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DESIGN FOR PRODUCT AND SERVICE INNOVATION IN INDUSTRY 4.0 AND EMERGING SMART SOCIETY

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Abstract. Within the context of the increasing digitalisation and intertwining cyber and physical dimensions connected by Internet, the paper aims at contributing towards understanding and conceptualising extent and scope of design integration for smart production and services and value generation for smart society including enterprises, customers and end-users. Research on design integration within the industry 4.0 or "internet of things" phenomena from strategic management perspective is still marginalised. Concepts from strategic and innovation management as well as open innovation including design and industry 4.0 perceptions are linked to propose a practice-oriented design integration approach for business practices in developing and exploiting new products or services in industry 4.0 context. The paper proposes conceptual approach to design integration and implementation within product or process development processes leading towards valuable innovations on corporate and societal level. It exemplifies how smart digitalisation and new enabling technologies might generate innovations driven by design as a tool and process. Design's role is demonstrated by intertwining dimensions of information, knowledge, technology, communication and society with different players and stakeholders, who share production or service inputs and outputs between different stakeholders in an open, distributed and co-existing way at different spatial and temporal scale.

Keywords: design, design-driven innovation, design value, value creation, industry 4.0.

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1. Introduction

In recent years, society is progressively moving towards a socio-technical-digital ecosystem, in which physical, virtual dimensions are increasingly intertwining, and more interactions between people, machines and digital technologies are taking place to serve the needs of society, to benefit the economy, environment, to improve our lives and to deliver meaningful experiences, which shared bring value added for all involved in the ecosystem –

manufacturers, services providers, customers and users.

Indeed, it is now a time of structural transformation within the ecosystem – economy and society. Evolutionary, it is moving from the agrarian society, over industrial revolution in 19th Century towards a smart industrial and service driven society characterised by advanced manufacturing and key enabling technologies, bio-based products, clean vehicles, sustainable construction, smart grids and digitalisation of business processes, networks, products and services (EU industrial policy, European Commission 2014, "For a European Industrial Renaissance").

In particular, it is a strong need for such developing trends when taking into account the socio-economic indicators in Europe and globally, and for innovations in the social, economic, environment, business, technological and societal setting. Europe demonstrates large and growing market potential in the context of smart ecosystem. Advanced manufacturing technologies change the way of companies' performance – they shift towards smart value chains or using technologies, which benefit the environment, e.g. environmentally friendly technologies (Wintjes 2013, p. 2; Guruz, Scherer 2014).

In this light, the present research presents an attempt of showcasing an increasing strategic role of design in the context of the current industrial evolution, smart production and digitalisation area and its value for different design stakeholders – companies, customers, end-users, etc. This will be undertaken by combining key approaches from the innovation and management fields – open innovation, design innovation. The paper is organised as follows. The next section presents the key concepts and common thread with integration of design and its tools to better embed design role and its potential in the context of industry 4.0 or smart production for innovations. The third section displays the methodology of the research. In the succeeding section, the results from the case studies are discussed. The fifth sections argues for a new perspective in the paradigm of value of design in smart production and potential of innovations through integration with consumers of smart products and services. The paper concludes with key observation-based implications and future research perspectives.

2. Theoretical background – industry 4.0, innovations and design

Aiming to reveal design value and integration within industry 4.0 trend, conceptual design of the present research is based on integration of concepts and approaches employed within strategic management – Porter's value chain and competitive advantage (Porter 1985; 1991; 1996), resources and capabilities (Barney 1991; Teece *et. al* 1997; Wahl, Prause 2013); innovation management – innovation process and open innovation (Trott 2012; Tidd, Bessant 2013; Chesbrough 2003; von Hippel, 1998; 2001; 2005; Grubicka, Matuska 2015; Hoffmann, Prause 2015). Through linking corresponding concepts and their conceptual meaning with design and its value proposition for innovations, design becomes crucial enabler for smart product manufacturing and service innovations.

2.1 Industry 4.0 and product / service innovations

Evolutionary, this trend refers to as fourth trend in industrial system – the so-called industry 4.0. Often, it is called the fourth industrial revolution. Term "Industry 4.0" has been predominantly used in the German scientific literature (Brettel *et al.* 2014; Sendler 2013; Kagermann *et al*. 2013; Bauernhansl *et al*. 2014; Kagermann 2015; Burmeister *et al*. 2015, etc.). Indeed, it was established by the German Ministry of Education and Research as a roadmap to promote German high-tech industry and its strategy. Research on industry 4.0 is highly interlinked with such phenomena as "Internet of Things", "Industrial Internet", "Internet of Things", "Data and Services" and "Smart Factory 4.0", "Advanced Manufacturing" and "Smart Manufacturing", etc. and their examination (Kagermann *et al.* 2013; Vermesan, Friess 2013; Porter, Heppelmann 2014; Westerlund *et al*. 2014; Simonite 2014; Tvaronavičienė 2014; Rezk *et. al.* 2015, etc.). The present research has adopted the term "Industry 4.0", as other concepts mentioned above are likely to be small and usually complement the complex phenomenon of industry 4.0, emphasising consistent digitalisation and linking physical objects and subjects,

real and virtual worlds and enabling them to communicate in a real time.

The core idea behind this trend is to secure high-tech manufacturing location, jobs and welfare to people in a certain region to generate the competitive advantage (Ramsauer 2013, p. 6; Avigdor *et al.* 2014, p. 2; Krückhans, Meier 2013, p. 31). Nevertheless, this current and future trend is of more evolutionary nature. It may be stated that the transfer towards industry 4.0 emerges in a smart society not from fast and disruptive changes, but as evolutionary process in a continuous and steadily way, integrating physical objects (technologies, machines and people) into the information network. The Internet has come before the fourth industrial revolution has started. Now, it is only about connecting through Internet with intelligent machines, systems production, processes, customers and consumers to form a sophisticated network, thus turning the real world into information system (Dujin *et al*. 2014, p. 7; Kagermann 2015, p. 25). Therefore, in this context, innovations are rather new adaptations or transformations by using technologies, which to some level are already developed. Foray *et al.* refers in this context to smart specialisation and structural evolution, which is driven not by radical innovations, but by adaptation to radical transformation. Generating new information and knowledge for the future economic value from an old, it is possible to arrive at new activities and new structural changes by using existing industrial commons, such as R&D, engineering, manufacturing and other capabilities that sustain innovation (Foray *et al.* 2011, 8; Rezk *et. al.* 2015). As a result, in this course, it can be referred more to incremental (Kirzner, 1973, p. 35) rather than radical innovations (Schumpeter 1911, p. 409-410; 1942 p. 82-83). Whereas incremental innovation implies the level, which improves a certain technology as compared to a previous level, i.e. continuous improvement, radical innovation has very far-reaching impact, e.g. automobile or airplane. Nevertheless, incremental innovations are important, since they constitute a basis for radical ones and bring with economic benefits (Fagerberg *et al.* 2006, p. 7-8). Yet, these industry 4.0 innovations are sustained rather disruptive innovations (Christensen 1997, p. 40f), whereas disruptive innovations bring a very different value as compared to the previous one and are likely to replace sustained ones. In this case, industry 4.0 can be understood as incremental process, which may enable either sustainable or radical disruptive innovations for the market and proposing new values for businesses.

Analysis of the value of design for product and services innovations in smart and digitalised production or service development processes remains narrowed mostly to research in the field of open innovation or user-centred approaches, such as user communities or user innovations (Jawecki *et al*. 2011; Füller *et al.* 2007, 2011, 2012; Gault 2011; Dell'Era and Landoni 2014; Baldwin, von Hippel 2009; von Hippel *et al.* 2011, etc.). Most of scientific outputs display service and organisational innovations for smart factories and digitalisation systems (e.g. Lee *et al.* 2014; Rezk *et. al.* 2015) losing a clear linkage with design and its value of design for product, service, social or organisational innovations. Role of design for innovations through user involvement related to industry 4.0 or smart production processes is likely to be underrepresented in this context.

