *Canadian government policy innovation labs: An experimental turn in policy work?*, Canad. Public Admin. **64** (2021), no. 4, 587–610.

[49] A. Eyring, N. Hoyt, J. Tenny, R. Domike, and Y. Hovanski, *Analysis of a closed-loop digital twin using discrete event simulation*, Int. J. Adv. Manufactur. Technol. **123** (2022), no. 1–2, 245–258.

[50] I. Fazey, N. Schäpke, G. Caniglia, A. Hodgson, I. Kendrick, C. Lyon, G. Page, J. Patterson, C. Riedy, and T. Strasser, *Transforming knowledge systems for life on Earth: Visions of future systems and how to get there*, Energy Res. Soc. Sci. **70** (2020), 101724.

[51] F. Fecher, J. Winding, K. Hutter, and J. Füller, *Innovation labs from a participants' perspective*, J. Bus. Res. **110** (2020), 567–576.

[52] R.G. Fichman, B.L. Dos Santos, and Z. Zheng, *Digital innovation as a fundamental and powerful concept in the information systems curriculum*, MIS Quart. **38** (2014), no. 2, 329–A315.

[53] A. Garzoni, I. De Turi, G. Secundo, and P. Del Vecchio, *Fostering digital transformation of SMEs: A four levels approach*, Manag. Decis. **58** (2020), no. 8, 1543–1562.

[54] R. Gey, L.-P. Meyer, and M. Thieme, *A conceptual framework for describing the phenomenon innovation laboratory: A structurational viewpoint*, Proc. XXIII Int. RESER Conf., Aix en Provence, France, 2013, pp. 1–17.

[55] P.M. Gilch and J. Sieweke, *Recruiting digital talent: The strategic role of recruitment in organisations' digital transformation*, German J. Human Resource Manag. **35** (2021), no. 1, 53–82.

[56] A. Goldfarb and D. Trefler, *Artificial intelligence and international trade*, A. Agrawal, J. Gans and A. Goldfarb (Eds.), The economics of artificial intelligence: An agenda, Chicago: University of Chicago Press, 2019, pp. 463–492.

[57] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*, MIT Press, 2016.

[58] A. Grguric, E. Vlacic, and N. Drvenkar, *Assessing firms'competitiveness and technological advancement by applying artificial intelligence as a differentiation strategy-a proposed conceptual model*, M. Milkovic, K. Hammes and O. Bakhtina (Eds.), Economic and social development: Book of proceedings, Varazdin Development and Entrepreneurship Agency, 2020, pp. 43–61.

[59] L. Guo and L. Xu, *The effects of digital transformation on firm performance: Evidence from China's manufacturing sector*, Sustainability **13** (2021), no. 22, p. 12844.

[60] M. Haenlein and A. Kaplan, *A brief history of artificial intelligence: On the past, present, and future of artificial intelligence*, California Manag. Rev. **61** (2019), no. 4, 5–14.

[61] L.A. Hall and S. Bagchi-Sen, *A study of R&D, innovation, and business performance in the Canadian biotechnology industry*, Technovation **22** (2002), no. 4, 231–244.

[62] S.Y. Han and S.J. Bae, *Internalization of R&D outsourcing: An empirical study*, Int. J. Prod. Econ. **150** (2014), 58–73.

[63] J. Han, I. Bose, N. Hu, B. Qi, and G. Tian, *Does director interlock impact corporate R&D investment?*, Decis. Support Syst. **71** (2015), 28–36.

[64] A. Hanelt, R. Bohnsack, D. Marz, and C. Antunes Marante, *A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change*, J. Manag. Stud. **58** (2021), no. 5, 1159–1197.

[65] A. Harraf, I. Wanasika, K. Tate, and K. Talbott, *Organizational agility*, J. Appl. Bus. Res. **31** (2015), no. 2, 675–686.

[66] R. Harris, A. Krenz, and J. Moffat, *The effects of absorptive capacity on innovation performance: A cross-country perspective*, J. Common Market Stud. **59** (2021), no. 3, 589–607.

