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INTRODUCTION

The purpose of this report is to highlight findings from the diagnosis of needs and demands for Factory of the Future (FoF) design. This document considers the most appropriate needs and requirements of enterprises - potential stakeholders of the FoF, and thus propose an adequate training program in the field of digital designing.

The report is based on results from questionnaire survey (Task 1.1) which is an integral part of Work Package WP1. It aims at creating a knowledge basis to understand main interest topic and knowledge gaps. The achieved results will be matched with the consortium`s competencies and skills in order to develop academic and continuous professional trainings. Moreover, the questionnaire survey allows the consortium to identify the most relevant needs of companies and map them to the skills and knowledge available in the DigiFoF project stakeholders.

1. RESEARCH DESIGN

The quantitative research was conducted according to the Computer-Assisted Web Interview (CAWI) and Paper & Pen Personal Interview (PAPI). The research tool used for gathering information assumed a form of an electronic or paper survey. Within the survey, the researchers collected data from manufacturing companies in six European countries (Italy, France, Finland, Poland, Romania, and Germany) with the aim to guide the development of training materials according to industrial needs. The survey was carried out in the period: from 14.04 - 27.05.2019 (Work Package 1, Task 1.1).

The questionnaire is composed of four different areas meant at exploring different topics:

- **General Information:** includes general questions regarding companies, their features and profiles allowing the analysis of respondents' basic characteristics.
- **Design skills and trainings**: this area includes questions regarding the design skills and the training in each specific company. It includes a focus on: the most frequent trainings used to develop design skills in the company, conditions of digital design trainings, workshops, laboratory-based trainings, personal digital

competencies of the employee of the FoF, the relevance level and the actual competence level in the company in the scope of the FoF;

- **Designing background**: it aims at exploring the topic of design. It includes questions to understand the companies' attitude towards design concepts, methods and tools as per the OMiLAB4FoF laboratory concept;
- **Area of interest and implementations**: the fourth set of questions explores the main interest areas to be treated in the FoF trainings. In particular it deals with automation of business, collection of data from the production system, designing and engineering data-driven services as well as the assessment of selected issues concerning production, product development, logistics, customer service as well as sales and marketing in an enterprise represented by a specific respondent.

The following chapters report the profile of the survey participants and results collected from the questionnaire as well.

2. GENERAL INFORMATION AND PARTICIPANTS PROFILE

The survey involved 87 representatives of enterprises, mainly from Romania, Poland, France and Italy. The representatives of Germany, Finland and the United States of America (enterprises operating in Romania) constituted smaller groups. The number of filled questionnaires exceeds the presumed success indicator for this task (expected number: 80 filled questionnaires).

The surveyed were primarily employed in large enterprises with 250-4,999 workers (39% respondents) and medium enterprises with 50-249 employees (28% respondents). The representatives of small (employing from 10 to 49 workers) and micro enterprises (characterised by the number of employed not larger than 9 people) constituted respectively 14% and 10% of the surveyed. The subjects working in very large enterprises with a number of employees bigger than 4,999 people were the most scantly represented group (9% participants). Fig. 1 illustrates the structure of respondents with regard to the size of the represented enterprises.

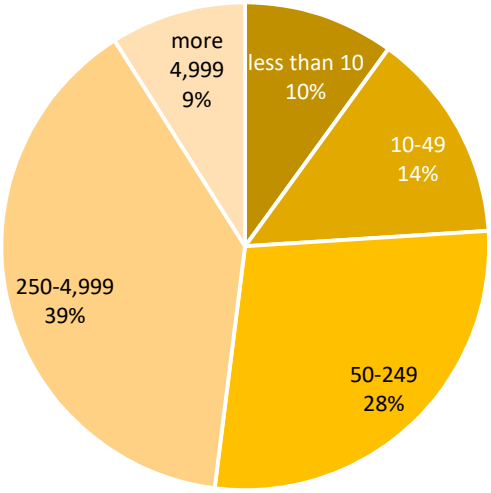

Fig. 1. Respondents structure with regard to the size of represented enterprises

Source: own study.

The respondents that participated in the survey most frequently represent the following fields: development and production of electronic devices for the automotive industry, development and testing of software as well as production related to metal structures.

It can be observed that the roles of the surveyed in a given organisation most often are as following:

- engineers working in product and/or service design;
- IT- and enterprise architects;
- strategists and innovators in charge of service/product/business model innovation;
- production workers.

A vital element that affects the assessment of the level of competencies as well as the perception of enterprises' activity and their preparation for implementing the assumptions of the FoF is the working experience of respondents. Fig. 2 presents the structure of the group of respondents that incorporates this factor.

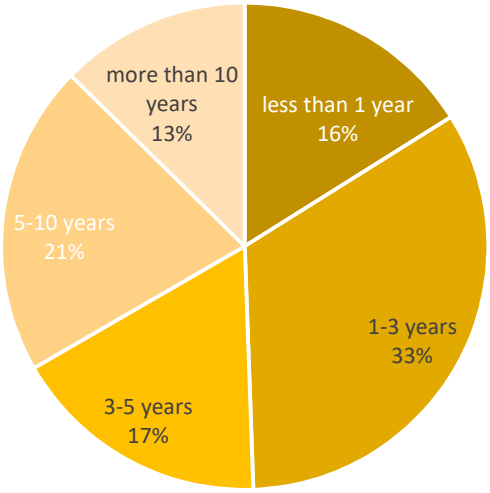

Fig. 2. Respondent structure with regard to the work experience at the current position

Source: own study.

Taking into account the respondent's work experience at the currently occupied position, it can be observed that one third of the surveyed were employees working between 1 and 3 years (33% respondents). A numerous group comprised employees with work experience of 5 to 10 years (21% surveyed). A slightly smaller group of participants constituted persons with an experience of 3 to 5 years (17% respondents), shorter than 1 year (16% surveyed) and longer than 10 years (13% subjects).

Hereafter is a summary of the survey results representing the next three sections of questionnaire:

- design skills and trainings;
- designing background;
- area of interest and implementations.

3. QUESTIONNAIRE RESULTS

3.1. Design skills and trainings

The starting point of diagnosing digital design skills for FoF entailed determining their relevance in building the current and future ability of enterprises with this respect. It is based on the role of digital design skills in the recruitment process in the analysed companies from six European countries.

The survey assumed that a design skill is an ability to intentionally create a plan or specification for the construction of an object/a service/a system/for the implementation of an activity or process. The scope of these skills involves e.g.: product design, service design, user interaction design, information system design, factory design, production process design, business process design, etc.

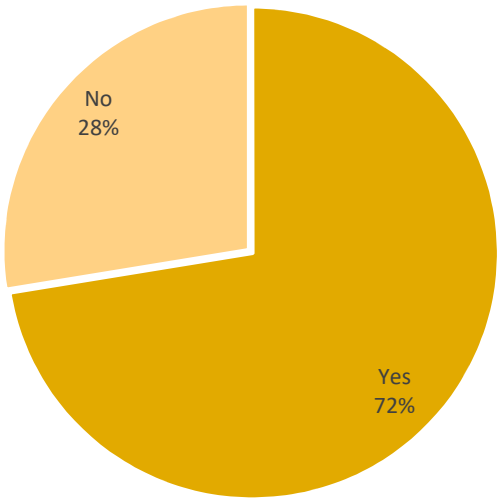

Fig. 3. Importance of design skills of a candidate during the selection process for employment

Source: own study.

With regard to the gathered results of the survey it can be claimed that 72% of enterprises takes into consideration skills in searching for new employees. This may provide evidence for noticing the significance of digital design skills for the development and for the implementation the concept of the Factories of the Future within the surveyed enterprises. A very high interest in such competencies on the side of employers (Fig. 3) may confirm the need to conduct trainings in the scope of shaping digital design skills.

A vital role of digital design skills stems from the fact that 80% of employers perceive this type of employees' skills as a factor that has a decisive impact of their promotion. This is also a significant issue that an employer takes into consideration in determining the level of employees' remuneration (Fig. 4). That observation may serve as an argument in favour of organising trainings and raising competencies among employees in the scope of process modelling and digital design.

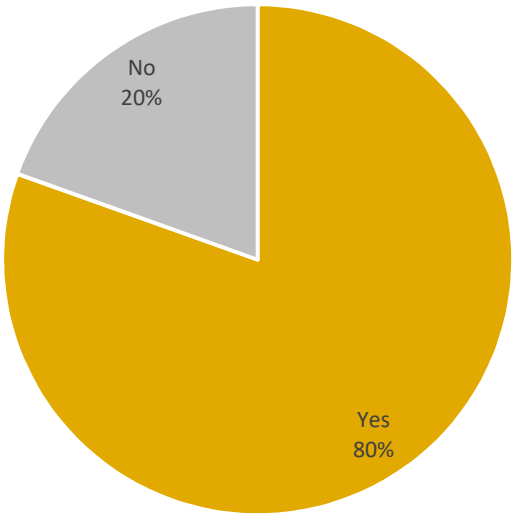

Fig. 4. Formal recognition of design skills of employees by their employers

Source: own study.

Despite the significance of digital design skills (Fig. 4), merely 62% of the enterprises interested in shaping digital design skills (importance of design skills of a candidate during the selection process and its recognition in promotion and increasing salary) provide or facilitate access for their employees to design trainings (Fig. 5).

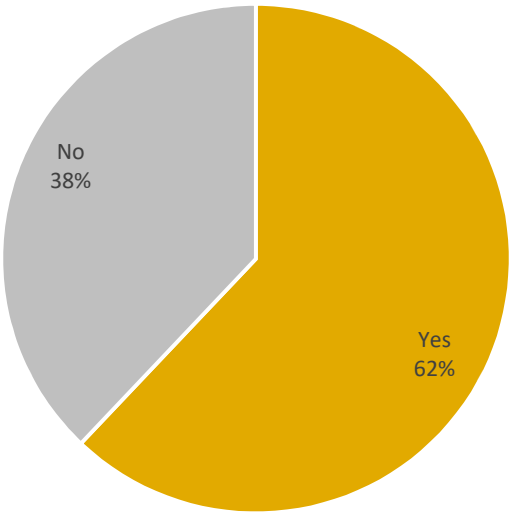

Fig. 5. Employees' access to design trainings in companies

Source: own study.

The survey resulted in the identification of a total number of 132 trainings most popular with the employees of the enterprises in question. The most popular ones were those that pertained to the following two areas:

- Software for designing;
- Project management;

The largest number of company employees participated in trainings within "Software for designing" (e.g. AutoCad, Catia, Inventor). Trainings in the scope of "Project management" entailed the basics of its methodology and issues connected with a general approach to management of software development projects (Agile) and Scrum methodology (Fig. 6).

Despite the above indicated most popular groups of trainings, the employees took part (in a smaller degree) as well in, trainings in the following areas:

- Programming;
- Software operation;
- Quality management;
- Innovation and problem solving.

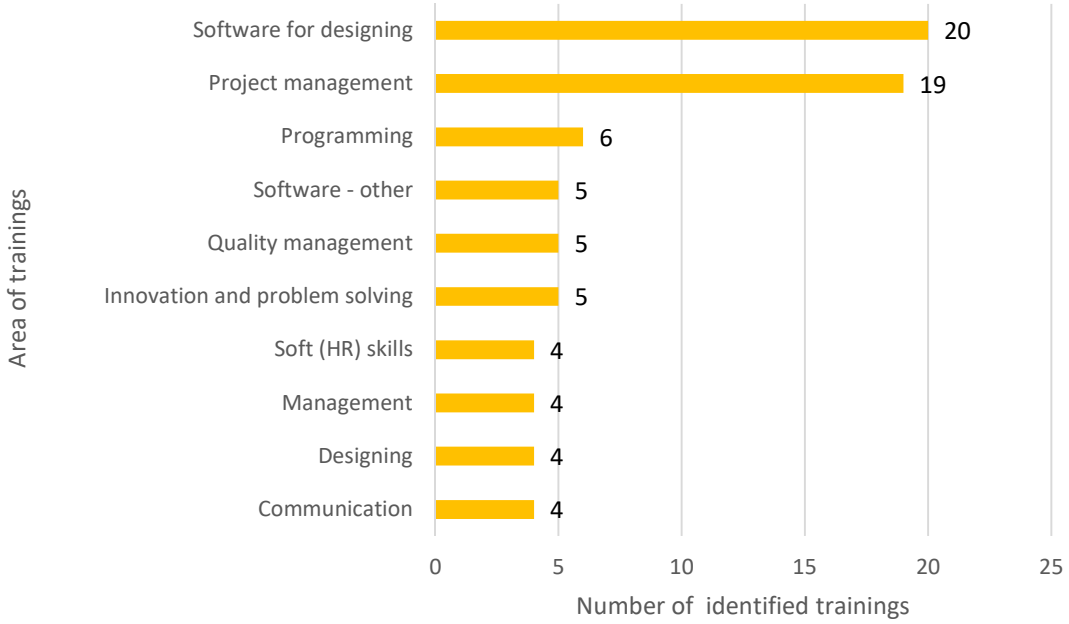

Fig. 6. Areas of trainings conducted in the companies

Source: own study.

Considering the scope of the conducted trainings, it can be stated that they concern mainly the aspect of tools, i.e. IT tools supporting designing services and products. Very rarely employees underwent specialist trainings within the methodology of process design and modelling or design thinking and creativity.

The results of the survey as well show that nearly 25% of the enterprises interested in building digital design skills (among those who recognise them as important ones, see Fig. 3 and Fig. 4) fail to conduct and/or ensure the access for their employees to trainings raising their digital design skills. This may point to the existing need to provide these companies with support in shaping their ability to train their employees for the Factories of the Future.

Not sufficient level of companies' ability in digital design trainings

Allowing for the fact that one of the major results of the DIGIFoF project is to develop the concept and a programme of trainings within digital design, it was possible to identify respondents' expectations in the scope of their form and organisation. The most popular form of training among the employees is a workshop (face-to face). It was selected by 90% of the surveyed (Fig. 7).