2.2 Design as a resource, capability and innovation enabler in industry 4.0

Significance of design and its value proposition for business and thus economy has been the research focus of strategic management (Kotler, Rath 1984; Borja de Mozota 1998; 2003; 2006; Raulik *et al.* 2008; Cooper, Press 1995; Dumas, Mintzberg 1989; 1991; Walsh *et al.* 1992; 1996), marketing and branding (Murphy 1990; Meier-Kortwig 1997; Meffert, Burmann 2002; Giersch 2008; Esch 2012) architecture and design methods (Asimov 1962; Archer 1965; Simon 1969; Jones 1970; Guruz, Scherer 2014), engineering (Lawson 1980; Rowe 1987; Cross 1986; March, Smith 1995; Hevner *et al.* 2004; Cuneo *et al.* 2014), organisational and entrepreneurship (Lorenz 1986; Bruce *et al*. 1999; Kretzschmar 2003; von Stamm 2004; Grzecznowska 2005; Acklin 2013; Design EntrepreneurSHIP project 2014) and innovation related studies (Dickson *et al*. 1995; Cawood 1997; Cox 2005; Theter 2006; Chiva, Alegre 2009; Verganti 2006; 2008; Brown 2008; Koostra *et al.* 2009; EU Commission Staff Working Document 2009 and 2013; Rampino 2008; 2011; Bitard, Basset 2014; Rezk *et. al.* 2015) and research for several decades.

Design, the same applies for innovation, can be used as a noun or verb. Here, the focus is on design as an activity and process leading towards strategic and competitive advantage and innovation. The focus is on how

the design process can be organised and managed towards product and service innovations on corporate and community (users) levels. Design as a process may propose tangible and intangible value, because it serves as a tangible/intangible source and connector between creativity, i.e. generating new ideas and innovation, i.e. placing new ideas on the market and applying creativity to all the activities necessary to bring these ideas into use either as product, service or process innovations, thus creating a value (Whyte *et al.* 2015, p. 2) and enabling organisations to differentiate and position of the market (Porter 1985, p. 35; 1991, p. 103; 1996, p. 70). Although design is not only about invention, i.e. creating something totally new, it is a way of making (in)tangible impact through the implementation of ideas, i.e. design of products, services and experiences that touch, change and improve people's daily lives (Design Management Conceptualisation and Application, Design EntrepreneurSHIP project 2014, p. 8). Using design to lower costs, achieve greater resource efficiency and quality on products and services compared to competitors and to gain stronger value and recognition by customers and users may lead to competitive advantage. Integrating design into specific organisational activities, which enable to create value – logistics (suppliers/partners), development, operations (manufacturing), marketing and sales and after sale services – design becomes a part of the value chain. Thus, strategic design value can be generated not only at the top level of the value chain, e.g. strategic management level, but also at operational level. For this, design can create customer value at primary operational activities through differentiation/positioning gained on the market, at functional level through integrating design at organisational support activities and using design to improve and better coordinate functions, e.g. product or service design process. On top level, design adds strategic value through anticipation of changes in organisational internal and external environment (Borja de Mozota 1998, p. 28).

Acknowledging design's value for organisations, its power to differentiate, position on the market and improve functionality of internal processes and external appearance of organisations (products, services), design can be *viewed* as a strategic resource. Following Resource-Based View (RBV), resources are all tangible and intangible assets, capabilities, organisational processes, attributes, information, knowledge etc., i.e. all potential, which, in turn, when controlled by the enterprise allows it to recognise and implement strategies bringing organisational efficiency and efficacy (Barney 1991, p. 101; Crook *et al.* 2008, p. 1150-1152). Design is a resource, because it is a process (Whyte *et al*. 2015, p. 2; Er 1997, p. 293; Hack *et al.* 2012, pp. 140-141). It is a resource, since design may bring value through being hardly duplicable, imperfectly imitable and non-substitutable (Barney 1991, pp. 105-106; Boxall 1996, p. 65), it may influence products through giving them sense. Being design as a source of making sense of things, design implies messages to users, within the styling (e.g. form), functionality of a product, service or process (technology, cost), emotional and symbolic value, i.e. meaning. Meaning proposes to users a system of values by using a specific language, e.g. signs, symbols and icons that deliver the message (Verganti 2008, p. 440). Thus, it is hardly to duplicate and imitate design, when a specific sense is given through design to a certain product, service or a process. Design is also knowledge, as it is used to generate new meanings or forms (Jonas 2011, p. 1). As a result, design can be used as an organisational asset as well as information for competitive advantage. Through combination of new information flows, organisation gets ability to exploit new linkages between its activities internally and externally (Porter, Millar 1985, p. 152). As a result, design becomes a valuable resource, as it enables to differentiate, integrate, transform and be a good business practice (Borja de Mozota 2006, p. 45). Further, understanding design as a resource may create and offer a value proposition, reach markets, maintain relationships with customer segments and earn revenues (Osterwalder *et al.* 2014, p. 152).

Design may be perceived as capability too, particularly when using design as an activity and process – capacity to deploy design resources by incorporating organisational processes to provide enhanced productivity of its resources as well as a strategic flexibility and protection for its final product or service. Design capabilities can be developed over long-term through learning processes and are based on developing, carrying and exchanging information through organisation's human capital. As a result, to deploy design resources, tangible or intangible capabilities need human input (would it be organisations, customers or users) for information-based organisational processes and intermediate goods / invisible assets (Amit, Schoemaker 1993, pp. 35-37). Nevertheless, in today's dynamic word, especially in changing ecosystem and new forms of organisation – industry 4.0, such design capabilities must be dynamic. As a result, design must be able to integrate, build and reconfigure internal

and external competences to address rapidly changing environments. In this, new and innovative forms of competitive advantage can be achieved through dynamic capabilities (Teece *et al.* 1997, p. 516), whereby design is recognised as resourcing, organisational coordinative, protective and innovative capability deploying design resources (Jevnaker 1998, p. 21).

Understanding design as a resource, knowledge, asset, information, capability allows tracing its value within product / service development process and effective commercialisation, i.e. innovation. Launch of innovations also require specific capabilities, knowledge, skills, facilities, resources, market knowledge, financial resources and certain level of infrastructure. It is, in other words, knowledge and entrepreneurial know-how that makes innovations successful on the market (Fagerberg *et al.* 2006, p. 5ff). It is process turning opportunity into new ideas, ensuring its practical application in the reality (Tidd, Bessant 2013, p. 18-22) and bringing value through its availability and access to it for its users via the market and/or other channels or distribution peer-to-peer and/or by the market (Gault 2011, p. 9). In this light, design becomes an important enabler for innovation within the dynamic emerging smart community. Design, the same applies for innovation, introduces a new meaning and value for its users.

From strategic intent, it might be argued then that design, which has been perceived as knowledge, as discussed above, can be strategically deployed and exploited for product/service innovation. Strategic acting of design within the business frame can be delineated as a critical dynamic collaboration across operational and management practices of organisations or companies successfully utilising design capabilities. In the context of industry 4.0, such strategic indicators of design enable clear strategic opportunities advocated by scholars and practitioners: competitive strength, flexible manufacturing, individual customised products and services, innovative business models, new working and collaboration ways, resource-efficiency (production on demand), production at a place of use or in the market and user engineering through his integration in development process (Bartevyan 2015 p. 2). Indeed, innovation, and thus design, as showcased above, can beat on the market with same value enablers (Francis, Bessant 2005, p. 172ff).

Design can be perceived as applied innovation, i.e. capturing the talent and resources available inside and outside organisation to create new products, environments and new user perspectives. Strategic initiatives are applied by using design to, e.g. foster culture of innovation (Design Management Journal 1998, p. 17) or as innovation process (Borja de Mozota 2006, p. 47). Similarly, Brown describes design thinking as an approach to innovation, i.e. to process, which ends with a certain innovative solution (Brown 2008, p. 9). Sharing the same conceptual grounds, design management and design thinking approaches can be also perceived as twin-concepts of innovation (Carlgren 2013, p. 56).

Taking the complementarity and intertwining of design and innovation pertaining to importance and impact for functionality, technology and strategic indicators for value creation, design integration within corporate product/service development process in the context of industry 4.0 can be conceptualised, as demonstrated in Figure 1. It presents a tentative approach within current economic and social environment on how design might be perceived, integrated and exploited for smart economic and social solutions. It also demonstrates the shifting paradigm away from design used to be subject to the validation through testing, prototyping and assessment in terms of technical feasibility towards integrated design assuring high level of playroom for creativity and its tangible/intangible outputs in form of products, services or processes.