[67] T.K. Hazra and B. Unhelkar, *Enterprise Architecture for Digital Business: Integrated Transformation Strategies*, CRC Press, 2020.

[68] O. Henfridsson, J. Nandhakumar, H. Scarbrough, and N. Panourgias, *Recombination in the open-ended value landscape of digital innovation*, Inf. Org. **28** (2018), no. 2, 89–100.

[69] S. Hielscher and A. Smith, *Community-based digital fabrication workshops: A review of the research literature*, SWPS 2014-08, Available at SSRN: https://ssrn.com/abstract=2742121, (2014).

[70] D. Horvat, H. Kroll, and A. Jäger, *Researching the effects of automation and digitalization on manufacturing companies' productivity in the early stage of industry 4.0*, Procedia Manufactur. **39** (2019), 886–893.

[71] L. Ivančić, V.B. Vukšić, and M. Spremić, *Mastering the digital transformation process: Business practices and lessons learned*, Technol. Innov. Manag. Rev. **9** (2019), no. 2.

[72] J.-S.R. Jang, *Fuzzy modeling using generalized neural networks and Kalman filter algorithm*, Proc. Ninth Nat. Conf. Artific. Intel. **2** (1991).

[73] J.-S. Jang, *ANFIS: adaptive-network-based fuzzy inference system*, IEEE Trans. Syst. Man Cybernet. **23** (1993), no. 3, 665–685.

[74] R.D. Johnson and K. Diman, *An investigation of the factors driving the adoption of cloud-based human resource information systems by small-and medium-sized businesses*, T. Bondarouk, H.J.M. Ruël and E. Parry, (Eds.) Electronic HRM in the smart era, Emerald Publishing Limited, 2017, pp. 1–31.

[75] J. Joseph and V. Gaba, *Organizational structure, information processing, and decision-making: A retrospective and road map for research*, Acad. Manag. Annal. **14** (2020), no. 1, 267–302.

[76] K.D. Joshi, L. Chi, A. Datta, and S. Han, *Changing the competitive landscape: Continuous innovation through IT-enabled knowledge capabilities*, Inf. Syst. Res. **21** (2010), no. 3, 472–495.

[77] J. Kallinikos, A. Aaltonen, nd A. Marton, *The ambivalent ontology of digital artifacts*, MIS Quart. **37** (2013), no. 2, 357–370.

[78] D. Karaboga and E. Kaya, *Adaptive network based fuzzy inference system (ANFIS) training approaches: a comprehensive survey*, Artif. Intell. Rev. **52** (2019), 2263–2293.

[79] J. Keizer, A. Liang, G. Salokhe, and M. Sini, *Towards an infrastructure for knowledge management within European Ethics: Methodologies for semantic integration of heterogeneous resources*, FAO, 2005.

[80] T. Komatsu, M. Salgado, A. Deserti, and F. Rizzo, *Policy labs challenges in the public sector: The value of design for more responsive organizations*, Policy Design Practice **4** (2021), no. 2, 271–291.

[81] M. Kotarba, *Digital transformation of business models*, Found. Manag. **10** (2018), no. 1, 123–142.

[82] T. Kretschmer and P. Khashabi, *Digital transformation and organization design: An integrated approach*, California Manag. Rev. **62** (2020), no. 4, 86–104.

[83] C. Lee and L. Ma, *The role of policy labs in policy experiment and knowledge transfer: A comparison across the UK, Denmark, and Singapore*, J. Compar. Policy Anal.: Res. Practice **22** (2020), no. 4, 281–297.

[84] S. Leminen and M. Westerlund, *Categorization of innovation tools in living labs*, PhD. Thesis, Laurea University, 2017.

[85] A. Lerro and G. Schiuma, *Assessing performance and impact of the technological districts (TDs): General modelling and measurement system*, Measur. Bus. Excel. **19** (2015), no. 3, 58–75.