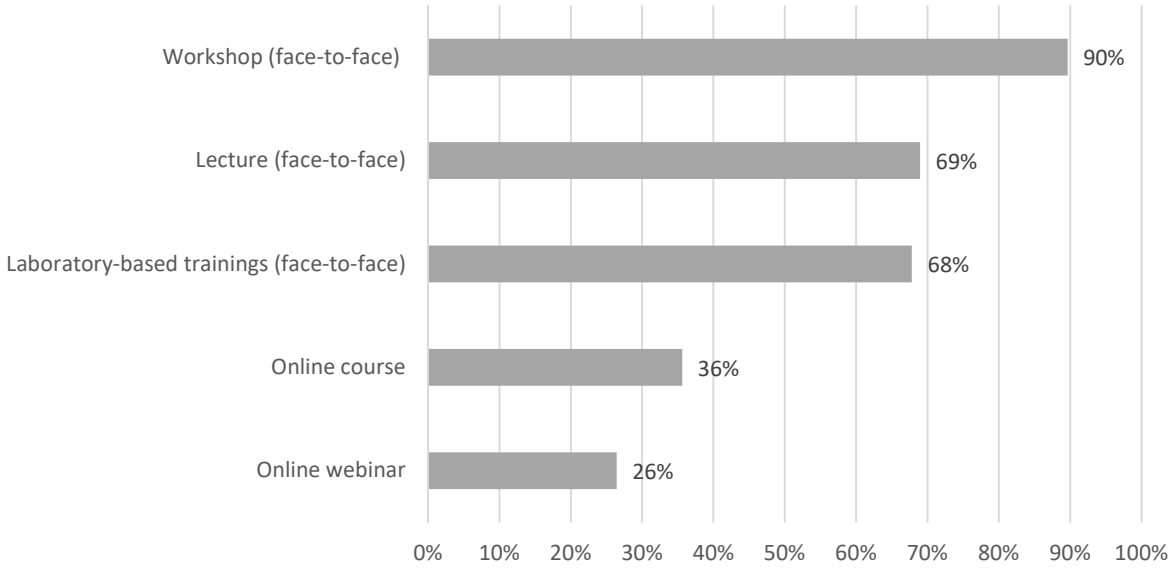

Fig. 7. Ranking of preferred techniques of digital design trainings

Source: own study.

With regard to respondents' preferences, trainings could be as well conducted in a form of lectures and laboratory-based trainings. For respondents a vital issue is ensuring direct contact (face-to-face) with the trainer (Fig. 7). Online courses and webinars were indicated as secondary forms of trainings. According to respondents' expectations, workshops or laboratory-based trainings should last from 4 to 8 hours, but in a cycle not longer than three days (Fig. 8). Moreover, respondents preferred trainings conducted in their mother tongue (74%). The remaining part declared their willingness to take part in trainings held in the English language. However, it is of note that there are no explicit factors (country, size of enterprise, experience, position) that affect the choice of this language.

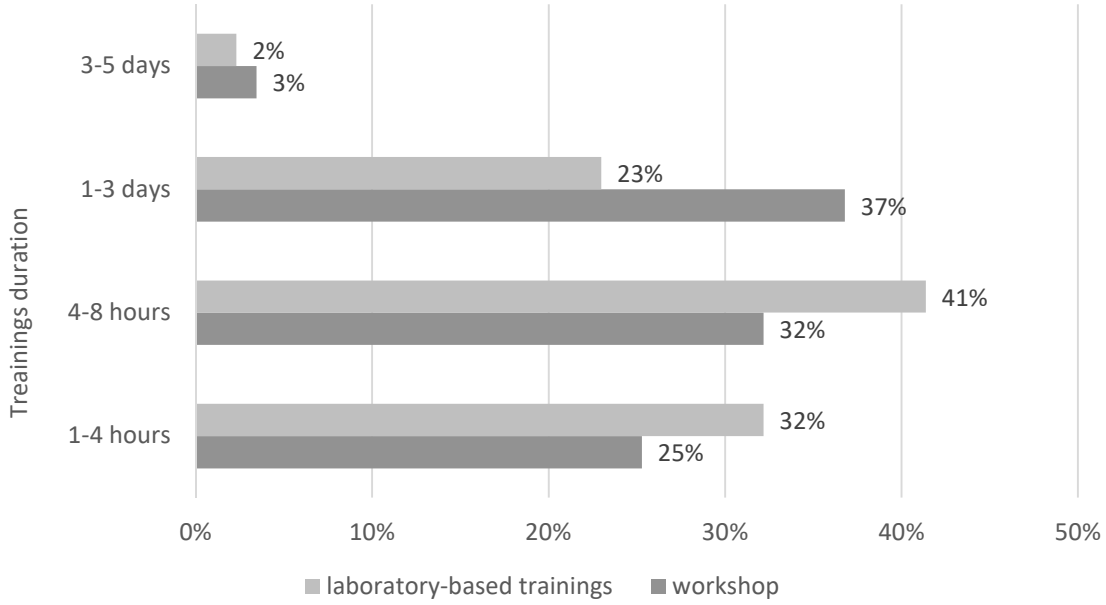

Fig. 8. The preferred duration fo workshop and laboratory-based trainings

Source: own study.

Trainings of digital design skills should be conducted face-to-face in local languages

Striving to adjust the planned trainings within shaping digital design skills, the authors identified the structure of roles of their potential users (employees of the Factory of Future). Among them there are ten groups of employees, from managers at various levels, through analysts, plant operation managers, to ordinary employees (Fig. 9). According to respondents, such trainings are most useful for "Engineers working in product and/or service design" (78% indications), "Strategists and innovators in charge of service/product/business model innovation" (70% indications) as well as "Middle managers" (68% indications). More than a half of the surveyed as well point to groups of "Business process managers", "Plant operation managers", "IT enterprise architects" and "Top managers" as those who are required to undergo these trainings. Still, data managers, business analysts and ordinary workers are groups of employees for whom, according to the majority of respondents, such trainings are not necessary.

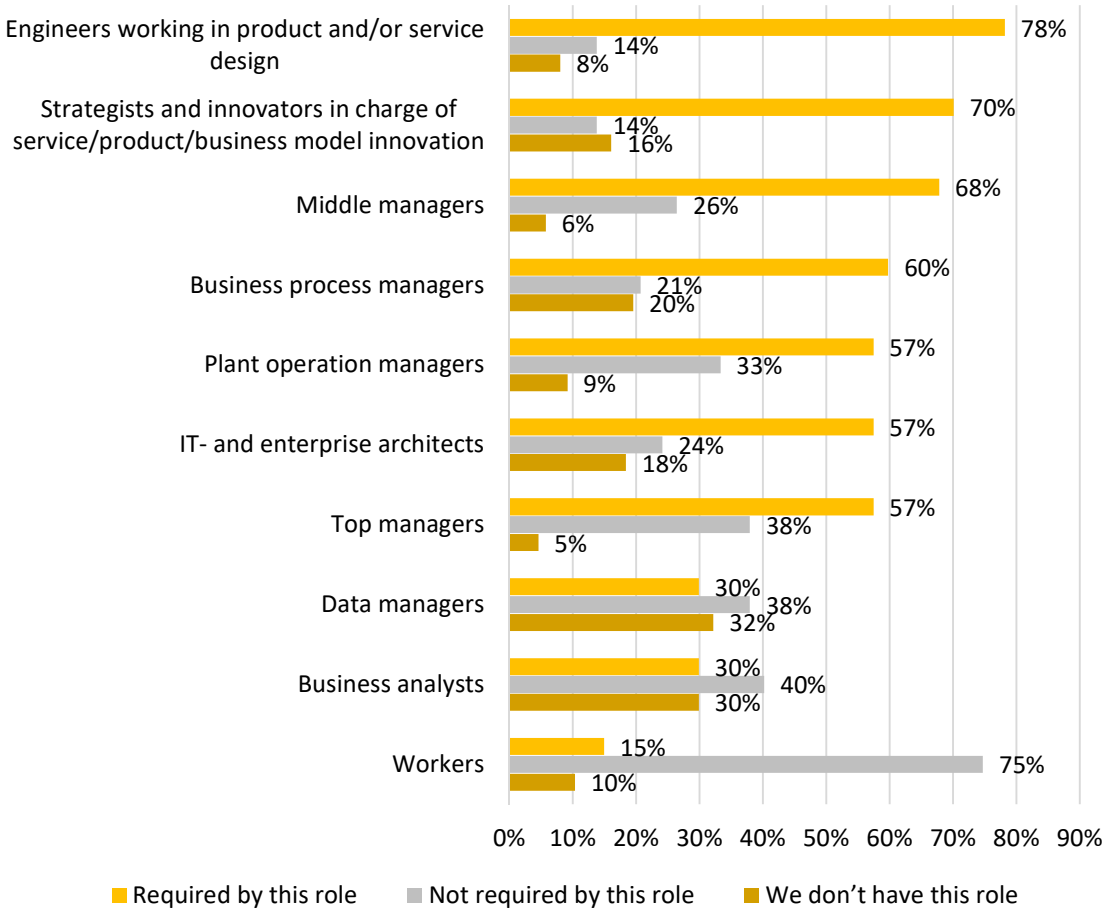

Fig. 9. Training needs in employee groups

Source: own study.

Because the scope of the survey was to identify the conditions for creating the Factory of the Future, a significant issue was determining the type of competencies of specific roles (positions) of employees (Fig. 10). The competencies were ascribed to four groups:

- possessing strictly theoretical knowledge,
- possessing strictly practical experience,
- possessing both theoretical knowledge and practical experience,
- lack of expert knowledge.

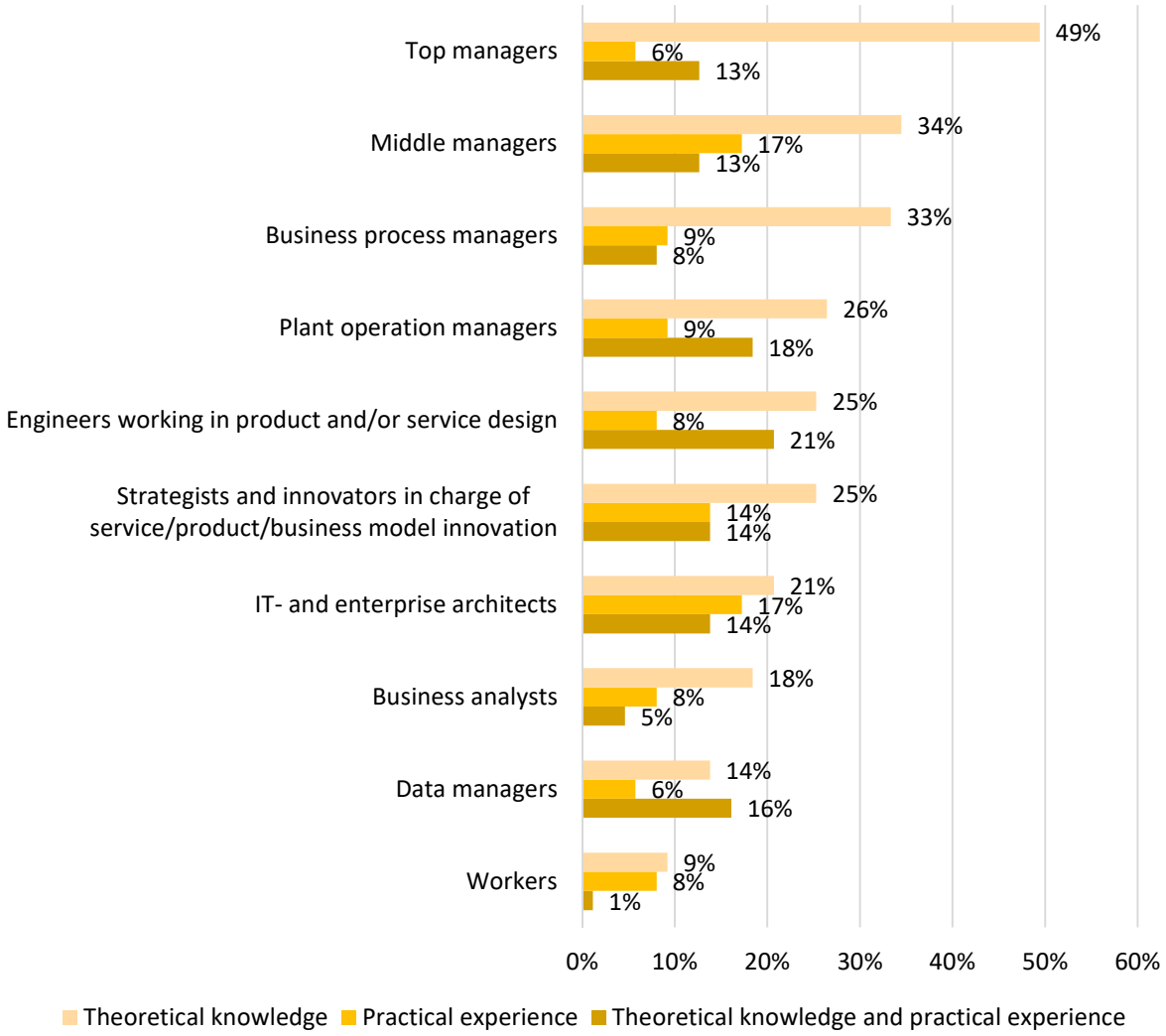

Fig. 10. Level of competencies within the FoF in groups of employees

Source: own study.

In most employee groups theoretical knowledge outweighs practical experience, and according to respondents, those groups of employees for whom the level of competencies within the FoF is mainly associated with theoretical knowledge are mostly top managers (49% indications), medium managers (34% indications) and business process managers (33% indications). Only within the group of data managers there are more indications towards theoretical knowledge and practical experience (16%) than theoretical knowledge itself (14%). Practical experience within the FoF was most popular with, though 17% in total, groups of medium managers and IT enterprise architects. The breakup of responses presented in Fig. 10 clearly indicates that all employees, according to respondents, possess a scant practical experience and that theoretical knowledge

dominates over practical experience. This may lead to the conclusion that an organisation should conduct trainings in the scope of building competencies for the needs of the Factory of the Future.

The map of training needs and business roles in Factory of the Future

In order to understand dependencies between respondents' indications with regard to the level of competencies and training needs in groups of employees, the authors conducted a correspondence analysis, which is one of the methods of statistical analyses used in studying relations between qualitative variables.