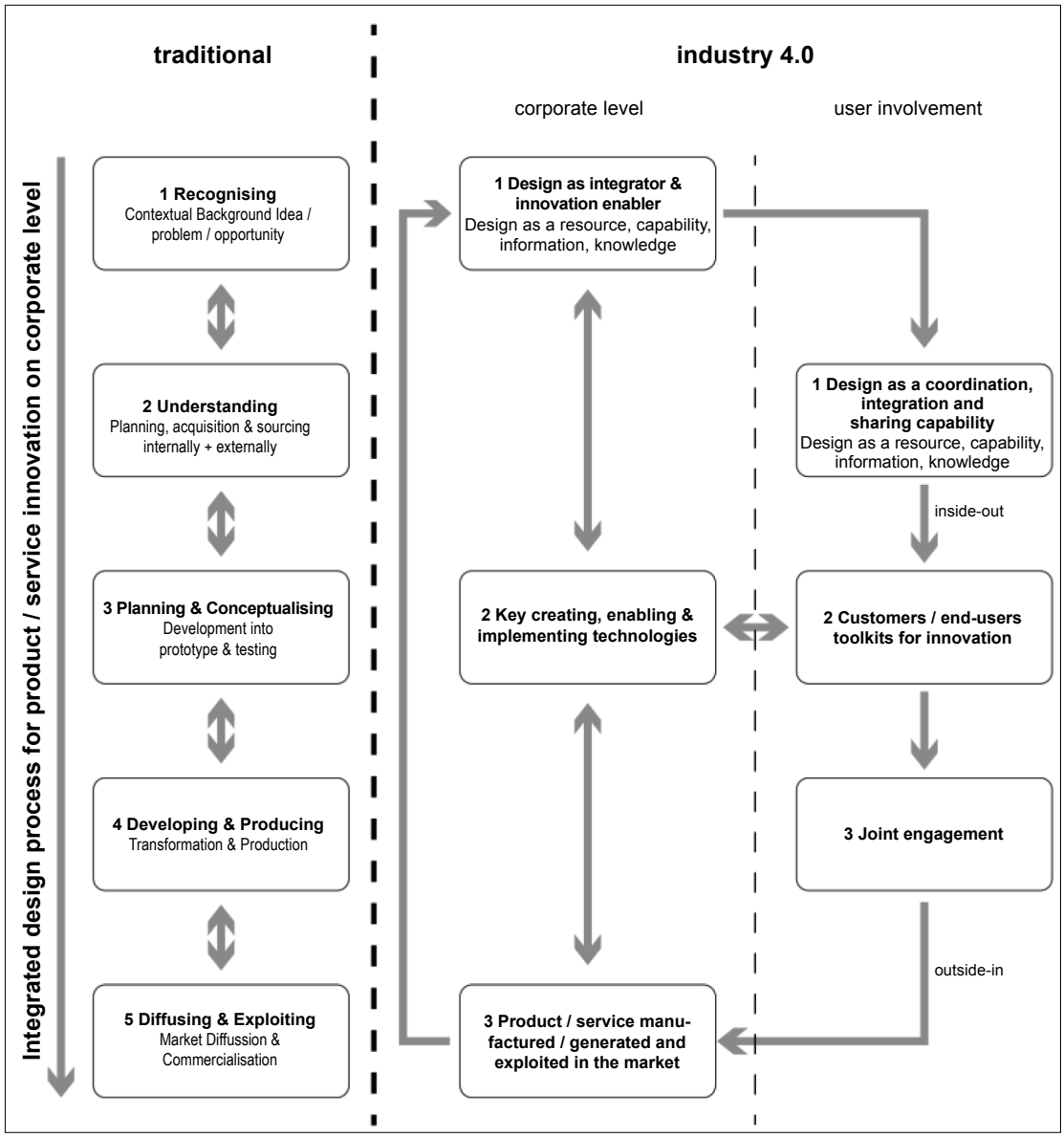

Fig. 1. Integrated design as a tool and process for innovations in industry 4.0 ecosystem

Source: compiled by the author

4. Methodology

The research analysis and assessment of design integration and exploitation practices in industry 4.0 discourses is reflected through integration of five principal research techniques: research approach, research type, methods, tools and scope. Since, as has been underpinned during the present research discourse, specific conceptual focus on integrated design process for innovations is to great extent lacking in the industry 4.0 research streams from strategic perspective (the present one being highly circled around individual segments and outputs of innovation processes, such as smart products, services and solutions), a qualitative approach is likely to be suited to increase significance of design application as innovative process for product/service innovation and to enrich the topical literature.

In the course of the present research process aimed at exploring visibility and feasibility of design integration and its value proposition and strategic advantage in industry 4.0. related discourses, the paper has adopted a qualitative research approach. As underpinned by Shields and Rangarajan, exploration-driven research is likely to be qualitative. It aims at understanding the topic, which seems to be underdeveloped (2013, pp. 26-27). A

deductive, thematic analysis and interpretation of data was conducted. The reasoning started with development of logical explanation behind the phenomenon of design integration and exploitation for product/service innovation and strategic value creation in industry 4.0 discourses. Yet, Spiggle designates her approach for consumer-related research, her research approach proposal is likely to be true for the present research (Spiggle 1994, p. 492ff). Drawing on the particular concept by Spiggle, categorisation of data was carried out according to the application and performance domains of industry 4.0, performance areas of design, operational and strategic indicators and key creating, enabling and implementing technologies within the context of industry 4.0.

The paper is built upon analytical, qualitative and practice-based research type. It can be argued that a "funnel" has been deployed for research purposes, i.e. the information and data have been acquired, assessed, deployed, distilled, justified, synthesised, amalgamated and presented. Building upon Dixon-Woods et al., both integrative and interpretative syntheses technique have been integrated. Particularly, material and information was combined concerned with the theme, pooled and compared. As a result, topical data was aggregated for the purpose of the analysis. It is also an interpretative attempt, since synthesis has been achieved through accumulating particular concepts in the research streams into higher-order conceptual approach (2005 p. 46).

With regard to research methods, there were employed descriptive and qualitative research methods, such as cross-case or multiple case analysis (Eisenhardt 1989; Miles, Huberman 1994, p. 101; Stake 1995, pp. 4-6; Yin 2009; 2012), thematic/content analysis, template (concept) based approach to analysis to explore the data gathered at a predefined scheme identified prior the analysis as well as generated inductively from the data (Crabtree, Miller 1992, pp. 93-109, etc.). The analysis results of design application and exploitation within industry 4.0 are presented in a narrative way. Integration of information from industry 4.0 cases becomes feasible through conceptual frameworks presented in the preceding section. Drawing on design as a common thread, design manifestation in industry 4.0 might be presented in the economic and social context, i.e. design conceptualisation and exploration in innovation processes on operational (product/services development), innovation output and impact level (operational, performance, economic, environmental and social efficiency, strategic advantage and value proposition for customers and users).

For the purpose of the research, the developed research tool – an integrative model in section 3 has been applied to analyse, synthesise and evaluate the data, and thus, design integration in industry 4.0. The research scope was not limited to any specific time frames, as the data were gathered from archives, and industry cases analysed are not bound to any specific period. Nevertheless, taking into account the novelty of this industry 4.0 trend, the cases concerned reveal role of design for innovations emerged on the market in the period of over last three to four years. Further, due to the regional background, this present research is limited to case studies from Germany in terms of location scope. The observation yields the natural context and is conducted without direct researcher participation. For this, it makes it is free from bias, which could arise through experimental research environment.

5. Results from the cross-case analysis

Taking into account the present context of industry 4.0, and potential domains of design integration for innovation in this discourse, the present section presents the examination results regarding design integration in the following chosen domains of industry 4.0 practices, and thus reveals the tenets of industrial and service design potential in the following discourses:

- Industrial manufacturing – design integration in product / service development (case 1);
- Service sector – transport and mobility servicing (vehicle maintenance) (case 2);
- Energy efficiency – energy saving at home (case 3); and
- Customer / user engagement – tools in vocational education schools (case 4).