[86] M. Lewis and J. Moultrie, *The organizational innovation laboratory*, Creat. Innov. Manag. **14** (2005), no. 1, 73–83.

[87] B. Lianto, M. Dachyar, and T.P. Soemardi, *Continuous innovation: a literature review and future perspective*, Int. J. Adv. Sci. Eng. Inf. Technol. **8** (2018), no. 3, 771–779.

[88] L. Linde, D. Sjödin, V. Parida, and H. Gebauer, *Evaluation of digital business model opportunities: A framework for avoiding digitalization traps*, Res.-Technol. Manag. **64** (2020), no. 1, 43–53.

[89] R. Linzalone, G. Schiuma, and S. Ammirato, *Connecting universities with entrepreneurship through digital learning platform: Functional requirements and education-based knowledge exchange activities*, Int. J. Entrepr. Behav. Res. **26** (2020), no. 7, 1525–1545.

[90] J. Liu, H. Chang, J.Y.-L. Forrest, and B. Yang, *Influence of artificial intelligence on technological innovation: Evidence from the panel data of China's manufacturing sectors*, Technol. Forecast. Soc. Change **158** (2020), p. 120142.

[91] W. Magadley and K. Birdi, *Innovation labs: An examination into the use of physical spaces to enhance organizational creativity*, Creat. Innov. Manag. **18** (2009), no. 4, 315–325.

[92] T.J. Marion and S.K. Fixson, *The transformation of the innovation process: How digital tools are changing work, collaboration, and organizations in new product development*, J. Prod. Innov. Manag. **38** (2021), no. 1, 192–215.

[93] M. McGann, T. Wells, and E. Blomkamp, *Innovation labs and co-production in public problem solving*, Public Manag. Rev. **23** (2021), no. 2, 297–316.

[94] A.B. Memon, K. Meyer, M. Thieme, and L.-P. Meyer, *Inter-InnoLab collaboration: An investigation of the diversity and interconnection among innovation laboratories*, J. Eng. Technol. Manag. **47** (2018), 1–21.

[95] M. Meyer, J. Kuusisto, K. Grant, M. De Silva, S. Flowers, and U. Choksy, *Towards new triple helix organisations? A comparative study of competence centres as knowledge, consensus and innovation spaces*, R&D Manag. **49** (2019), no. 4, 555–573.

[96] C. Møller, *ERP II: A conceptual framework for next-generation enterprise systems?*, J. Enterpr. Inf. Manag. **18** (2005), no. 4, 483–497.

[97] J. Møller Jensen and T. Hansen, *An empirical examination of brand loyalty*, J. Prod. Brand Manag. **15** (2006), no. 7, 442–449.

[98] S. Nambisan,*Architecture vs. ecosystem perspectives: Reflections on digital innovation*, Inf. Org. **28** (2018), no. 2, 104–106.

[99] S. Nambisan, K. Lyytinen, and Y. Yoo, *Digital innovation: towards a transdisciplinary perspective*, Handbook of digital innovation, Cheltenham, UK: Edward Elgar Publishing, 2020, pp. 2–12.

[100] S. Nambisan, M. Wright, and M. Feldman, *The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes*, Res. Policy **48** (2019), no. 8, p. 103773.

[101] S. Nascimento, *Critical notions of technology and the promises of empowerment in shared machine shops*, J. Peer Prod. **5** (2014), 1–4.

[102] M. Nasiri, M. Saunila, J. Ukko, T. Rantala, and H. Rantanen, *Shaping digital innovation via digital-related capabilities*, Inf. Syst. Front. **25** (2023), no. 3, 1063–1080.

[103] I. Nonaka and H. Takeuchi, *The Wise Company: How Companies Create Continuous Innovation*, Oxford University Press, 2019.

[104] M. Núñez-Merino, J.M. Maqueira-Marín, J. Moyano-Fuentes, and P.J. Martínez-Jurado, *Information and digital technologies of Industry 4.0 and Lean supply chain management: A systematic literature review*, Int. J. Prod. Res. **58** (2020), no. 16, 5034–5061.