Correspondence analysis is a descriptive, exploratory technique of multivariate statistical analysis, allowing for defining the nature and structure of the relationship between qualitative variables, measured in nominal and ordinal scales. Correspondence analysis technique includes the following steps:

- determination of the correspondence matrix, row and column profiles and masses;
- calculation of the distances between the rows (columns) using the chi-squared metric;
- presentation of row (column) profiles in the space generated by the columns (rows) correspondence matrix;
- determination of the average row and column profiles;
- reducing the dimension of space;
- plotting the correspondence map, as a common row and column profiles chart (bi-plot).

The visualisation of the correspondence map allows the researcher to find diversity within the analysed variables, as well as the co-occurrence of different categories. The analysis of correspondence allowed to examine the relationship between the training needs and the level of competences in the groups of employees.

The obtained results are presented in a form of adequate correspondence maps for each identified business role (position) of the FoF employees. Identified co-occurrence of categories (employee position and type of needed competencies) are indicated by envelopes (Fig. 11).

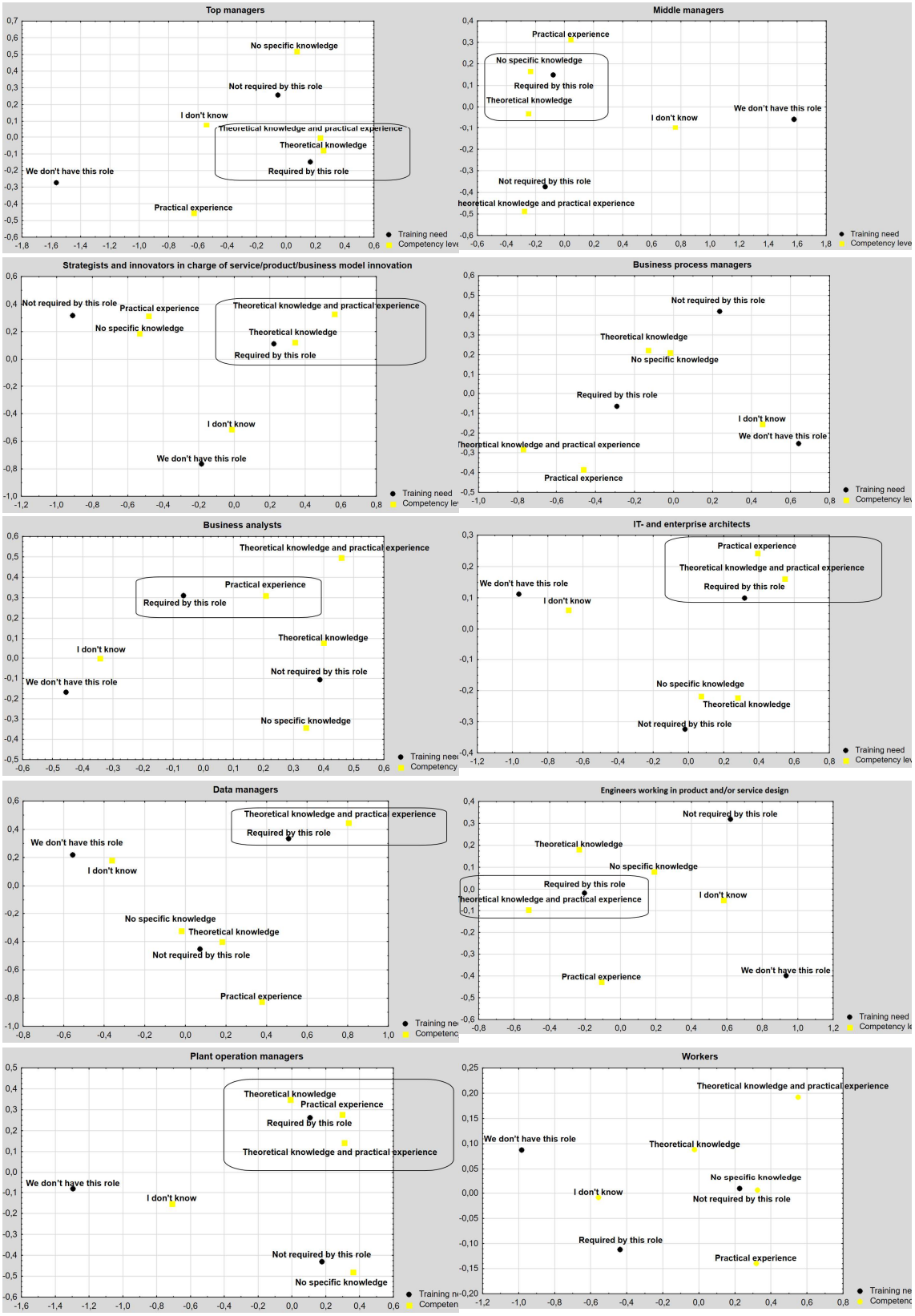

Fig. 11. Correspondence maps of training needs and competencies and business roles of FoF employees

Source: own study.

Those respondents who pointed to training needs for **top managers** most often paid attention to their theoretical knowledge or theoretical knowledge and practical experience within the FoF. The same dependency applies to responses related to **strategists and innovators** in charge of innovations and **plant operation managers** (Fig. 11). In case of **data managers** and **engineers working in product and/or service design**, the training need was more often indicated in its relation to determining competencies as theoretical knowledge and practical experience.

In the group of **business analysts**, the most popular was the training need together with determining competencies as practical experience. However, in the group of **IT enterprise architects**, practical experience and theoretical knowledge with practical experience had an impact on the training need.

The training need among **medium managers** was mostly indicated by those respondents that considered the competencies of the employees within this group as theoretical knowledge or lack of specific knowledge. In the remaining two groups, i.e. business process managers and workers, there were no explicit dependencies between competencies and training needs (Fig. 11).

Top managers, innovators and plant operation managers need a theoretical knowledge related to Factory of the Future

Networks of competencies in FoF

Another analysed issue raised in the survey was the aspect of the most important personal digital competencies of the employee of the FoF. Here, respondents received a list of 12 personal digital competencies that entailed: (1) adaptive learning, (2) creativity, (3) critical thinking, (4) complex problem solving, (5) information and data literacy, (6) digital content analysis & creation, (7) digital identity management, (8) data protection, (9) teamwork in a virtual environment, (10) social networking, (11) communication and collaboration based on new digital technologies and (12) netiquette. The surveyed were requested to make two indications: whether a given competency is currently needed and whether a given competency will be needed within the nearest 5 years, indicating most five relevant items.

Based on the gathered data, the authors prepared a network that illustrates both assessments (Fig. 12). One node was ascribed to a single competency. The size of the node reflected the number of respondents' indications connected with the current need for possessing a given competency, which means that the larger the data in visualisation, the more the respondents considered it as currently needed. The percentage of indications characterising each competency was provided together with its name in the node's label. If a given respondent considered a given pair of competencies as currently needed, there appeared a connection between competencies in the indicated pair. The more respondents pointed to a given pair, the stronger and the clearer was the connection in the visualisation. The node was as well provided with colour marking that reflected respondents' opinions within the need for possessing a given competency in the period of the forthcoming 5 years. There are three divisions connected with the frequency of indications towards a given competency as needed in the future. The larger the percentage of respondents indicating a given competency as needed in the close future, the darker its colour.

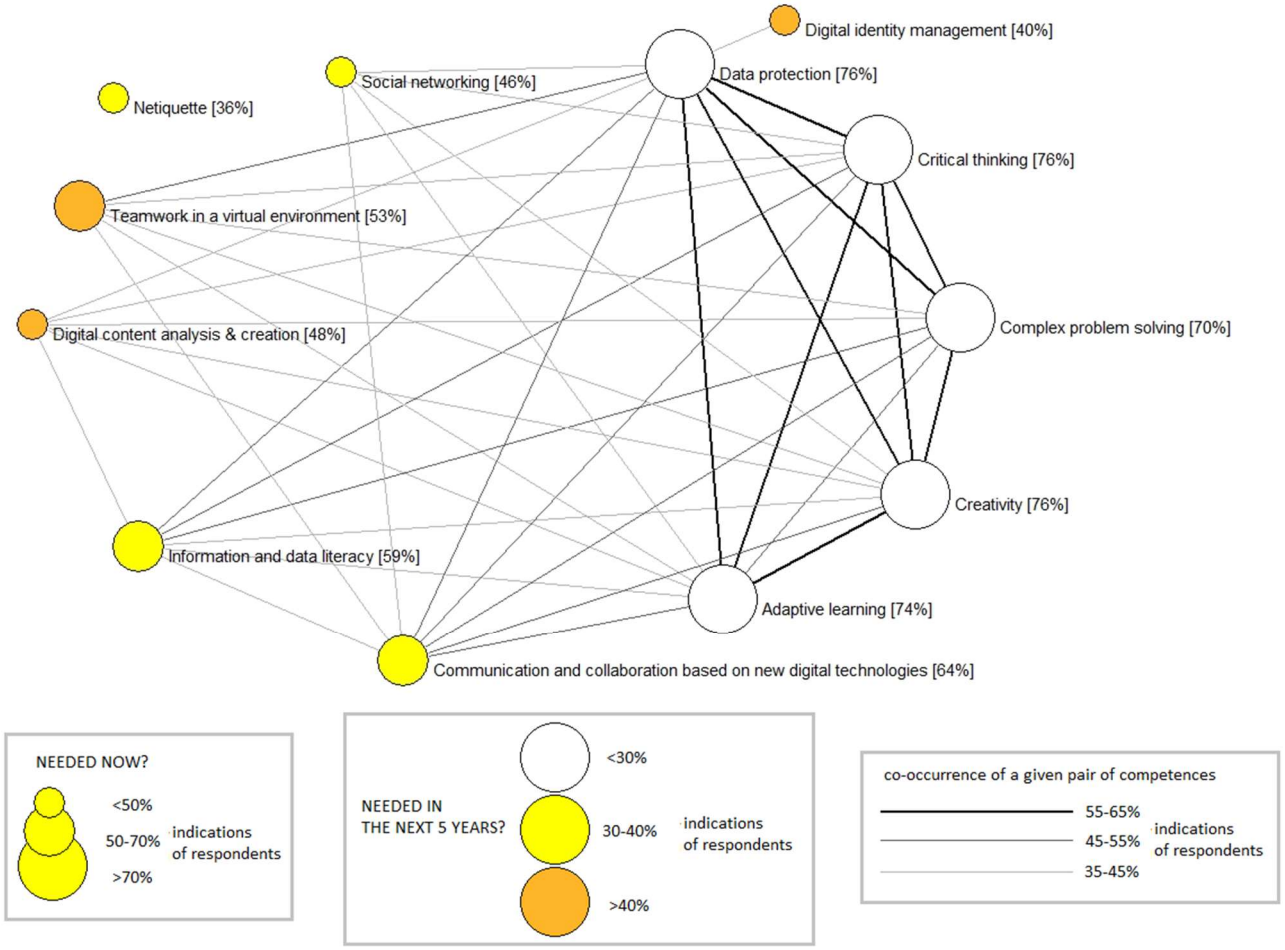

Fig. 12. The assessment of respondents in the context of the most important personal digital competencies of the employee of the FoF

In analysing the visualisation presented in Fig. 12, it can be observed that the competencies indicated by respondents the most frequently (over 70% indications) appeared the following: data protection, critical thinking, complex problem solving, adaptive learning and creativity. These were at the same time the most closely interrelated competencies (connected by 55-65% of respondents). This means that, according to respondents, these competencies create the most desired set at present. What is interesting, at the same time they obtained the lowest share (<30%) of indications in the scope of the need of their possession in the nearest future. The competencies that according to the surveyed will be the most needed within the next 5 years turn out to be three types. The first one is "Digital content analysis & creation", mostly connected with the entire set of competencies that are currently the most needed (though merely at the level of 35-45% indications), another – "Digital identity management" – currently indicated only in connection with "Data protection" (connection at the level of 35-45% of indications). Both the enumerated competencies received at the same time the lowest score in the context of the current need for their possession in the entire set. The third competency to be needed in the future (as stated by over 40% of respondents) was "Teamwork in a virtual environment". It is at the same time a competency indicated as currently needed by 50-70% of the surveyed. At present, it most frequently co-occurred with "Data protection" (connection at the level of 45-55% indications).

It is of note that respondents' indications in the scope of currently needed competencies were considerably numerous (fluctuating from 36 to 76%), whereas in the scope of assessing future needs, the percentage was remarkably lower (22-48%).

Another aspect raised in the survey was the issue of the level of competencies from key FoF areas in enterprises represented by the respondents. The assessment involved both the relevance level for the company with regard to competencies in a given key area as well as the current level of competencies in a given area among an enterprise's employees. The first assessment concerning the relevance level was made on a scale from 1 to 5, where these values mean respectively:

- 1 – "no relevance";
- 2 – "low relevance";
- 3 – "medium relevance";
- 4 – "high relevance";

5 –"very high relevance".

The second assessment, in turn, that referred to the current level required the selection of one of the values from 1 to 5, where these values mean respectively:

- 1 – "no competencies";
- 2 – "low competencies";
- 3 – "medium competencies";
- 4 – "high competencies";
- 5 – "excellent competencies" of the employees of the company in the key fields of the FoF.

The surveyed again received a set of key competency areas for a FoF employee. It entailed 13 areas: (1) IT infrastructure management, (2) data processing and analysis/analytics, (3) data security/cybersecurity, (4) computer programming/coding, (5) internet of things and cyber-physical systems, (6) automation, (7) robotics, (8) additive manufacturing (e.g. 3d printing), (9) cloud technologies and big data, (10) product simulation, (11) process design and simulation, (12) service design and engineering and (13) knowledge management.

The obtained results allowed for identifying the relevance level for the company regarding competencies in a given key area as well as their current level in a given area among employees. The effect of the analysis is a network of assessments of these two aspects presented in a form of a network of key competency areas of a FoF employee (Fig. 13).