It is clear that the cross-case analysis might bear an extensive challenge in making complex research results more critical in terms of comparison as well as when articulating specific conclusions that reveal the role of design for innovations in industry 4.0 as well as its perception and performance in terms of different process

segmentation. Nevertheless, the multiple cases were examined based on the structural approach presented in the section on the concept taking into account key variables of design performance from the processual point of view (development phase) within a particular industry 4.0 discourse (one of the four fields mentioned above), innovation creation and value capturing.

The present paper does not describe the individual cases in detail due to limited scope. Indeed, the description of case studies does not influence the aim of the research and showcasing of key outputs when integrating the design. On the contrary, the analysed cases demonstrate the individual segments of innovation creation and value creation in operational, economic, social and environmental context. As a result, the cases were broken down in a particular segments in terms of their contents, necessary to reveal the contribution of design to innovation on operation and strategic level in the economic and social context. As a result, the landscape of cases is presented only to what is necessary from the research objective point of view.

5.1. Design for innovative products / services

Complying with the principles of the cross-case analysis, the focus remains on understanding and revealing the research phenomenon – design and its embedding in the industry 4.0 context. From the comprehensive umbrella perspective, as the analysed results from all four industry / sector domains of industry 4.0 trend demonstrate, all innovative processes reveal the integration of design or tend themselves to be integrative design-driven innovation processes.

First, the design integration and tangibility in all four cases concerned is evident. It is a development process, an innovative process, since it marks the change of development product / service as compared to the previous ones exploited on the market. Indeed, as it is stressed in the research streams, design process can be twinned with innovations process against the background of the same processual segments and output indicators shared. In case 1, where the industry player and manufacturer of industrial product chosen – washing machines for households – does change the development process of producing spare parts for household washing machines. Supply of spare parts after the end of the product life cycle, i.e. injection moulded plastic part of household washing machines. In this particular case, we may argue that the integrated design process (as showcased in figure 1) already starts with the deploying design as information, knowledge and a specific research.

As the previous practices showed on the corporate level, the design output (the plastic part) produced did not seam to be sustainable and efficient in terms of economic, operational and environmental sustainability. The spare parts for household washing machines maintenance were produced in advance to secure a demand from customers / users based upon request for maintenance. Further, they did not seam to ensure higher level of functionality, technical and economic flexibility: in case of stopped manufacture of a specific household washing machine model, the produced spare parts in advance were subject to change and could not be integrated in the available models. On the contrary, the use of design in the industry 4.0 context becomes possible when understanding design, as underpinned above, as a certain knowledge and organisational / corporate capability to deploy the design resources (Teece *et al.* 1997, p. 516), in this particular, case all resources that enable production of the output (product) in a new way – meanings, functions and forms.

In such a case, combining design resources, capabilities, information and knowledge on how a new, specifically defined and tailored spare part for a particular model of household washing machine can be expressed via new form, meaning or function, design enables generation of innovation – new spare part produced on demand, i.e. whenever needed by the customer / end-user. In contrast to a common integrated design process, design process in the context of industry 4.0 does integrate a different number of process stages (reference figure 1). Innovation generation in step 1 emerged from adopted, new, modified or absorbed design knowledge, resources deployed, knowledge and capabilities utilised, can be directly linked to developed product (in this particular context – spare part) exploited on the market by households (customers / end-users). In this light, innovation generation (conceptualisation) and its exploitation on the market are linked through key creative (design) innovation technologies that directly refer to design (design software enabling form and shape of a new spare part),

drawing, prototyping, visualisation and simulation) and key enabling technologies that link innovation generation and exploitation (production) via design. In case 1, it is 3D printing as creative innovation technology that enables the design of product to be implemented and produced. The spare part for household washing machine is produced through match of creative technology (3D printing) with ITC technologies, as Internet and software. Owing to the creative technologies that enable innovation and linking up with the enabling parameters, the design process can be speeded up, streamlined and customised.

Within the industry 4.0 context, it might be argued, design becomes as a cornerstone of the innovation processes that enables delivery of innovative products and processes. Design is likely to be embedded in all segments of the development processes – starting from design as an integration and enabler (knowledge, capability, etc.), deploying design capability in visualising and producing the desired product and delivering it to the customers / end-users. On the corporate level, an efficient and effective utilisation of design capabilities is a key for innovations. As the case 1 demonstrates, sufficient design knowledge, deployed by using specific creative technology may generate the desired product. Souring externally, acquiring new knowledge and sources, developing prototypes and testing become to a highly extent redundant. Stages 2-4 as known from the traditional integrated design process for product / service innovations can be merged and / or replaced by key creating, enabling and implementing technologies (Dodgson *et al.* 2008, pp. 5-6). Combined, such technologies already integrate the traditional stages, as, e.g. planning, conceptualisation, validation, (thus, excluding the need of prototyping) and production.

As the system linking up enabling indicators with such creative innovation technologies has been validated, a playroom for designers or creative potential and capabilities employed in the product innovation process is extensive. Specific design knowledge and capabilities integrated in the development process (such as knowledge on combining shape, material and securing functionality of a spare part for household washing machine) are necessary when matching the appearance of a product and its functionality. As claimed by Wood *et al.* 2011, design (shape and form, meaning, function) must satisfy the functionality of such a product, which should be chosen also in terms of materials and functionality compliance. Furthermore, design principles are integrated in all three types of technologies, as all of them hold design-immanent properties. Design being as a driver for development process, can aggregate all the necessary components making up a product, and much more important, make the product / service visible, tangible through form and shape and valuable for customer / end-user through specific meanings and values generated. Without design being as a stepping stone for any development process, no efficient and effective form, functionality and meaning of a product / services can be achieved in industry 4.0.

Addressing the integration of design and its potential for innovation, or even, in more revolutionary terms, being innovation, on the corporate level, design also acts as enabler integrating customers / end-users into product / process development processes (cases 2-4). Industry 4.0 calls for integration of people, machines and technologies. It is community and customer experience that has been prioritised within the industry 4.0 on the European level (European Commission, Innovation Policy 2015). Customer experience and communities are regarded as necessary enablers for growth and efficiency drivers, infrastructure and technology for industry 4.0. in Europe (Bechtold *et al.* 2014, p. 5). For this reason, involvement of customers, users or end-users into innovation processes – open innovation processes – respectively, where customers and end-users do contribute towards increasing product / process efficiency with their inputs towards product / service, becomes essential. In this regard, design and integrated design processes (Figure 1) serves as an approach for capitalising from customers / end-users experiences and contributions for organisations and companies. Perception of design as coordinative, integrative and sharing activity within an organisation enables to involve customers / end-users (von Hippel 2001, p. 9). Sharing the design as a tool, its conceptualisation and generation via key enabling technologies, customers / end-users can be effectively and efficiently involved in the innovation process today (von Hippel, Katz 2002; von Hippel 2001; 2005, etc.).

To exemplify, case 2 deals with the transport and mobility service sector in Germany, specifically vehicle maintenance in the automotive trade sector, including full-service supply of car workshops to their customers / end-users. Compared to the previous case 1, this particular case covers both parts of the integrated design

process in industry 4.0 – corporate and user-involvement (Figure 1). In this case, effective product and services development process as well as both target groups are essential for the entire value chain and value creation to both customers / end-users. Design is integrated in all three segments of the supply and value chain – spare parts producing sector / supplier, automotive trades / vehicle maintenance workshops and vehicle customers / end-users. When integrating the key creating, implementing and enabling technologies – which can be called design / innovation technologies – in this supply and value chain, design becomes a key competence and capability in terms of coordination, integration, knowledge and competence sharing as well as innovation enabler. Respectively, design can increase efficiency and effectiveness of supply chain performance (in terms of supply / delivery time) and value chain performance (streamline value creation and perception by customers / end-users through ascribing or granting new meanings, symbolic values, etc. to the products and services concerned). In this particular case, key creative (innovative technology) – 3D printing – transfers the value of design into a new, innovative dimension. Particularly, this is a case for old-timers, which are to a higher extent subject to replacement of wear parts. Through deployment of design capabilities into this field (visualisation, simulation and combination to the technologies and functionalities), replication (production) of vehicle parts, which are no longer on the market as a result of stopped manufacturing) becomes feasible. As a result, through design, the value of old-timers and especially related higher repair costs get new meaning within end-users (car owners). The same applies to other segments and stakeholders of the supply and value chain. For instance, through streamlining of key creative (design) technologies for innovation (e.g. adopting more flexible printing of spare parts, cheaper materials, etc.), efficient design capabilities, when deployed, can lead towards more flexible and efficient supply and value chain – in certain cases, for instance, becoming independent as automotive trades / vehicle maintenance workshops from the supply of spare parts from the spare parts producer and transforming to supply of such spare parts to the customers / end-users directly.