[105] E. Ofek and M. Sarvary, *R&D, marketing, and the success of next-generation products*, Market. Sci. **22** (2003), no. 3, 355–370.

[106] D.E. O'Leary, *Artificial intelligence and big data*, IEEE Intel. Syst. **28** (2013), no. 2, 96–99.

[107] K. Olejniczak, S. Borkowska-Waszak, A. Domaradzka-Widła, and Y. Park, *Policy labs: the next frontier of policy design and evaluation?*, Policy Politics **48** (2020), no. 1, 89–110.

[108] F. Osorio, L. Dupont, M. Camargo, P. Palominos, J.I. Peña, and M. Alfaro, *Design and management of innovation laboratories: Toward a performance assessment tool*, Creat. Innov. Manag. **28** (2019), no. 1, 82–100.

[109] A. Osterwalder, Y. Pigneur, G. Bernarda, and A. Smith, *Value Proposition Design: How to Create Products and Services Customers Want*, John Wiley & Sons, 2015.

[110] N. Pandey, P. Nayal, and A.S. Rathore, *Digital marketing for B2B organizations: structured literature review and future research directions*, J. Bus. Ind. Market. **35** (2020), no. 7, 1191–1204.

[111] A. Panori, C. Kakderi, N. Komninos, K. Fellnhofer, A. Reid, and L. Mora, *Smart systems of innovation for smart places: Challenges in deploying digital platforms for co-creation and data-intelligence*, Land Use Policy **111** (2021), 104631.

[112] M. Polk, *Achieving the promise of transdisciplinarity: a critical exploration of the relationship between transdisciplinary research and societal problem solving*, Sustain. Sci. **9** (2014), 439–451.

[113] A.B. Powell, *Open culture and innovation: integrating knowledge across boundaries*, Media Culture Soc. **37** (2015), no. 3, 376–393.

[114] H. Preskill and T. Beer, *Evaluating Social Innovation*, Austrian Platform for Research and Technology Policy Evaluation, 2012.

[115] P. Raja and B. Pahat, *A review of training methods of ANFIS for applications in business and economics*, Int. J. u-and e-Serv. Sci. Technol. **9** (2016), no. 7, 165–172.

[116] A. Rangaswamy, N. Moch, C. Felten, G. Van Bruggen, J.E. Wieringa, and J. Wirtz, *The role of marketing in digital business platforms*, J. Interact. Market. **51** (2020), no. 1, 72–90.

[117] M. Ringel, A. Taylor, and H. Zablit, *The most innovative companies 2016*, BCG reports, https://media-publications.bcg.com/MIC/BCG-Most-Innovative-Companies-2015-Nov-2015.pdf, 2016.

[118] T. Ritter and C.L. Pedersen, *Digitization capability and the digitalization of business models in business-to-business firms: Past, present, and future*, Ind. Market. Manag. **86** (2020), 180–190.

[119] S.J. Russell, *Artificial Intelligence: A Modern Approach*, Pearson Education, Inc., 2010.

[120] F. Saadatmand, R. Lindgren, and U. Schultze, *Configurations of platform organizations: Implications for com-*

plementor engagement, Res. Policy 48 (2019), no. 8, p. 103770.

[121] T. Saarikko, U.H. Westergren and T. Blomquist, *Digital transformation: Five recommendations for the digitally conscious firm*, Bus. Hor. **63** (2020), no. 6, 825–839.

[122] J.-M. Sahut, L. Iandoli, and F. Teulon, *The age of digital entrepreneurship*, Small Bus. Econ. **56** (2021), 1159–1169.

[123] J. Sandberg, J. Holmström, and K. Lyytinen, *Digitization and phase transitions in platform organizing logics: Evidence from the process automation industry*, Manag. Inf. Syst. Quart. **44** (2020), no. 1, 129–153.