The node of the resulting network was a single area with a size depending on the percentage of respondents' indications that point to a high or excellent level of the current level of competency in the area. This means that the more respondents point to possessing competencies in a given area at a high or excellent level, the bigger the node representing a given area. In turn, connections between a given pair of areas suggest that they were indicated as relevant for an enterprise at a high or very high level by the same respondent. The larger the number of respondents indicating the same pairs of areas, the stronger and clearer the connection between them in the visualisation. The visualisation as well incorporated colour markings that correspond with the assessment of the relevance level of a given competency area in an enterprise. The larger the percentage of respondents who assessed a given area as highly or very highly relevant for the enterprise, the darker the node representing the area in the network.

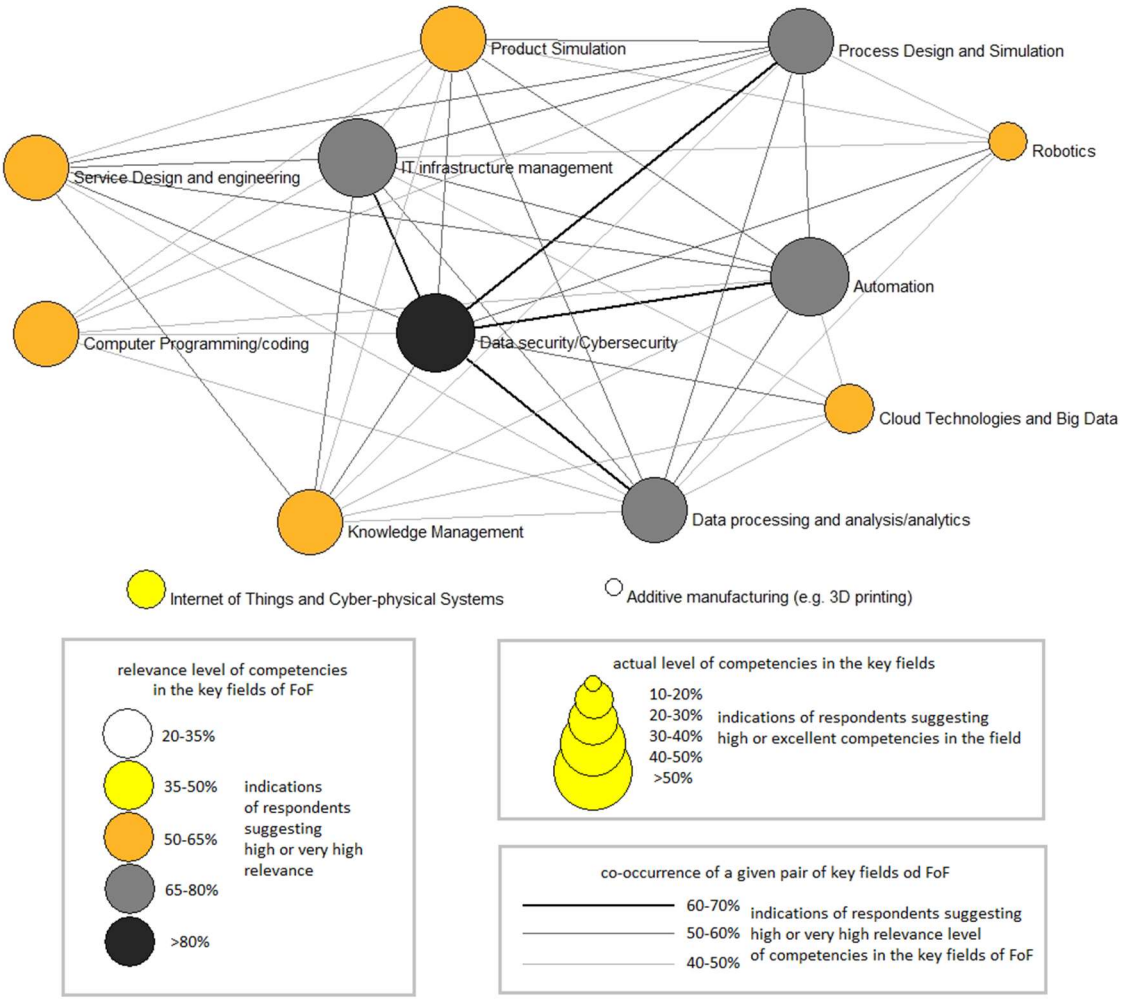

Fig. 13. The assessment of respondents in the context of the relevance level for their company and the current level of competency of the employees of the company in the key fields of Factory of the Future

Source: own study.

While analysing Fig. 13, it can be observed that the most relevant competency area in the opinions of respondents are competencies within "Data security/cybersecurity" (over 80% of indications at a high or very high level). Next, the relevant ones (65-80%) were considered: "IT infrastructure management", "Automation", "Process design and simulation", "Data processing and analysis/analytics". Each of the four enumerated areas was most often connected (60-70% of indications at a high or very high level) with the area of "Data security/cybersecurity". Still, the areas characterised by a current high or excellent competency level were three out of those above mentioned: "Data security/cybersecurity", "IT infrastructure management" and "Automation" (indicated as such by over 50% of respondents). The most interesting

competency areas are those characterised by low current competency level and the simultaneous high relevance of a competency in a given area for an enterprise (these are the smallest but at the same time the darkest nodes). In case of most areas, the current competency level grew together with the assessment of relevance with regard to a given competency area, which means that enterprises mostly care about the development of competencies in areas considered as relevant. However, the area that requires more attention is mostly a competency area within "Robotics". It was considered as relevant at a high or a very high level by 50-65% of the surveyed, whereas the current competency level in this area was considered as high or very high by merely 20-30% of respondents. Another area that should be mentioned is "Cloud technologies and big data" which were as well indicated as relevant at a high or very high level by 50-65% of the surveyed, where the current competency level in this area was considered as high or very high by 30-40% of respondents. These areas constitute competency gaps that should be filled by means of choosing proper employee trainings. Among areas considered by the respondents as the most relevant (indicated by 65-80% of the surveyed as highly or very highly relevant) are the following: "Data processing and analysis/analytics", "Process design and simulation". It is also possible to identify them as minor, potential competency gaps since the level of current competencies in these areas was considered as high or very high according to 40-50% of the respondents.

IT infrastructure management, automation, process design and simulation, data processing and analysis/analytics are the most relevant competencies for FoF in context of data security/cybersecurity

3.2. Designing background – companies ability

The first thematic area mentioned in the third part of the questionnaire was the aspect of innovation techniques. Asked about their use at the level of strategy and product/service innovation, half of the respondents indicated that they use innovation techniques (59% indications – namely 51 persons), and 41% stated that they do not use them (36 persons). Fig. 14 presents the quantitative breakup of specific responses in a given scope. At the end of the figure name, is presented in the brackets N equal with the number of respondents that are considered for this question.

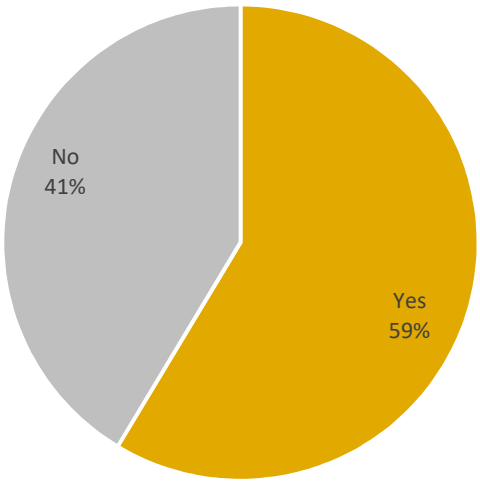

Fig. 14. Responses referring to the use of innovation techniques

Those who do not use innovation techniques were asked to provide the reason for such a state of affairs. Almost 40% of the surveyed within this group stated that they do not possess relevant qualifications (N=36 respondents) and 19% said that they have no knowledge in that extent (Fig. 15). At the end of the figure name, is presented in the brackets "N" equal with the number of respondents that are considered for this question.

Companies are moderate innovators

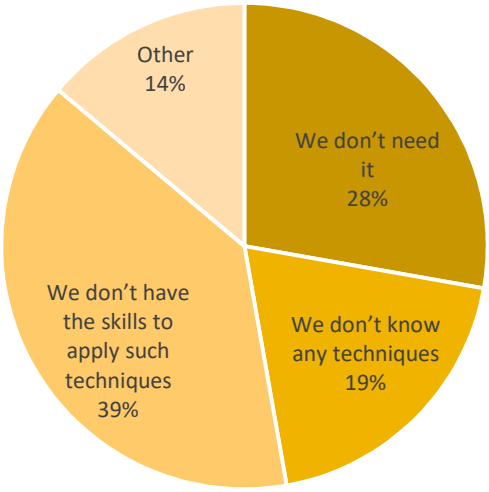

Fig. 15. Assessment of respondents about the causes of their failure to apply innovation techniques (N=36)

The same group was asked a question regarding to their plans in connection with this area in the future. Half of the surveyed who did not use innovation techniques intend to acquire the necessary competencies internally. 31% of the surveyed in this group plan to employ an external consultant to gain the necessary competencies. Only 19% of the surveyed who did not use innovation techniques indicated that they want to maintain this state of the act. Fig. 16 illustrates the described results.

Fig. 16. Responses concerning the use of innovation techniques in the future (N=36)

Those who indicated that they have used so far innovation techniques were asked about two issues. Firstly, they were requested to indicate in what area they use these techniques at present and in what area they plan to use them. The compilation concerning specific areas is presented in Fig. 17. The areas where innovation techniques are currently used the most frequently (at least 80% indications) are product innovation, costumer-oriented innovation and technology innovation. These results significantly differed from the indications within other areas. Still, in the time perspective, the frequencies of indications were not as diversified and among the most frequently indicated ones there were "Product-service-innovation", "Business process innovation" and "Service innovation".

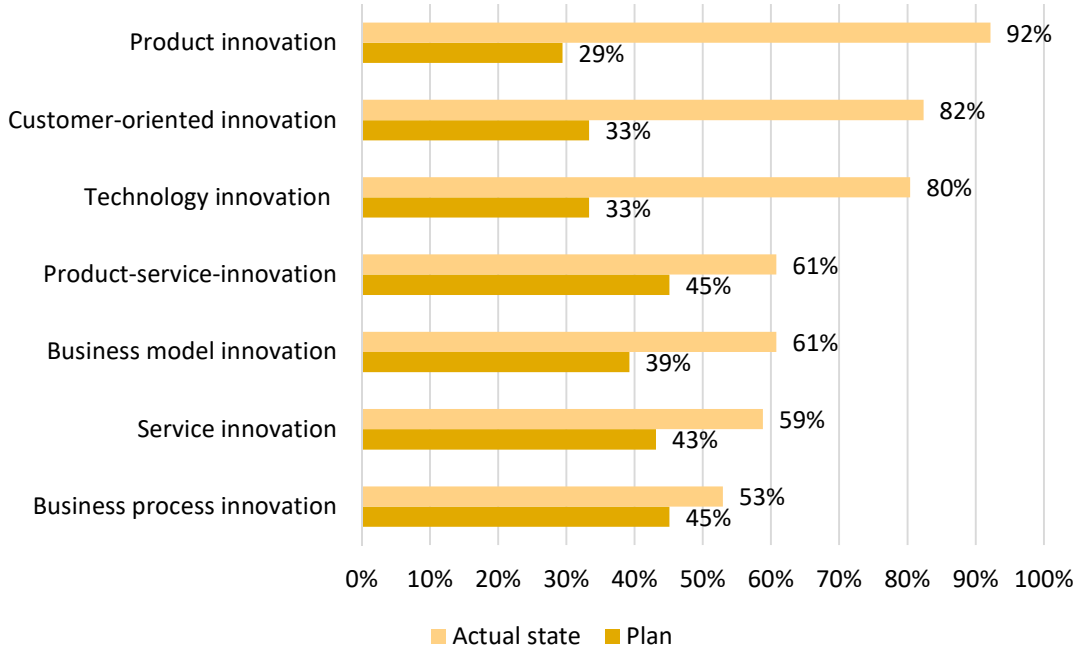

Fig. 17. Respondents' indications about current and planned areas of application of innovation techniques (N=51)

The respondents applying innovation techniques were asked which ones they used. The surveyed could assess a given set of techniques, indicating that they do know a given technique and use it, know it without using it or not know it. Fig. 18 presents the responses provided by the surveyed for each technique.