Similar are observations made from case 3, however, here, customers / end-users are left much more extensive space of action. With regard to one of the industry 4.0 tenets, as prioritised on the European level – the issue of smart home or smart living – characterised by higher energy savings as well as energy efficiency reveals a slightly different performance or appearance of design in innovation products. More specifically, design is a source and resource of new value creation and new coordinative and sharing competence and capability. The new value creation emerges only upon adaptation of new design tools for innovation technologies and involvement of customers / end-users into the product / service development and exploitation. To exemplify, German companies used to produce traditional products necessary for households and ensuring comfortable and cosy living, mainly, divided in four key product groups (windows and systems; security installations; home access (garage, gates); outdoor). New innovation in this field and transformation trend towards smart living or smart home emerged owing to integration of new, combined design skills and capabilities – design tools. For instance, design role of being integrator and coordinator enabled integration of customers / end-users together with operational control of home devices and installations produced by such German companies. The innovation itself and new value creation emerged via granting design new properties – design became as a customer / end-user tool in form of applications that can easily be installed and managed via key enabling indicators – Internet, WiFi, accessibility of server, etc.) as well as key creative (design) technologies – apps (applications). Customers / end-users are granted extensive manoeuvring room in terms of designing, i.e. conceptualising, adapting and utilising the functionalities of a product / service enabled by the producer / service provider. In such a case, customer / end-user and producer / service provider are linked through the so-called design tools, in this particular case – app (von Hippel, Katz 2002; von Hippel 2001; 2005, etc.). In this regard, the producer / service provider of a product / service for smart home / smart living has access to the generation and exploitation of the design tools by customer / end-user and thus may benefit in making additional necessary adaptations of product / service or other movements on the market. Further, the design capability of customers / end-users can be also utilised by producers through key enabling technologies to benefit from design capability of customers / end-users through individualisation of the app and application of different functionalities to the personal needs in terms of new innovative utilisation ways, adaptation possibilities, etc.

Connected with the results mentioned above are evaluation results from case 4, where playroom for design capabilities are left to pupils of vocational education schools, especially in terms of completing half of the

vocational education in laser producing specialised enterprise. In this context, the educational hardware (e.g. tablets) is used by pupils to enable them to develop and utilised design (innovative) capabilities. In contrast to the previous cases examined, the results from these particular cases reveal the design capability for innovation within the educational array. In this case, pupils as end-users are utilising design resources, tools and thus building design-driven capabilities, which integrated in the form of tablets, can be utilised as a new knowledge and information to be integrated in the corporate product / service development processes (design as integrator).

5.2 Design impact level for innovation outputs and strategic value creation

Bearing in mind the role of design, which has been already revealed in the preceding section, this part summarises key observations regarding specific areas of impact of design within the innovation processes and its impact reach. All analysed cases showcase positive value creation and its strategic role on operational, corporate strategic, environmental and social levels based on integrated design process approach for product / service development. It is to be emphasised here that value creation and capturing includes both corporate and customer / end-user level. Nevertheless, from the perspective of strategic design manifestation greater focus is placed on strategic contribution of design for organisations.

Operational level. Building upon observation of design manifestation in all four fields of application within the industry 4.0 context (cases 1-4) the present research may state that the role of design on operational level is crucial, since it influences, first, operational efficiency. As all cases demonstrate, operational efficiency has been streamlined or sustained either through design in product or service development in form of innovations within the industry 4.0 discourse. To exemplify, aesthetic appearance is of vital importance in both product and service development. In case, where form / shape of the product (external appearance expressed through design) is highly linked to the meaning or symbolic value, external appearance of the product / services embedded through design becomes crucial for generating new meanings of such a product / service. Integrated design in development processes enables manufacturing of new feasible forms and / or combinations of products / services (e.g. smart living when combining traditional products with new design-driven processes (apps user involvement in design processes, spare parts production for old cars, or production of spare parts on demand, etc.).

Further, with regard to the development process, effective and efficient design integration acts as a driver for efficient utilisation of resources (materials, personnel, equipment, etc.) and related capabilities. Key design capabilities and innovation implementing technologies in the industry 4.0 array are likely to be sufficient to develop innovative product / processes (in the cases analysed). As exemplified, development processes become shorter through effective design integration – creative (innovation) implementing technologies (e.g. 3D printing). Indeed, such technologies already integrate design knowledge, resources and capabilities, as products / services are already designed in their shape / form with visualisation or similar software and linked in terms of the viability and the available technology – 3D printing – to ensure the highest possible functionality of such a product / service. When utilised in the development process, such technologies tend to contribute to shorter development cycles – planning, research, testing and prototyping – and may become redundant for producing a new product / service and exploiting it on the market. Such technologies do already possess the validation of design (meaning and functional appearance) and thus ensures durability of a product / service over a longer time of use. In this sense, also manufacturability of products / generation of services may be streamlined in terms of time and resources employed. Supply, delivery or production time is reducing. Materials utilised are deployed in an efficient way and ensure flexibility in terms of resources acquisition and deployment. Enabling technologies ensure higher integrity of design internal and external properties and peculiarities for product / service innovation. Quality of a product / service is a key result of integrated design, as it efficiently and effectively merges the symbolic representation of a product in form / shape with technology, thus achieving aesthetics and functionality of the final result (product / service) (Candi 2005, p. 3).

Such design integration and implementation enables value creation and value capturing within operational practices, as mentioned above – addressing real-time and emergent needs in a predictive manner, offering an in-

novation product / process synergising and involving customers / end-users in the development process to share and benefit from the experiences. Possibility of easy replication (e.g. spare parts produced using 3D printing) assures value capturing. It is not necessary to predict the needed number of spare parts any longer and to produce them in advance storing them in warehouses. They can be manufactured on demand taking into account shorter production cycles, resources efficiency and stronger customer / end-user involvement.

Corporate strategic level. With regard to this indicator, design enables crucial economic efficiency in terms of increased productivity (e.g. spare parts) as well as flexibility within the supply and value chain through control / adaptation of design resources, competences and capabilities. A manufacturing enterprise, which traditionally used to be subject to production and warehousing of spare parts, is able now with utilisation of, e.g. creative (design technologies) to produce such spare parts on demand. This, in turn, enables cost savings originally used for production and rent costs and location flexibility.

Creating something new (invention) and utilising this new on the market with creative (design tools), e.g. 3D printing, visualisation software, apps, etc. enable organisations to differentiate and gain new positioning. Companies utilising such design tools and integrating it in product / service development process may easier enter new markets or market niches as well as streamline their supply and value chains (e.g. direct customers, end-users involvement). As a result, flexible operational capacity enabled through real-time aggregated and mobilised design capabilities significantly contribute towards several strategic assets – productivity optimisation and strategic flexibility.

Environmental context. From the environmental responsibility perspective, design integration and implementation in the industry 4.0 context enables organisations to introduce more environmentally friendly practices. Linking up with the example mentioned above, new integrated design approaches combined with key innovation creating technologies (3D printing) have positive impact on corporation strategic orientation: from the logistical point of view, production of spare parts on demand reduces logistical practices, and thus, environmental impact. Energy and fuel consumption can be efficiently saved through reduced logistical interactions, as the need for warehouses and their integration in the supply chains become unnecessary. As a result, the environmental impact is also reduced through saved energy usage and fuels used to transport and distribute spare parts concerned. This, in turns, allows greater sustainability of product / service through material savings, reduced resource usage and ecological mindset.