[124] F. Santarsiero, A. Lerro, D. Carlucci, and G. Schiuma, *Modelling and managing innovation lab as catalyst of digital transformation: Theoretical and empirical evidence*, Measur. Bus. Excel. **26** (2022), no. 1, 81–92.

[125] O. Schilke, *On the contingent value of dynamic capabilities for competitive advantage: The nonlinear moderating effect of environmental dynamism*, Strat. Manag. J. **35** (2014), no. 2, 179–203.

[126] G. Schiuma, *Managing knowledge for business performance improvement*, J. Knowledge Manag. **16** (2012), no. 4, 515–522.

[127] S. Schmidt and V. Brinks, *Open creative labs: Spatial settings at the intersection of communities and organizations*, Creat. Innov. Manag. **26** (2017), no. 3, 291–299.

[128] S. Schmidt, V. Brinks, and S. Brinkhoff, *Innovation and creativity labs in Berlin: Organizing temporary spatial configurations for innovations*, Z. Wirtsch. **58** (2014), no. 1, 232–247.

[129] J.B. Schor, C. Fitzmaurice, L.B. Carfagna, W. Attwood-Charles, and E.D. Poteat, *Paradoxes of openness and distinction in the sharing economy*, Poetics **54** (2016), 66–81.

[130] Y.R. Shrestha, S.M. Ben-Menahem, and G. Von Krogh, *Organizational decision-making structures in the age of artificial intelligence*, California Manag. Rev. **61** (2019), no. 4, 66–83.

[131] A. Smith, S. Hielscher, S. Dickel, J. Soderberg, and E. van Oost, *Grassroots digital fabrication and makerspaces: Reconfiguring, relocating and recalibrating innovation?*, University of Sussex, SPRU Working Paper SWPS 2013-02, Available at SSRN: https://ssrn.com/abstract=2731835, (2013).

[132] M. Stacey, *The FAB LAB network: A global platform for digital invention, education and entrepreneurship*, Innov.: Technol. Govern. Glob. **9** (2014), no. 1–2, 221–238.

[133] A. Ståhlbröst, *A living lab as a service: Creating value for micro-enterprises through collaboration and innovation*, Technol. Innov. Manag. Rev. **3** (2013), no. 11.

[134] T.J. Tanenbaum, A.M. Williams, A. Desjardins, and K. Tanenbaum, *Democratizing technology: Pleasure, utility and expressiveness in DIY and maker practice*, Proc. SIGCHI Conf. Human Factors Comput. Syst., 2013, pp. 2603–2612.

[135] E. Tavoletti, N. Kazemargi, C. Cerruti, C. Grieco, and A. Appolloni, *Business model innovation and digital transformation in global management consulting firms*, Eur. J. Innov. Manage. **25** (2022), no. 6, 612–636.

[136] A. Thorpe and S. Rhodes, *The public collaboration lab: Infrastructuring redundancy with communities-in-place*, She Ji: J. Design Econ. Innov. **4** (2018), no. 1, 60–74.

[137] J. Tidd, *The competence cycle: translating knowledge*, In: From knowledge management to strategic competence: Measuring technological, market and organizational innovation, World Sci. **3** (2000), no. 1.

[138] K. Timeus and M. Gascó, *Increasing innovation capacity in city governments: Do innovation labs make a difference?*, J. Urban Affairs **40** (2018), no. 7, 992–1008.

[139] D. Tortora, R. Chierici, M.F. Briamonte and R. Tiscini, *'I digitize so I exist'. Searching for critical capabilities affecting firms' digital innovation*, J. Bus. Res. **129** (2021), 193–204.

[140] H. Torvinen and K. Jansson, *Public health care innovation lab tackling the barriers of public sector innovation*, Public Manag. Rev. **25** (2023), no. 8, 1539–1561.

[141] G. Tsaramirsis, A. Kantaros, I. Al-Darraji, D. Piromalis, C. Apostolopoulos, A. Pavlopoulou, M. Alrammal, Z. Ismail, S.M. Buhari, and M. Stojmenovic, *A modern approach towards an industry 4.0 model: From driving*

technologies to management, J. Sensors **2022** (2022), 1–18.