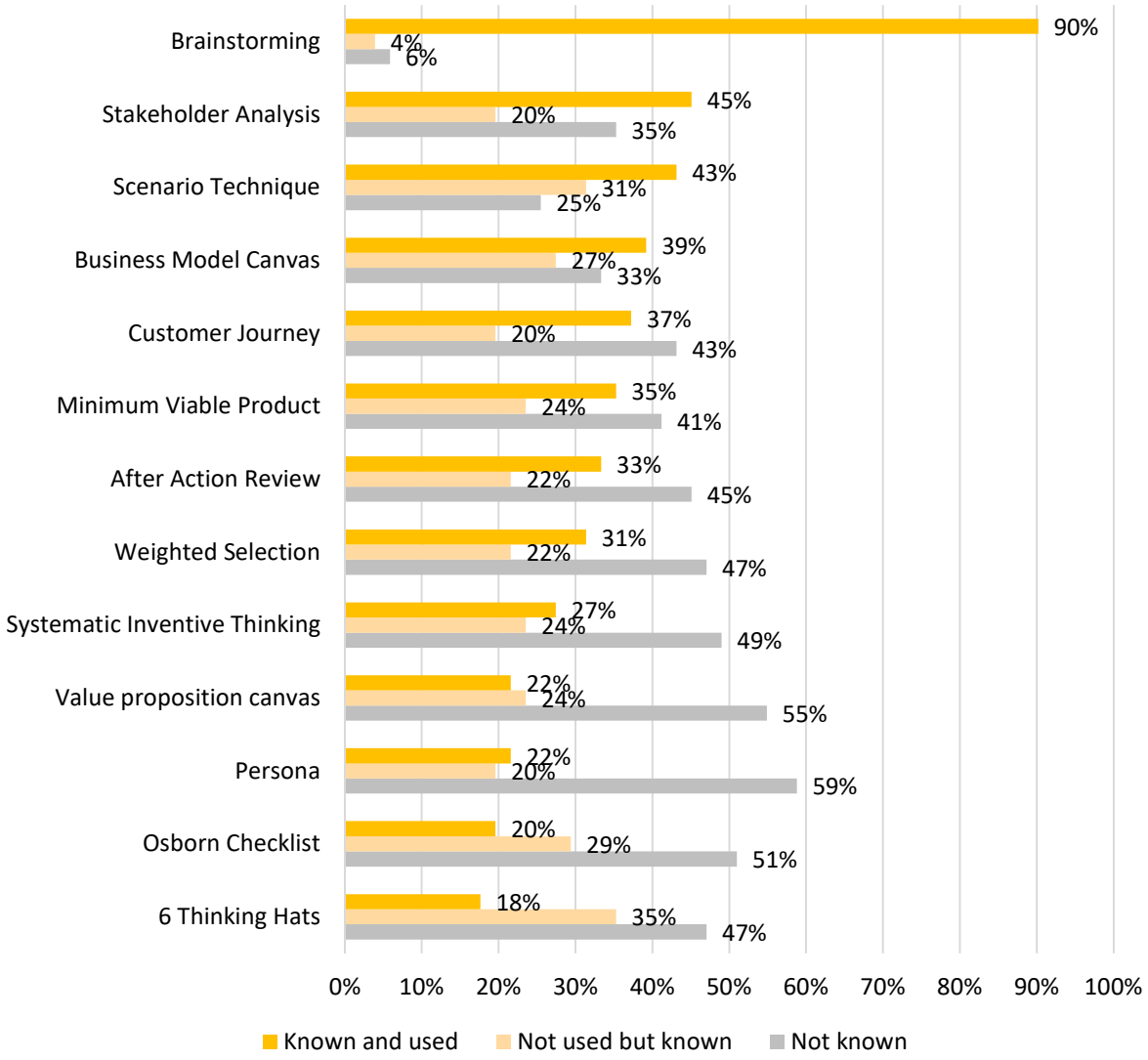

Fig. 18. Respondents' indications within the knowledge and application of specific innovation techniques (N=51)

In the light of the collected data, it can be claimed that "Brainstorming" is the most popular and most willingly used technique among respondents in creating innovative solutions. In case of "Stakeholder analysis", "Scenario technique" and "Business model canvas" the most frequent answers were the ones that claimed that these techniques are both relatively well-known and used by the respondents. However, they are not as common as "Brainstorming". They are unknown to 25% to 35% of the surveyed (Fig. 18). Among less known and less frequently used techniques there were "Customer journey", "Minimum variable product" or "After action review". The least known techniques for creating innovation solutions are "Osborn checklist",

"Persona" and "Value proposition canvas". More than a half of respondents indicated a lack of knowledge on their existence.

Advanced innovation techniques are not very common in analysed companies

One of the most significant aspects within design is the enterprise's capacity to fully understand processes, which constitutes a basis for their proper modelling. The models of processes play a crucial role both in projects within improving and managing processes as well as in those connected with designing and implementing IT systems. These two aspects can be considered as vital in creating the foundations of the Factory of the Future.

Among the surveyed enterprises, 61% declare that they model their business processes. Their employees (from 40% to 60% - depending on area of implementation) asses their competencies at a high or excellent level within the following areas:

- IT infrastructure management;
- Data processing and analysis/analytics;
- Knowledge Management;
- Service Design and engineering;
- Process Design and Simulation.

Modelling business processes in business practice is used by most medium (58%) and large enterprises (64%) that operate in the countries covered for the survey. Approximately 39% of the respondents indicated that the enterprises for which they work do not apply process modelling. These are mainly enterprises located in Poland and Romania (around 50% of survey participants). The respondents consider a lack of skills in this scope or a lack of access to necessary infrastructure as the major reason for such a state of affairs (Fig. 19).

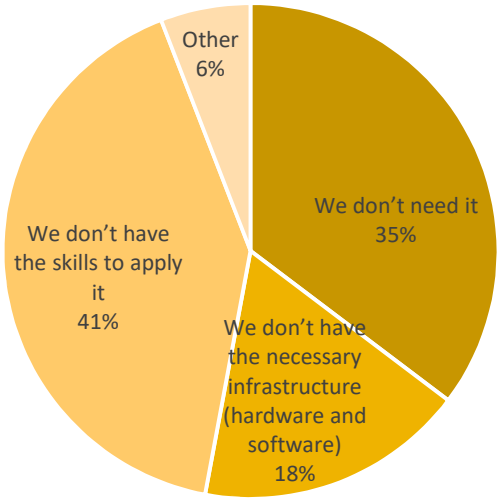

Fig. 19. Process modelling - state of the art in companies (N=43)

Source: own study.

However, it should be highlighted that enterprises that at present do not model processes mostly (62%) intend to use process modelling in the nearest future. Approximately 38% of the enterprises declare their lack of interest/need for process modelling (Fig. 20).

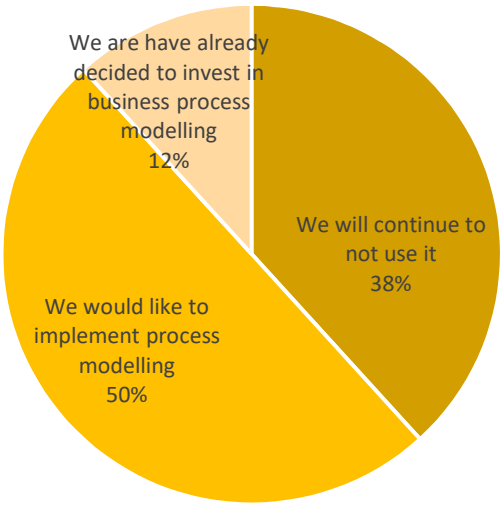

Fig. 20. Companies' future attitude to process modelling (N=34)

Source: own study.

Enterprises are interested in process modelling

The mostly indicated area of applying process modelling is "Production" (43%) and "Purchasing" (24%). Enterprises do not see the need to use process models in management/automation of the areas of their activity connected with distribution and administration (finance, personnel, etc.) (Fig. 21). Such a situation may point to the concentration solely on basic processes (short head and long tail effect) and a lack of a complex approach to the creation of process architecture. This can be to some extent confirmed by the areas of applying process modelling, as indicated by the respondents (Fig. 22).

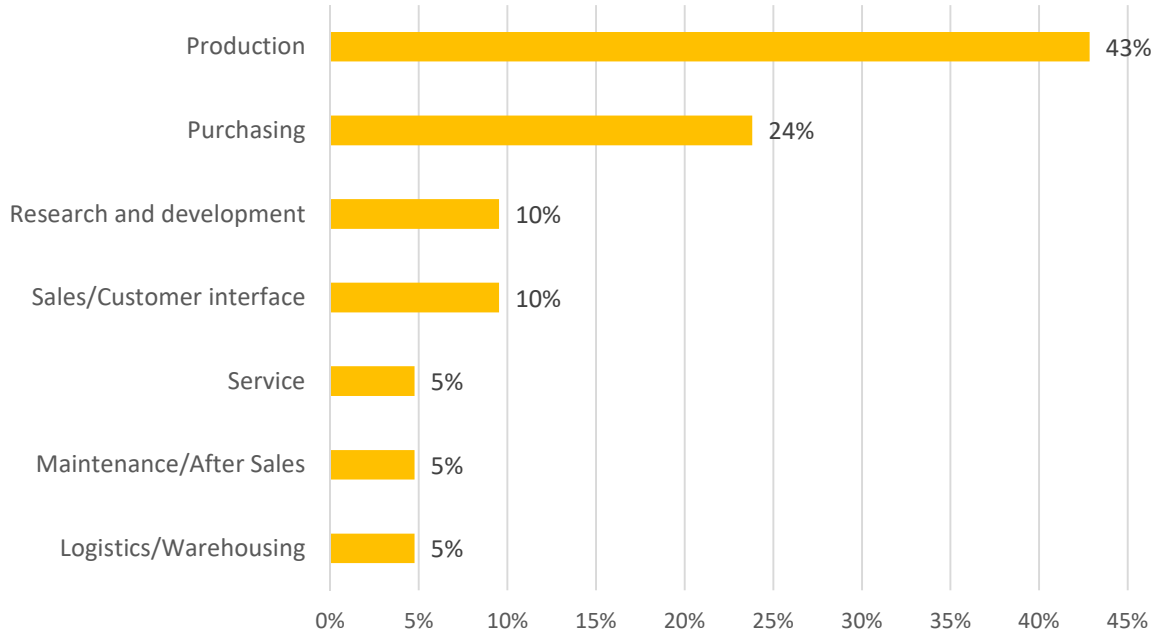

Fig. 21. Potential future areas of process modelling in the company (N=21)

Source: own study.

Modelling is perceived as fundamental in optimisation and redesigning processes in enterprises

Still, those enterprises that model processes do that primarily to optimise and re-design them (60%). Process models are also perceived as useful while forming an element of Digital Transformation (45%) and a tool that supports decision-making processes in enterprises. Taking into consideration the breakup of respondents' indications, it can be claimed that they are excessively perceived as a repository of knowledge on processes and an effective tool of communication between process stakeholders (Fig 22).

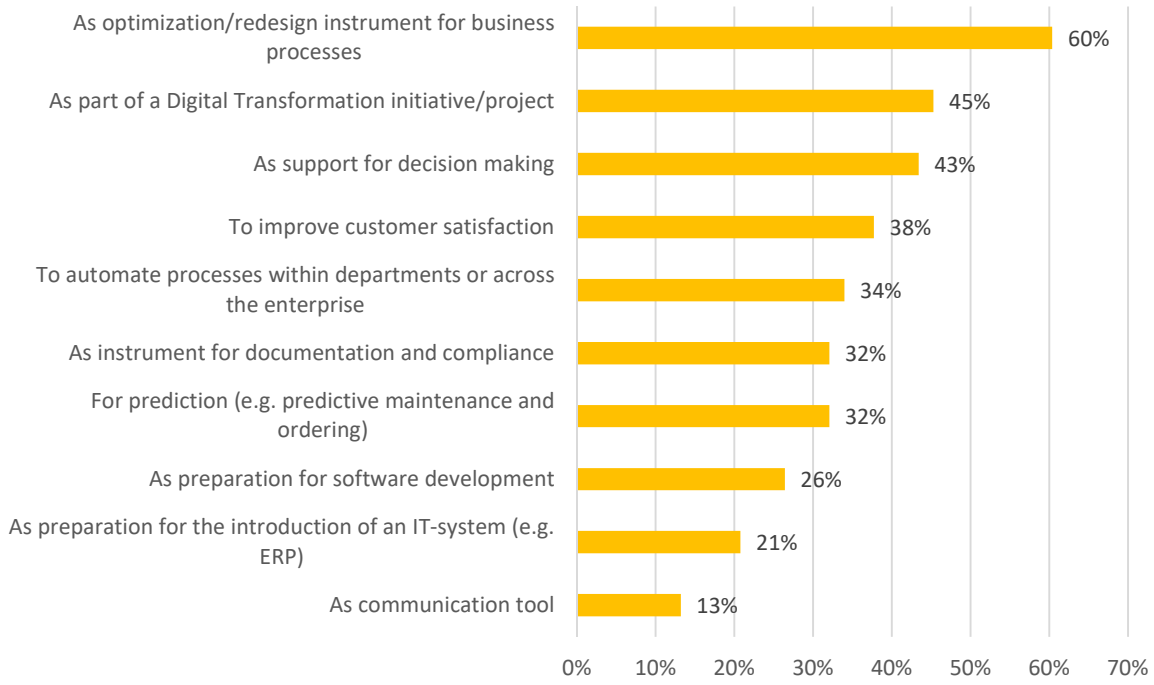

Fig. 22. Areas of process modelling implementation (N=53)

Source: own study.

The modelling of processes in enterprises involves techniques that allow for creating flow-charts. To a very small extent, enterprises apply such specialist modelling notations as Business Process Modelling Notation (BPMN) and Event-Driven Process Chains (EPC). They are mainly used by large organisations (with over 250 employees).

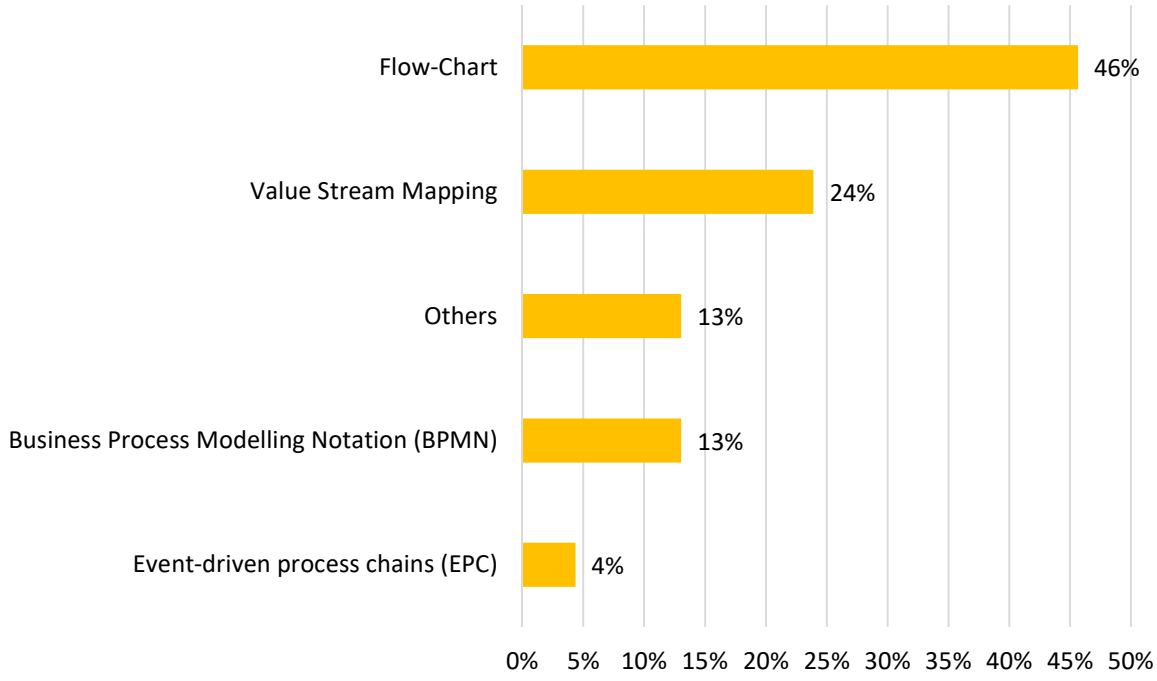

Fig. 23. Business process modelling languages used for process designing (N=46)

Source: own study.