Taking into account the last indicator of design – design for social efficiency – this performance can be underpinned through observations from cases referring to service generation and exploitation (mainly cases 3 and 4). This is particularly crucial in context of digitalisation and open innovation. Specifically, design integration in development processes allows increased individual customisation through providing customers / end-users with design generating and implementing tools. Customers / end-users can individually design the final stage and performance of their own products (e.g. as in case on app to adapt to the individual needs house installations, devices, etc. in terms of energy saving, security, etc.). Using the provided design tools (technical app), customers / end-users are able to develop the products / services they need – e.g. increase / decrease lighting or heating, control security installations over the app. In this, they do not change the original products / services provided, but grant new meanings to the existing ones, making these innovative.

From the corporate perspective, this bears an important value creation and capturing for organisations. Through joint engagement of enterprise experts and customers / end-users and their connectivity possible through creative innovation implementing technologies and enabling indicators (Internet, software, platforms, apps, etc.), enterprises are granted access to design knowledge, resources and information generated by customers / end-users. Respectively, this new knowledge can be deployed by enterprises for adaptation or replication of new products / processes that meets customers / end-users needs to a greater extent than original ones (reference figure 1). Meeting of customers / end-users needs through providing them with a greater playroom for creativity (designing products / services by themselves) can be seen also as an important source of customers loyalty and new potential customers / end-users involvement.

6. Concluding observations and implications

Currently, design enjoys increasing recognition as an integral part in innovation-driven economy on organisational, business, societal and policy levels. Nonetheless, its integration within the industry 4.0 research streams is emerging, especially from the conceptual perspective. Growing advocacy of design is highly associated with the retrenching European industrial and business performance patters, mounting competition and socio-economic challenges having stronger direct and indirect impact on our society (e.g. health, energy, mobility, environment, etc.).

In the context of industry 4.0, the present research contributes towards deeper understanding of capitalisation possibilities through design integration, implementation and exploitation in product or service development processes for enterprises. Practice-oriented approach proposes a solution on how design can be traced, integrated and utilised within innovation processes. It also underpins perception of design within innovation processes. Integrated design process for product / service development can be perceived as innovation process, and design is an essential knowledge, resource and capability in innovation process of industry 4.0.

From the strategic perspective, design might positively influence value creation and capturing on organisational operational and strategic levels, for both enterprises and customers / end-users, as observations showcase. Particularly, design-driven development processes lead towards flexible manufacturing and servicing, individual customised products and services, innovative business models, new working and cooperation patterns, resource-efficiency (production on demand), production location flexibility and effective customers / end-users engagement through their integration in development process.

Design also proposes value in terms of sustainability, environmental and social efficiency. Effectively employed, design as a tool and process can streamline performance of supply and value chains, reduce logistical interactions and make additional activities redundant. This, in turn, has positive implications for environment through, e.g. carbon footprint and energy reduction, at the same time ensuring social efficiency – stronger social recognition by customers / end-users for socially and environmentally responsible performance of an enterprise.

Design is perceived as a driving force for smart manufacturing, smart products and services connected with customers and consumers, increasing resource efficiency, business performance and competitiveness and level of innovations. Nevertheless, with regard to the findings, the intensity or external perception of design and its integration within the innovation product or process development process may differ. The reason behind this is a level of design tangibility and perception.

Design is traceable and viable via tangible appearance (would it be sign, form, shape, styling, etc.) combined with function and technology as well as through giving this specific form significant and designating its relation to other things, end-users, economic, environmental or social environment, customers and end-users. Through specific signs, symbols and forms, the product service developed becomes more tangible than compared to other cases, where the perception and tangibility of design is attached to intangible tenets, such as meanings, symbolic values, etc. In these particular cases, the meaning is expressed through a particular service, which can become valuable when exploited on the market by consumers or end-users.

As a result, the proposed framework integrates both perspectives – industrial and service design, targeted to support enterprises to better understand and streamline their operational and strategic patterns internally and externally on the market. The shortcoming of this proposed conceptual approach lies in the limited application practices and a number of qualitative cases observed. For this reason, the forthcoming research is set out to enrich the body of empirical findings highlighting practical orientation of the proposed framework and its integration in modern enterprises practices within the industry 4.0 trend. It is intended to specifically support this grounded framework and demonstrate its increasing coordinative, integrative and innovative capacity for product or service development practices.

References

Acklin, C. 2013. Design Management Absorption Model: A Framework to Describe and Measure the Absorption Process of Design Knowledge by SMEs with Little or no Prior Design Experience, *Creativity and Innovation Management* 22(2): 147-160.

Amit, R. and Schoemaker, P. J. H. 1993. Strategic Assets and Organisational Rent, *Strategic Management Journal* (14)1: 33-46.

Archer, L. B. 1965. *Systematic Method for Designers*, The Design Council: London, 40p.

Asimow, M. 1962. *Introduction to Design*. Englewood Cliffs, Prentice-Hall: New York, 135p.

Avigdor, G., Gauders, N., Hollanders, H., Lucas, R., Mielech N. and Wintjes, R. 2014. *Trend report Smart factories, clean tech and customer experience; how to scale-up the success of learning with users?* Business Innovation Observatory Contract No 190/PP/ENT/CIP/12/C/N03C01, European Union, Directorate-General for Enterprise and Industry, Directorate B "Sustainable Growth and EU 2020", Unit B3 "Innovation Policy for Growth".

Baldwin, C. and Hippel, E. von. 2009. *Modelling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation*, Working Paper 10-038, 1-34.

Barney, J. B. 1991. *Firm Resources and Sustained Competitive Advantage*, Journal of Management (17)1: 99-120.

Bartevyan, L. 2015. *Industry 4.0 – Summary report*, DLG-Expert report 5/2015, 1-8.

Bauernhansl, T., Hompel, M. ten and Vogel-Heuser, B. (Eds). 2014. *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration*, Springer Vieweg: Wiesbaden, 648p.

Bechtold, J. and Kern, A. 2014. *Industry 4.0 – The Camgemini Consulting View: Sharpening the Picture beyond the Hype*, The Camgemini Consulting, 1-36.

Bitard, P. and Basset, J. 2014. *Mini Study 05 – Design as a tool for innovation: A Project for DG Enterprise and Industry*, INNO GRIPS, PRO INNO Europe, 1-79.

Blythe, C. 2014. Business Models for value generation in the Internet of Things, in *Data- and Value-Driven Software Engineering with Deep Customer Insight, Proceedings of the Seminar no. 58314308*, 8-15.

Borja de Mozota, B. 1998. Structuring Strategic Design Management: Michael Porter's Value Chain, *Design Management Journal, Spring* (9)2: 26-31.

Borja de Mozota, B. 2003. Design and competitive edge: A model for design management excellence in European SMEs, *Design Management Journal Academic Review*, The Design Management Institute (2): 88-103.

Borja de Mozota, B. 2003. *Design Management. Using Design to Build Brand Value and Corporate Innovation*, Allworth Press: New York.

Borja de Mozota, B. 2006. The Four Powers of Design: A Value Model in Design Management, *Design Management Review*, The Design Management Institute (17)2: 44-53.

Boxall, P. 1996. The Strategic HRM Debate and The Resource-Based View of The Firm, *Human Resource Management Journal* (6)3: 59-75.

Brown, T. 2008. Design Thinking, *Harvard Business Review*, June, 1-10.

Bruce, M., Cooper, R. and Vazquez, J. 1999. Effective design management for small businesses, *Design Studies* (29)3: 297– 315.

Burmeister, C., Lüttgens, D. and Piller, F. T. 2015. *Business Model Innovation for Industrie 4.0: Why the "Industrial Internet" Mandates a New Perspective on Innovation,* RWTH Aachen University, Technology and Innovation Management (TIM).

Candi, M. 2005. *Design as an Element of Innovation: Evaluating Design Emphasis and Focus in New Technology-Based Firms*, VDHR-SBWP-2005-01, 1-14.

Carlgren, L. 2013. *Design Thinking as an Enable of Innovation*, Chalmers University of Technology: Gothenburg.

Cawood, G. 1997. Design Innovation and Culture in SMEs. *Design Management Review* (8)4: 66-70.