[142] R. Tucker, *Starting an Innovation Lab? Avoid These Pitfalls*, Forbes, 2017.

[143] R. Van Goolen, H. Evers, and C. Lammens, *International innovation labs: An innovation meeting ground between SMEs and business schools*, Proc. Econ. Finance **12** (2014), 184–190.

[144] R. Verganti, L. Vendraminelli, and M. Iansiti, *Innovation and design in the age of artificial intelligence*, J. Prod. Innov. Manag. **37** (2020), no. 3, 212–227.

[145] P.C. Verhoef, T. Broekhuizen, Y. Bart, A. Bhattacharya, J.Q. Dong, N. Fabian, and M. Haenlein, *Digital transformation: A multidisciplinary reflection and research agenda*, J. Bus. Res. **122** (2021), 889–901.

[146] S.-L. Wamba-Taguimdje, S. Fosso Wamba, J.R. Kala Kamdjoug, and C.E. Tchatchouang Wanko, *Influence of artificial intelligence (AI) on firm performance: the business value of AI-based transformation projects*, Bus. Process Manag. J. **26** (2020), no. 7, 1893–1924.

[147] C. Wang, J. Hong, M. Kafouros, and M. Wright, *Exploring the role of government involvement in outward FDI from emerging economies*, J. Int. Bus. Stud. **43** (2012), 655–676.

[148] K.S. Warner and M. Wäger, *Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal*, Long Range Plann. **52** (2019), no. 3, 326–349.

[149] A. Whicher and T. Crick, *Co-design, evaluation and the Northern Ireland innovation lab*, Public Money Manag. **39** (2019), no. 4, 290–299.

[150] Y. Wijngaarden, E. Hitters, and P.V. Bhansing, *Cultivating fertile learning grounds: Collegiality, tacit knowledge and innovation in creative co-working spaces*, Geoforum **109** (2020), 86–94.

[151] S. Wildevuur, D. Van Dijk, T. Hammer-Jakobsen, M. Bjerre, A. Äyväri, and J. Lund, *Connect: Design for an Eempathic Society*, BIS Publishers, 2013.

[152] B. Williamson, *Governing methods: Policy innovation labs, design and data science in the digital governance of education*, Educ. Admin. History **47** (2015), no. 3, 251–271.

[153] D. Witschel, A. Döhla, M. Kaiser, K.-I. Voigt, and T. Pfletschinger, *Riding on the wave of digitization: Insights how and under what settings dynamic capabilities facilitate digital-driven business model change*, J. Bus. Econ. **89** (2019), 1023–1095.

[154] Y. Yoo, *The tables have turned: How can the information systems field contribute to technology and innovation management research?*, J. Assoc. Inf. Syst. **14** (2013), no. 5, p. 227.

[155] Y. Yoo, O. Henfridsson, and K. Lyytinen, *Research commentary—the new organizing logic of digital innovation: an agenda for information systems research*, Inf. Syst. Res. **21** (2010), no. 4, 724–735.

[156] W. Yu, C.Y. Wong, R. Chavez, and M. Jacobs, *Surfing with the tides: how digitalization creates firm performance through supply chain entrainment*, Int. J. Oper. Prod. Manag. **43** (2023), no. 12, 2008–2030.

[157] M. Zeschky, B. Widenmayer and O. Gassmann, *Frugal innovation in emerging markets*, Res.-Technol. Manag. **54** (2011), no. 4, 38–45.

[158] R. Zhao, X. Li, S. Joty, C. Qin, and L. Bing, *Verify-and-edit: A knowledge-enhanced chain-of-thought framework*, arXiv preprint arXiv:2305.03268, (2023).

[159] C. Zurbriggen and M.G. Lago, *An experimental evaluation tool for the Public Innovation Lab of the Uruguayan government*, Evidence Policy **15** (2019), no. 3, 437–451.