In the light of the gathered data, it was also possible to state that merely 17% of enterprises (that are modelling their processes) apply a model-based design for cyber-physical systems. Such a low level of applying process modelling in designing mainly stems from the specifics and conditions of enterprises' functioning (lack of such a need) as well as the lack of necessary skills and infrastructure (Fig. 24).

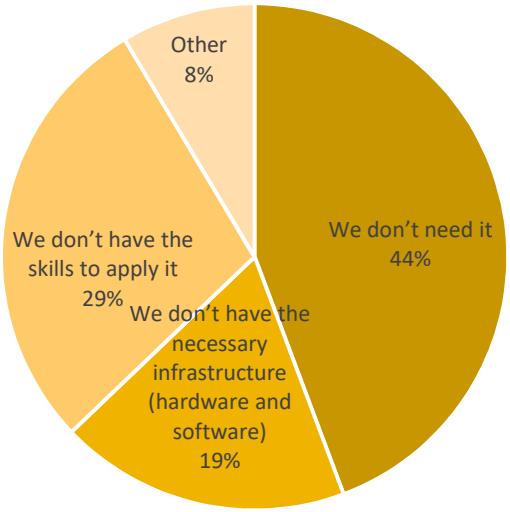

Fig. 24. Barriers to model-based designing for cyber-physical systems (N=71)

Source: own study.

A relatively small group of enterprises (17%) that uses model-based designing for cyber-physical systems is based on:

- SysML (2 companies);
- Functional Mockup Interface (3 companies);
- UML class diagrams + OCL (4 companies).

The surveyed assess that the knowledge of programming languages used for the automation of cyber-physical systems is at a considerably high level (Fig. 25). The most popular ones are:

- Java;
- C/C++;
- Industrial Robot Languages.

Lack of knowledge, skills and infrastructure for process modelling and model-based designing

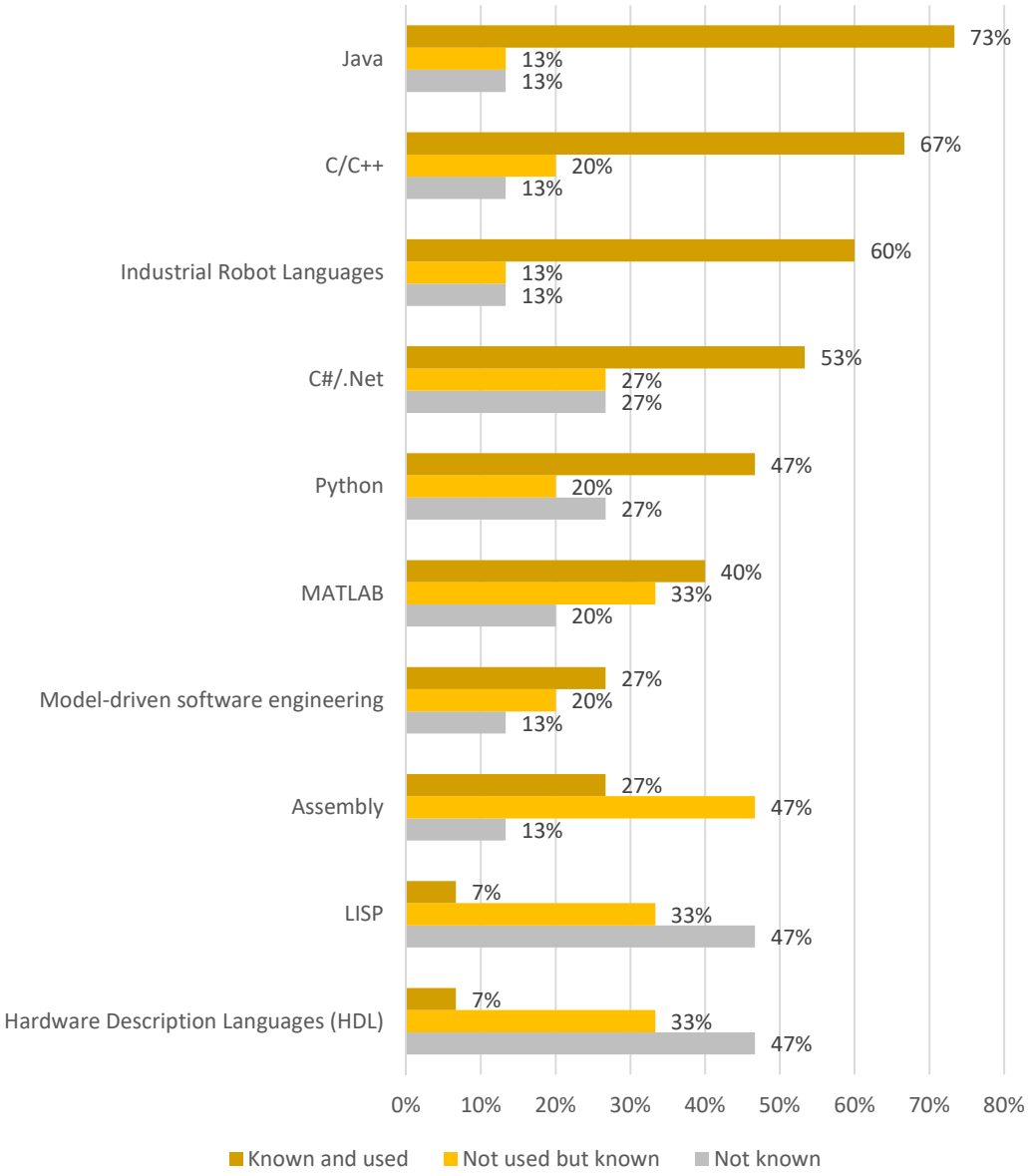

Fig. 25. Programming languages used in companies for the automation of cyber-physical systems (N=15)
Source: own study.

Still, in the light of the gathered data (Fig. 26), the most popular tools used in designing are:

- data modelling;
- product data management;
- computer-aided design.

Respondents assessed their competencies within "Enterprise architecture management", "Business modelling" and "Digital mock-up" at a relatively high level. However, despite the knowledge of these tools, they fail to use them in business practice (Fig. 26).

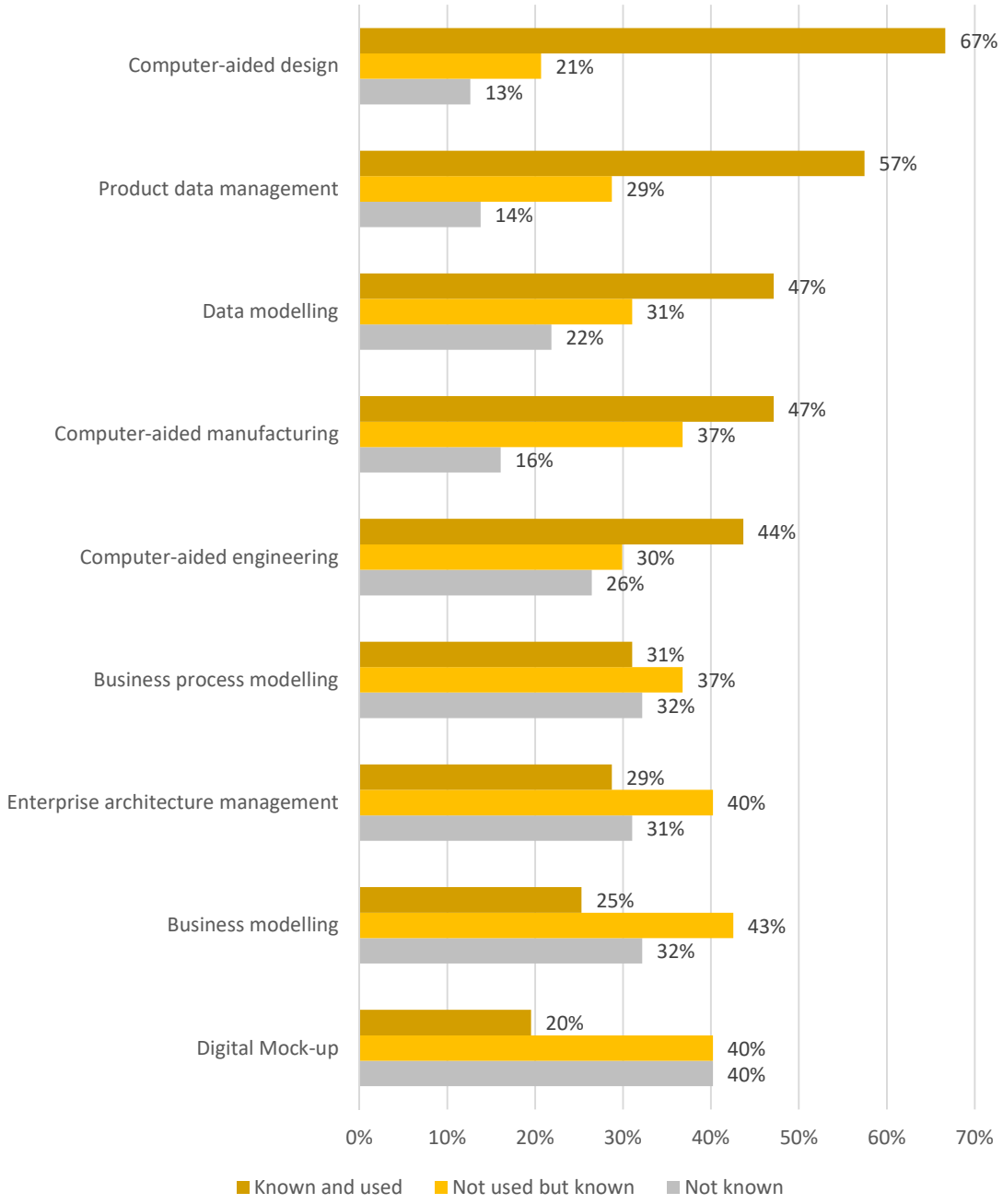

Fig. 26. Design tools known in companies (N=87)

Source: own study.

3.3. Area of interest and implementations

The objective of this part of the research was to identify and assess the condition of digitalising enterprises. In order to achieve this goal, in the survey are used a series of questions on the assessment of digitalising various areas of the enterprise: production, logistics, customer service and sales.

With regard to the question on the application solutions, where work piece controls itself autonomously through production in enterprises, almost half of the surveyed provided negative answers (Fig. 27). Slightly more than ¼ of the respondents confirmed the existence of such capabilities in their enterprises but only in selected sub-areas, and 15% of the surveyed admit that such a solution is present in the company, but only in the test and pilot phase.

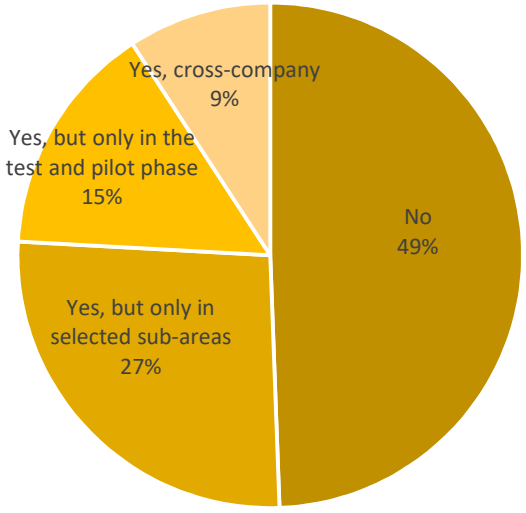

Fig. 27. Companies' ability to control of work piece autonomously through production

Source: own study.

The respondents indicated technological areas, where it is possible to use automation in the company (Fig. 28). Technological areas that the surveyed considered as proper in the process of company automation are mainly Data Analysis, as indicated by more than a half of the respondents (57% indications). Collaborative robotics (48%), Artificial Intelligence (46%), Traditional robotic systems (44%) and the Internet of Things (43%) are other technological areas, where their application was considered as vital in striving for automation. The lowest score in the analysed context was attributed to:

- Augmented Reality (21%);

- 3D-printing (20%);
- Cyber-physical Systems (14%).

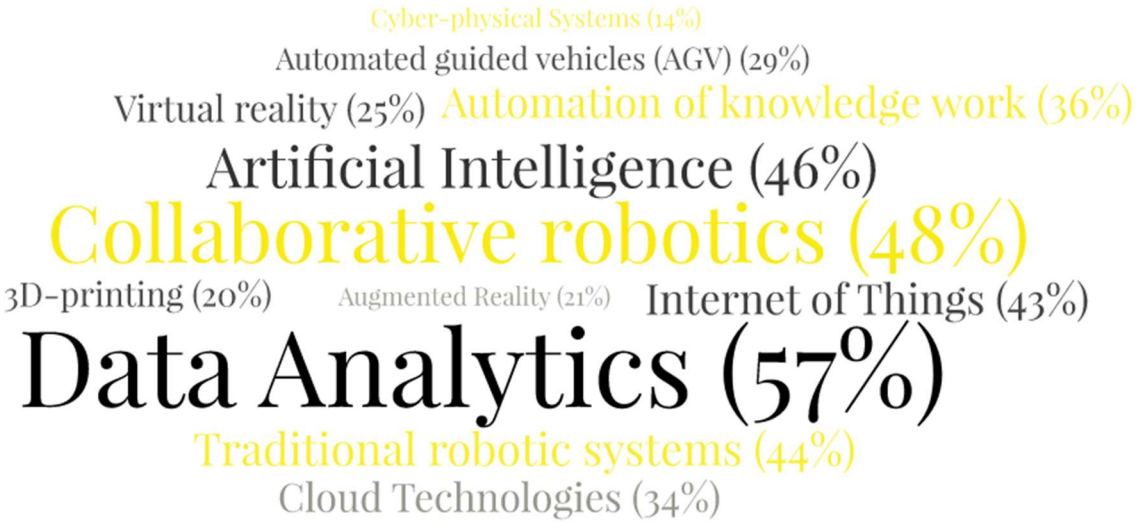

Fig. 28. Frequency of technological area indications to be used in enterprise automation as indicated by the respondents

Source: own study.