Chesbrough, H. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business School Press: Boston, 227p.

Chiva, R. and Alegre, J. 2009. Investment in Design and Firm Performance: The Mediating Role of Design Management, *The Journal of Product Innovation Management* 26: 424-440.

Christensen, C. M. 1997. *The innovator's dilemma*, Harper Business: New York, 225p.

Cooper, R. and Press, M. 1995. *The Design Agenda: A Guide to Successful Design Management*, John Wiley &Sons: Chichester, 298p.

Cox, G. 2005. *Cox Review of Creativity in Business: Building on the UK's Strengths*. Design Council, London, 46p.

Crabtree, B. F. and Miller, W. 1992. *Doing Qualitative Research*, Newbury Park, Sage: CA, 276p.

Crook, T. R., Ketchen Jr., D. J., Combs, J. G. and Todd, S. Y. 2008. Strategic Resources and Performance: A meta-analysis, *Strategic Management Journal* 29: 1141-1154.

Cross, N. 1986. The Development of Design Methodology in Architecture, Urban Planning and Industrial Design, in R. Trappl (Ed.) *Cybernetifs and Systems '86: Proceedings of the Eight European Meeting o Cybernetics and Systems Research*, D. Reidel Publishing Company: Dordrecht, 173-180.

Cuneo, A.; Ferrari, M. L.; Traverso, A. and Massardo, A. F. 2014. Sustainable district development: a case of thermoeconomic optimization of an energy hub, *Entrepreneurship and Sustainability Issues* 2(2): 74–85. DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(3)

Dell'Era, C. and Landoni, P. 2014. Living Lab: A Methodology between User-Centred Design and Participatory Design, *Creativity and Innovation Management* (23)2: 137-154.

Design EntrepreneurSHIP Project. 2014. Design Management Conceptualisation and Application: Handbook of Practices on Design Management Application into Business, Documentation from the EU-funded project, Design EntrepreneurSHIP – Integration and Education of Students, Graduates and SMEs in terms of Industrial Design Management, 87p.

Design Management Journal (DMJ).1998. 18 Views on the Definition of Design Management, *Design Management Journal* (18)3: 14-19.

Dickson, P., Schneider, W., Lawrence, P. and Hytry, R. 1995. Managing Design in Small High Growth Companies, *Journal of Product Innovation Management* 12(5): 406-415.

Dodgson, M., Gann, D. and Cooptmans, C. 2008. *Playful Technologies: Creativity, Innovation and Organisation, in DRUID's 25th Anniversary Conference on Entrepreneurship and Innovation – Organisations, Institutions, Systems and Regions*, Copenhagen, 1-20.

Dujin, A., Geissler, C. and Horstkötter, D. 2014. *Think Act Industry 4.0. The new industrial revolution: How Europe will succeed*, Ronald Berger Strategy Consultants GmbH: Munich, 24p.

Dumas, A. and Mintzberg, H. 1989. Managing Design, Designing Management, *Design Management Journal* (1)1: 37-43.

Dumas, A. and Mintzberg, H. 1991. Managing the Form, Function and Fit of Design, *Design Management Journal* 2(3): 26-31.

Eisenhardt, K. M. 1989. Building Theories from Case Study Research, *The Academy of Management Review* (14)4: 532-550.

Er, H. A. 1997. Development Patterns of Industrial Design in the Third World: A Conceptual Model for Newly Industrialised Countries, *Journal of Design History* (19)3: 293-307.

Esch, F.-R. 2012. *Strategie und Technik der Markenführung*, Vahlen, München, 784p.

European Commission. 2014. For a European Industrial Renaissance, Communication from the Commission COM(2914) 14 final, Brussels.

European Commission. 2015. Business Innovation Observatory, Available on Internet <http://ec.europa.eu/enterprise/policies/innovation/policy/business-innovation-observatory/case-studies/index_en.htm>, accessed 20 May 2015.

Fagerberg, J., Mowery, D. C. and Nelson, R. R. 2006. *The Oxford handbook of innovation*, Oxford University Press: New York, 765p.

Foray, D., David, P. A. and Hall, B. H. 2011. *Smart Specialisation: From academic idea to political instrument, the surprising career of a concept and the difficulties involved in its implementation*, MTEI Working Paper, Lausanne, 1-16.

Francis, D. and Bessant, J. 2005. Targeting innovation and implications for capability development, *Technovation* 25(3): 171-183.

Füller J., Matzler K. 2007. Virtual product experience and customer participation – A chance for customer-centred, really new products.

Technovation (27): 378-387.

Füller, J. Matzler K., Hutter K and Hautz, J. 2012. Consumers' Creative Talent: Which Characteristics Qualify Consumers for Open Innovation Projects? An Exploration of Asymmetrical Effects, *Creativity and Innovation Management* (21)3: 247-262.

Füller, J., Huttner, K. and Faullant, R. 2011. Why co-creation experience matters? Creative experience and its impact on the quantity and quality of creative contributions, *R&D Management* (41)3: 259-273.

Giersch, J. 2008. *Corporate Brand Management international tätiger Unternehmen – Verhaltenswissenschaftliche Analyse interner und externer Zielgruppeneffekte unter Berücksichtigung landeskultureller Aspekte*, Gabler: Wiesbaden, 456p.

Grubicka, J. and Matuska, E. 2015. Sustainable entrepreneurship in conditions of UN (Safety) and technological convergence, *Entrepreneurship and Sustainability Issues* 2(4):188–197. DOI: http://dx.doi.org/10.9770/jesi.2015.2.4(2)

Grzecznowska, A. 2005. *Design Impact on the Economic Output of Enterprises and their Competitive Position*, presented at the Design Research, Industries and a New Interface for Competitive Conference, 22-24 September, University of Art and Design, Helsinki, 356p.

Guruz, R.; Scherer, R. 2014. Sustainable energy entrepreneurship through architectural design: a key point controlled method, *Entrepreneurship and Sustainability Issues* 2(2): 60–73. DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(2)

Hack, A., Prause, G. and Maknyte, L. 2012. Design Management and Branding for SMEs: Experiences from the DesignSHIP', in T. Muravska and G. Prause (Eds.) *European Integration and Baltic Sea Region Studies: University-Business Partnership through the Triple Helix Approach*, Berliner Wissenschafts-Verlag: Berlin, 129-148.

Hevner, A. R., March, S. T. and Park, J. 2004. Design science in Information Systems research, *MIS Quarterly*, 28: 75-105.

Hippel E. von and Katz, R. 2002. Shifting innovation to users via toolkits, *Management Science*, 48 (7): 821-833.

Hippel, E. von, Jong, J. P. J. de and Flowrers, S. 2011. *Comparing Business and Household Sector Innovation in Consumer Products: Findings from a Representative Study in the UK*, 1-29.

Hippel, E. von, Ogawa, S. and Jong, J. P. J. de. 2011. The Age of the Consumer-Innovator, *MIT Sloan Management Review* (53)1: 1-16.

Hippel, E. von. 2001. Perspective: User Toolkits for Innovation, *Journal of Product Innovation Management* (18)4: 247-257.

Hippel, E. von. 2005. *Democratizing Innovation*, Cambridge, MIT Press: MA. 654p.

Hippel, E. von. 1988. Lead user analysis for the development of new industrial products, *Management Science*, (34)5: 569-582.

Hoffmann, T. and Prause, G. 2015. How to keep open-source based innovation approaches sustainable: a view from the intellectual property perspective, *Entrepreneurship and Sustainability Issues* 2(3): 133–141. DOI: http://dx.doi.org/10.9770/jesi.2014.2.3(2).

Jawecki, G., Füller, J. and Genauer, J. 2011. A Comparison of Creative Behaviours in Online Communities across Culture, *Creativity and Innovation Management* (20)3: 144-156.

Jevnaker, B. H. 1998. Building up organizational capabilities in design, in M. Bruce & B. H. Jevnaker (Eds.), *Management of design alliances. Sustaining competitive advantage*, John Wiley & Sons: Chichester, 13-38.

Jonas, W. 2011. *A sense of vertigo. Design thinking as a general problem solver?* 9th European Academy of Design Conference (EAD). Porto, 1-11.