Another issue raised in the survey was the occurrence of data collection from the production system in the surveyed enterprises. A vast majority of the surveyed enterprises (76%) performs such activities. Those companies that fail to do that (24%) mostly explain that they do not need to gather data from the production system (62% indications), whereas the remaining 38% of enterprises state that do not possess the required infrastructure (equipment and software) for collecting data from the production system. The enterprises that currently do not collect data were asked about the future plan in this extent. Nearly half of them (43%) have no intention to gather data in the future, but 38% plan to implement data collection and 19% would wish to implement data collection but have no relevant competencies in this scope (Fig. 29).

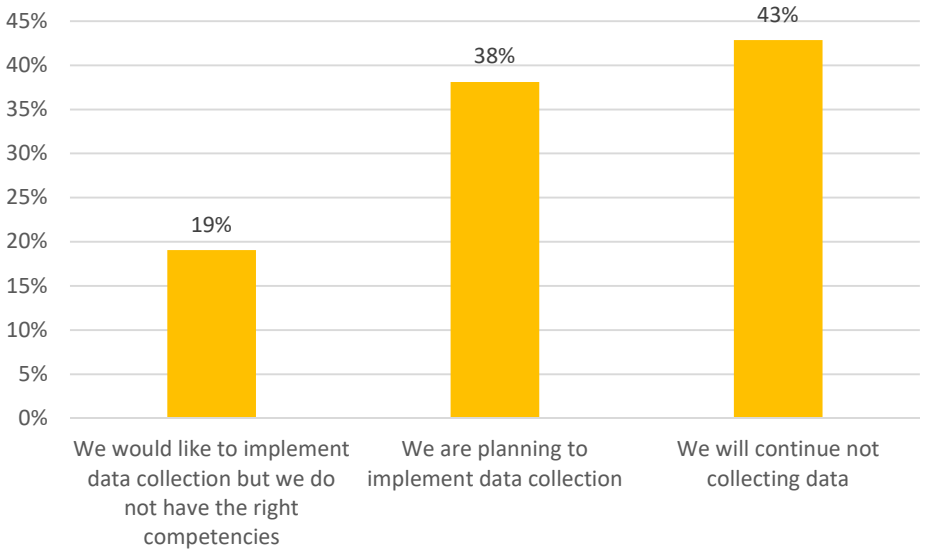

Fig. 29. Future plans of enterprises about collecting data on the production system (N=21)

Source: own study.

The enterprises that collect data from the production system mostly indicate (33% responses) that their machine data is fully and automatically available in real time and manual tasks are transferred immediately after completion. 29% of the enterprises that collect data claim to possess fully automated feedback of data taking place in real time with the use of proper technologies. Data recording in a paper form and the lack of their transfer to an IT-system occurs in 15% of companies that collect data and 14% record feedback on paper that is digitised with a time-delay. The smallest number of enterprises (9%) receive feedback by means of PDA terminals shortly after order completion (Fig. 30).

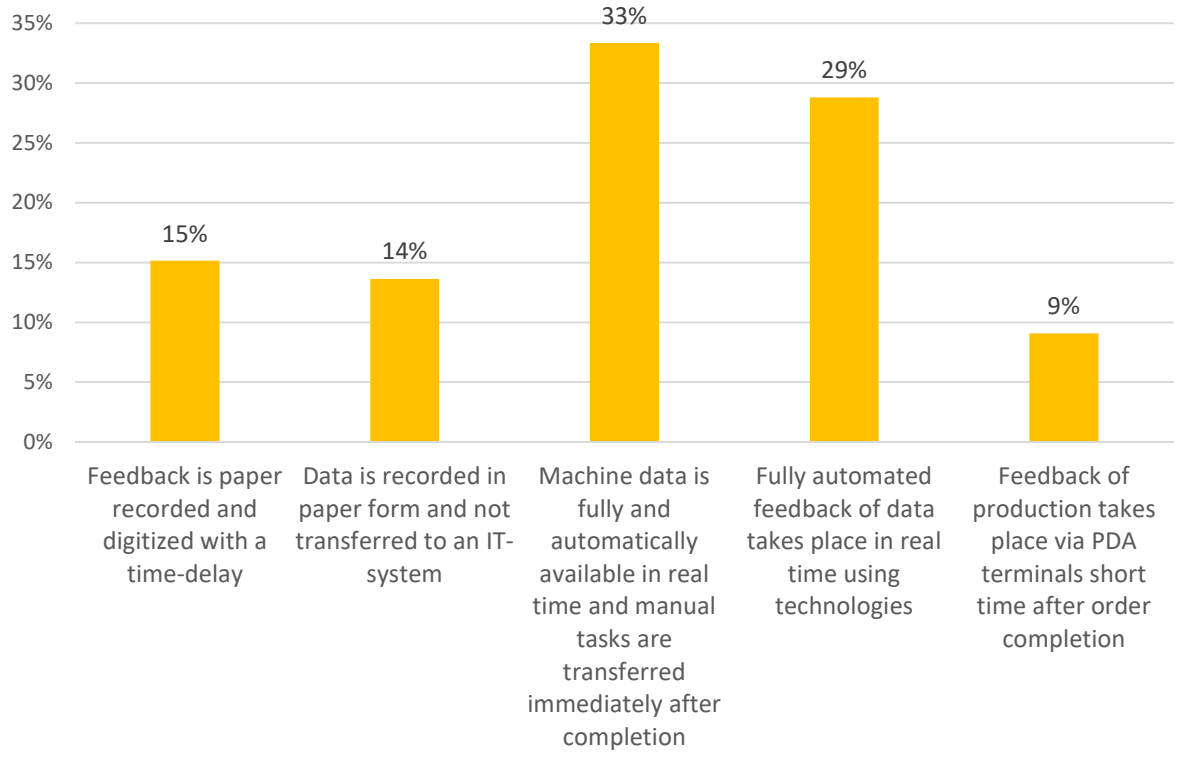

Fig. 30. Methods of data collection from the production system in the surveyed enterprises (N=66)

Source: own study.

The enterprises that collect data from the production system were asked how they design and engineer their data-driven services. Approximately 30% of the enterprises do not design or engineer services and 20% do not offer data-driven services. The remaining companies, even if they design and engineer services, mostly (24% indications) do that jointly with product design, with a structured approach. Still, service design and engineering together with product design but without a structured approach is observable in 14% of the enterprises. The same percentage of companies point to service design and engineering, but independently from product design (Fig. 31).

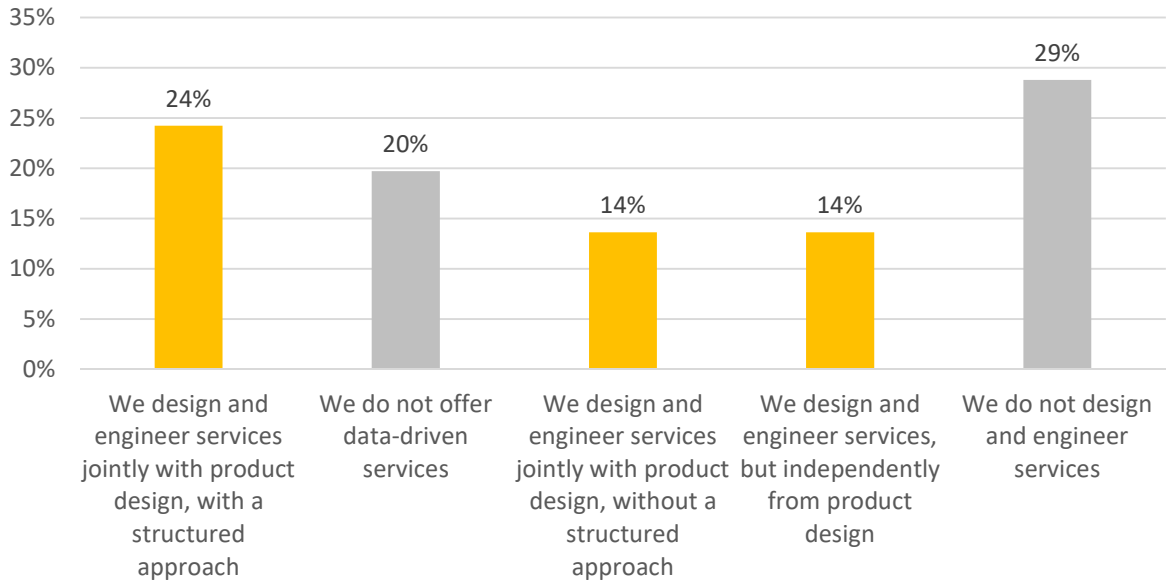

Fig. 31. Manners of data-driven service design and engineering (N=66)

Source: own study.

The surveyed enterprises were requested to characterise the production area in the context of its digitalisation. The majority of companies, as many as 75%, indicate that in their production process computers are connected with each other. More than a half of the surveyed enterprises (59%) own machines that are equipped with computers or digital interfaces, and in almost half of them (49%) production uses a central system for planning and control. Much less frequently (13% indications) the surveyed enterprises point to the existence of such a solution in production which allows for sending an order autonomously to another available machine if a machine is defective. In every fifth company production is automatically controlled by the system and every third applies monitoring the condition of production machines (Fig. 32).

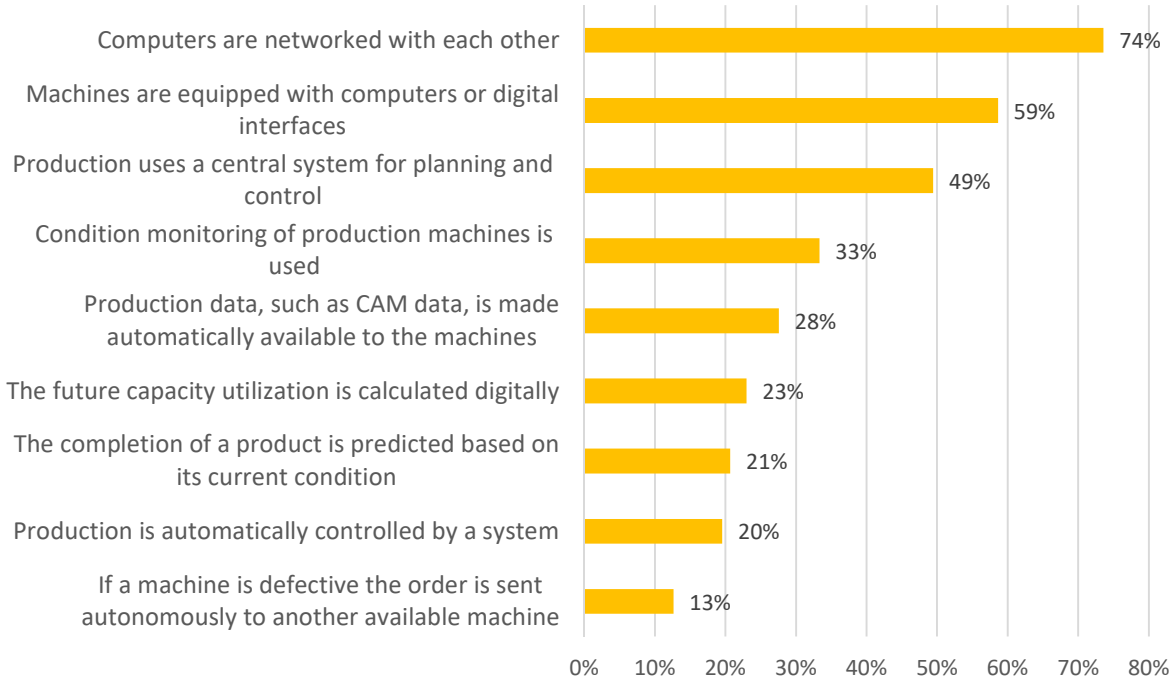

Fig. 32. Production process digitalisation in the surveyed enterprises

Source: own study.

The companies pointed to the digitalisation condition that concerned their product development. Almost a half of the surveyed (45%) indicated that in their enterprises new products can be tested and analysed (partly) automatically, and 38% state that product development is accompanied by automated steps. Every third enterprise stated that product development uses simulation models to test suitability. Only 11% of the surveyed takes pride in full automation while generating and assessing new products (Fig. 33).

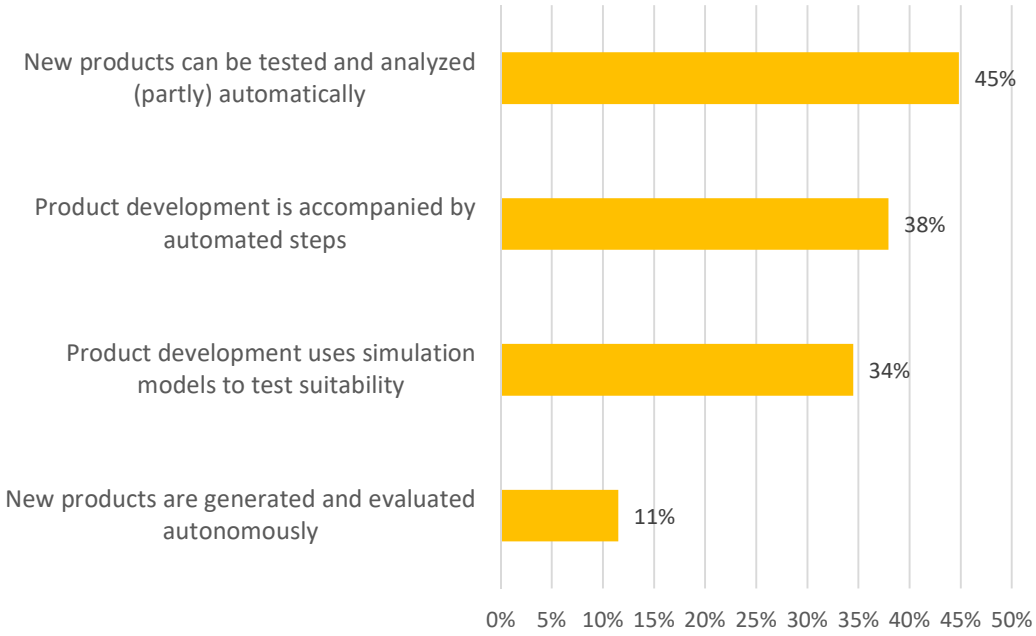

Fig. 33. Automation of product development in the surveyed enterprises

Source: own study.

Another area where the survey involved the assessment of automation was logistics of the enterprises under study. Nearly 60% of the companies declare that they use computer software for warehouse management, and almost a half of them (46%) – for logistics management. 47% of the surveyed point to the connection of logistics with IT systems, which allows for e.g. retrieving data such as delivery notes from the ERP system. Less frequently in the surveyed enterprises (36% indications) incoming and outgoing goods are automatically booked and ordered, for example, by forwarding agents. Every fourth company applies automated computing and foresight in assessing future stock shortages, and every fifth applies autonomous ordering of missing goods (Fig. 34).

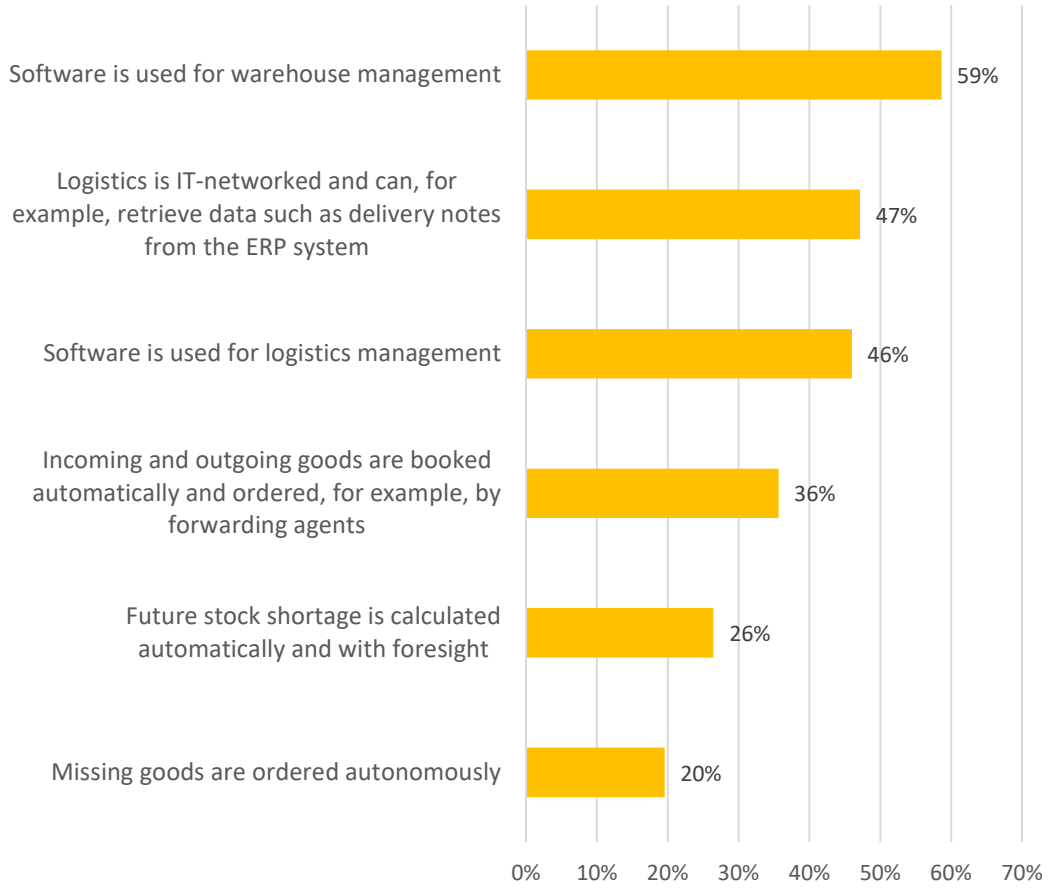

Fig. 34. Automation within logistics in the surveyed enterprises

Source: own study.

Customer service constitutes another area of surveying enterprises which entails an assessment of company digitalisation. For more than a half of the surveyed (60%), service cases such as customer complaints, repairs or maintenance orders are recorded digitally. Less than a half (40%) own a central customer service system, such as a service desk or a ticket management system. In only 15% of the surveyed enterprises customers have the option to make service and maintenance requests automatically. Only a scarce number of companies (less than 10%) indicate that necessary repairs are detected in advance and prevented by autonomously placed maintenance orders and that information on repair and maintenance orders are automatically generated based on the collected data (Fig. 35). It is as well of note that 23% of the surveyed enterprises offer no digitalisation (automation) in the sphere of customer service.

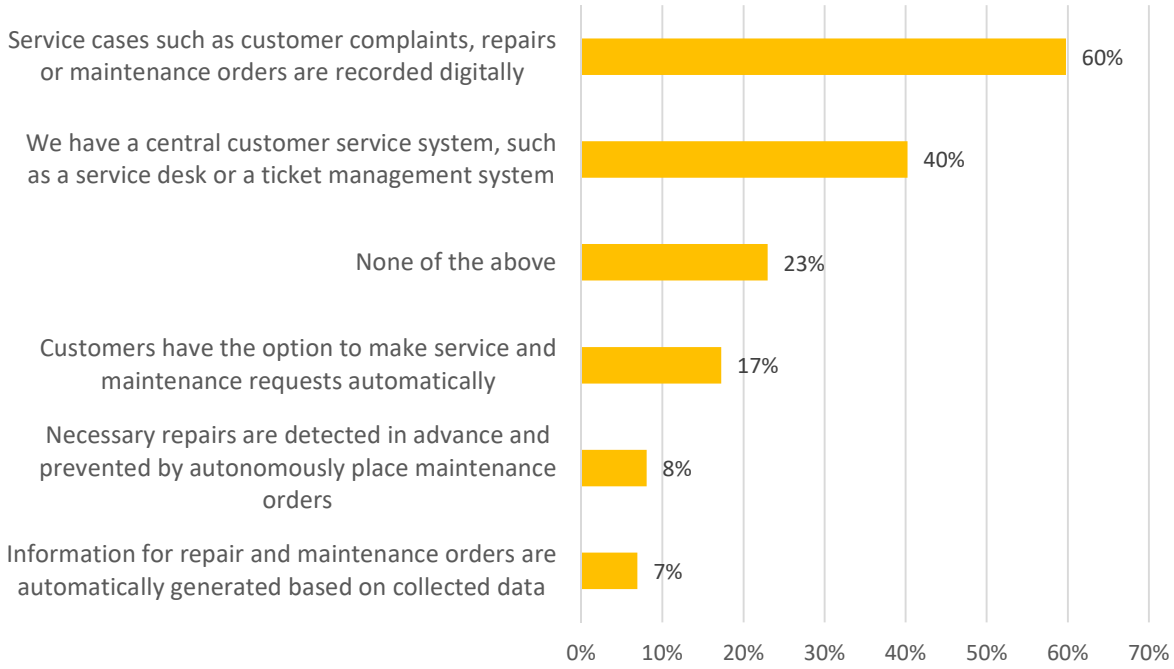

Fig. 35. Automation within customer service in the surveyed enterprises

Source: own study.

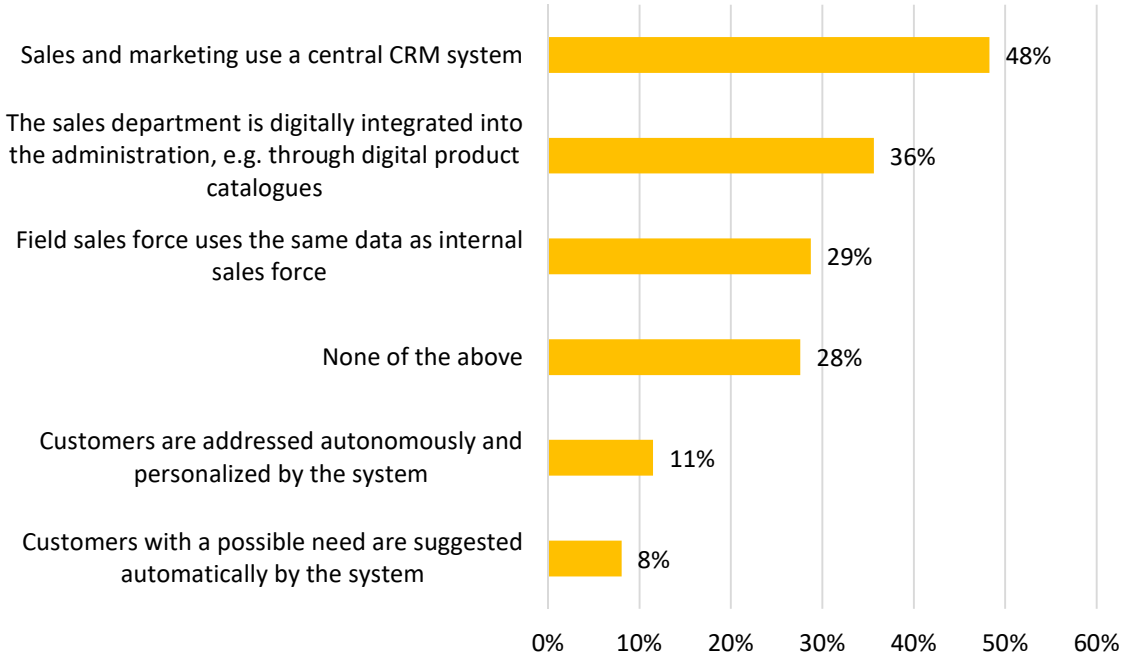

Fig. 36. Automation in sales and marketing departments of the surveyed enterprises

Source: own study.

Low/moderate level of process digitalisation in enterprises

The application of automation in the field of sales and marketing was the subject of survey as well. The companies mostly favour the application of a central CRM system in sales and marketing (48% indications). In approximately one third of the surveyed enterprises, the sales department is digitally integrated into the administration, e.g. through digital product catalogues. The use of the same data by field and site sellers is indicated by 29% of the surveyed companies. Only in every tenth enterprise the customers are addressed autonomously and personalised by the system, and in 8% of the companies customers with a possible need are automatically suggested by the system. As many as 28% of the surveyed enterprises do not apply any of the described automation options in the sales and marketing department (Fig. 36).

4. FINDINGS AND RECOMMENDATIONS

The companies that participated in the survey are diverse in terms of their current digital designing abilities. However, the results of the research confirm the significant role of possessing and building digital designing knowledge and skills among present and potential employees of manufacturing companies.

Transformation towards the FoF needs a change not only within digital technology skills and knowledge but also needs a strong orientation on innovations as well. The level of competence in the analysed group of companies is not satisfactory in this field. The following is a summary of the main findings from the survey:

- importance of digital design skills in companies;
- not sufficient level of companies' ability in trainings for FoF;
- companies under the study are moderate innovators;
- knowledge gap exists in the scope of advanced methods and tools supporting the development of innovative products and services;
- respondents recognize the need to improve them mainly through organization and participation in additional internal trainings;

- enterprises are interested in process modelling and it is perceived as fundamental in optimisation and redesigning processes in enterprises
- a lack of skills or a lack of access to necessary infrastructure supporting process modelling and model-based designing for cyber-physical systems;
- formal notations of process modelling (BPMN, EPC) are not common in use;
- programming languages (Java, C/C++) are widely used for automation of cyber-physical systems;
- a lack of s practical experience within an enterprise architecture management, business modelling and digital mock-up;
- low/moderate level of process digitalisation in enterprises;
- process automation and controlling represents mostly low or moderate level.

Employees of the surveyed enterprises have participated in training courses related most often to improving skills in the use IT tools supporting designing services and products. Very rarely employees underwent so far trainings within the methodology of process designing and modelling or design thinking and creativity. Moreover, respondents declared a competency gap within robotics, cloud technologies and big data.

Considering future training needs and demands the most needed skills within the next five years are:

- digital content analysis & creation;
- digital identity management;
- teamwork in a virtual environment.

The most relevant competencies for FoF (in context of data security/cybersecurity) are:

- IT infrastructure management;
- automation;
- process design and simulation;
- data processing and analysis/analytics.

Taking into account expectations of respondents, potential trainings on digital designing should be organised and addressed as follows:

- the trainings should ensure a direct contact (face-to-face) with the trainers (workshops, lectures and laboratory-based trainings);
- the trainings should support development a theoretical knowledge & digital designing methodology;

- a theoretical knowledge related to FoF should be represented by top managers, innovators and plant operation managers;
- workshops or laboratory-based trainings should be conducted in participants mother tongue and should last from 4 to 8 hours, but in a cycle not longer than three days;
- the main beneficiary group of FoF trainings consist of engineers working in product and/or service design, strategists and innovators in charge of service/product/business model innovation as well as middle managers.

Theoretical knowledge is perceived as fundamental issue of competency building of potential employees in Factory of Future. According to analysed needs of respondents theoretical knowledge outweighs practical experience. A practical experience within the FoF should be a target for medium managers and IT enterprise architects. Top managers, on the other hand, should have adequate theoretical knowledge in this area. It is expected that data managers and engineers working on product and/or service design should have and combine both theoretical knowledge and practical experience.

The overall conclusion of the survey is that digital skills are increasingly needed in contemporary businesses. However, due to the identified lack of experience and knowledge in this area, training on digital designing should be conducted systematically and adapted to the conditions of business operations. This can overcome the lack of awareness of the FoF concept, a knowledge from this field and thus fears of new digital technologies implementation.

5. LIMITATIONS OF THE STUDY

This report should be considered as a pilot study for future research. The main limitation of the survey results is the non-representative sampling among the FoF stakeholders (in partners countries). In consequence, our findings and recommendations could be perceived as a point for further discussion but should not be directly generalized to other enterprises or regions without detailed inquiry. Another important limitation is the lack of understanding of FoF and of the terminology and ideas of the digital designing, that may affect the legitimacy of the final conclusions. However, to eliminate this effect, the key concepts have been introduced to the survey participants from FoF area. Furthermore, achieved results confirm importance of digital design skills and revel the competency gap of the group of surveyed companies.

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