Jones, J. C. 1970. *Design Methods*. John Wiley & Sons: New York and Chichester, 472p.

Kagermann, H. 2015. The Role of Cooperation, Co-Determination and Networks in Organising Change', in H. Allback, H. Meffert, A. Pinkwart and R. Reichwald (Eds.) *Management of Performance Change*, Springer: Wiesbaden,765p.

Kagermann, H., Wahlster, W. and Helbig, J. 2013. *Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, Final report of the Industrie 4.0 Working Group, acatech – National Academy of Science and Engineering, 678p.

Keller, R. T. 2004. A Resource-Based Study of New Product Development: Predicting Five-Year Later Commercial Success and Speed to Market, *International Journal of Innovation Management* (8)3: 243-260.

Kirzner, I. 1973. *Competition and Entrepreneurship,* University of Chicago Press: Chicago and London.

Koostra, Gerd L. 2009. *The Incorporation of Design Management in Today's Business Practices: An Analysis of Design Management Practices in Europe*, Design Management Europe: ADMIRE, pp. 1-63.

Kotler, P. and G. A. Rath. 1984. Design: A Powerful but Neglected Strategic Tool, *Journal of Business Strategy* (5)2: 16-21.

Kretzschmar, A. 2003. The Economic Effects of Design, *National Agency for Enterprise and Housing Copenhagen* 1-34.
Lawson, B. 1980. *How Desigers Think: The Design Process Demystified*, Elsevier Architectural Press: Oxford, 276p.

Lee, J. Hung-An, K. and Yang, S. 2014. Service innovation and smart analytics for Industry 4.0 and big data environment, *Procedia CIRP* 16: 3-8.

Lorenz, C. 1986. *The Design Dimension: The New Competitive Weapon for Business*, Basil Blackwell: Oxford, 675p.

March, S. T. and Smith, G. F. 1995. Design and natural science research on information technology, *Desition Support Systems* 15: 251-266.

Meffert, H., Burmann, C. and Koers, M. 2002. Stellenwert und Gegenstand des Markenmanagement, in H. Meffert, C. Burmann and M. Koers (Eds.) *Markenmanagement: Grundfragen der identitätsorientierten Markenführung. Mit Best Practice-Fallstudien*, Gabler: Wiesbaden, 3-15.

Meier-Kortwig, H. J. 1997. *Design Management als Beratungsangebot*, German Design Council Cologne, 456p.

Miles, M. B. and Huberman, A. M. 1994. *Qualitative data analysis: an expanded sourcebook*: Sage Publications, 345p.

Murphy, J. M. 1990. *Brand Strategy*, Director Books: Cambridge, 567p.

Osterwalder, A. and Pigneur, Y. 2010. *Business model generation. A handbook for visionaries, game changers, and challengers*, Campus: Frankfurt a. M., 288p.

Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A. and Papadakos, T. 2014. *Value Proposition Design: How to Create Products and Services Customers Want (Strategyzer)*, John Wiley & Sons: Hoboke, New Jersey, USA, 678p.

Porter, M. E. 1985. *Competitive Advantage: Creating and Sustaining Superior Performance*, Free Press: New York, 876p.

Porter, M. E. 1991. Towards a Dynamic Theory of Strategy, *Strategic Management Journal, Special Issue: Fundamental Research Issues in Strategy and Economics* 2: 95-117.

Porter, M. E. 1996. What is Strategy?, *Harvard Business Review* 6: 61-78.

Porter, M. E. 2000. Location, Competition and Economic Development: Local Clusters in a Global Economy, *Economic Development Quarterly* (14)15: 15-34.

Porter, M. E. and Heppelmann, J. E. 2014. How Smart, Connected Products are Transforming Competition*, Harvard Business Review* 11: 1-23.

Porter, M. E. and Millar, V. E. 1985. How information gives you competitive advantage, *Harvard Business Review* (63)4: 149-160.

Rampino, L. 2008. *Design as a Strategic Competence for Continuous Innovation*, International DM Education Conference, Cergy-Pointoise: France, 563p.

Rampino, L. 2011. The Innovation Pyramid: A Categorization of the Innovation Phenomenon in the Product-design Field, *International Journal of Design* (5)1: 3-16.

Raulik, G., Cawood G and Larsen, P. 2008. National Design Strategies and Country Competitive Economic Advantage, *The Design Journal* (11)2: 119-135.

Rezk, M. R. A.; Ibrahim, H., H.; Tvaronavičienė, M.; Sakr, M. M.; Piccinetti, L. 2015.Measuring innovations in Egypt: case of industry, *Entrepreneurship and Sustainability Issues* 3(1): 47-55. DOI:http://dx.doi.org/10.9770/jesi.2015.3.1(4)

Rowe, P. 1987. *Design Thinking*. Cambridge, MIT Press: MA, 675p.

Schumpeter, J. A. 1911. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Translated by Redvers Opie. Cambridge, Mass.: Harvard University Press, 1934, 255p.

Schumpeter, J. A. 1942. *Capitalism, Socialism, and Democracy*, Harper & Brothers: New York, 768p.

Sendler, U. (Ed.) 2013. *Industrie 4.0 – Beherrschung der industriellen Komplexität mit System* Springer: Berlin, 456p.

Shields, P. M. and Rangarajan, N. 2013. *Playbook for Research Methods: Integrating Conceptual Frameworks and Project Management*, Stillwater: New Forums Press, 210p.

Simon, H. A. 1969. *The Sciences of the Artificial*, MIT Press: Cambridge, 342p.

Simonite, T. 2014. The Internet of Things, *MIT Technology Review*, (17)4: 68-78.

Spiggle, S. 1994. Analysis and Interpretation of Qualitative Data in Consumer Research, *Journal of Consumer Research* (21)12: 491- 503.

Stake, R. E. 1995. *The Art of Case Study Research*, Sage Publications, Thousand Oaks: California, 75p.

Stamm, B. von. 2004. Innovation – What's Design Go to Do with It?, *Design Management Review* (15)1: 10-19.

Teece, D. J., Pisano, G., and Shuen, A. 1997. Dynamic capabilities and strategic management, *Strategic Management Journal* 18: 509-533.

Tether, B. 2005. *Think piece on the Role of Design in Business Performance*, DTI: London, 453p.

Tidd, J. and Bessant, J. 2013. *Managing Innovation: Integrating Technological, Market and Organisational Change*, 5th edition, John Wileky & Sons, 680p.

Trott, P. 2012. *Innovation Management and New Product Development*, 5th edition, London, 345p.

Tvaronavičienė, M. 2014. If industrial sector development is sustainable: Lithuania compared to the EU, *Entrepreneurship and Sustainability Issues* 1(3):134–142. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(2).

Verganti, R. 2006. Innovating Through Design, *Harvard Business Review*, 1-9.

Verganti, R. 2008. Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda, *Journal of Product Innovation Management* 25: 436-456.

Wahl, M. and Prause, G. 2013. Toward understanding resources, competencies, and capabilities: business model generation approach, *Entrepreneurship and Sustainability Issues* 1(2): 67–80. DOI: http://dx.doi.org/10.9770/jesi.2013.1.2(1).

Walsh, V. 1996. Design, innovation and the boundaries of the firm, *Research Policy*, 25: 09-529.

Walsh, V., Roy, R., Bruce, M. and Potter, S. 1992. *Winning by Design: Technology, Product Design and International Competitiveness*, Blackwell Business, Oxford, 564p.

Whyte, J., Bessant, J. and Neely, A. 2015. *Management of creativity and design within the firm*, DTI Thick Piece, 1-36.

Wintjes, R. W. 2013. *Un-locking the potential of business and societal innovation; how to scale-up successful new business and production models?*, Trend report, Business Innovation Observatory Contract No 190/PP/ENT/CIP/12/C/N03C01, European Union, Directorate-General for Enterprise and Industry, Directorate B "Sustainable Growth and EU 2020", Unit B3 "Innovation Policy for Growth".

Wood, B., Whiting, M. and Stocks, D. 2011. How Design Thinking Can Enrich Business and Marketing Innovation. Available on the Internet <http://www.innovationmanagement.se/2011/12/26/how-design-thinking-can-enrich-business-and-marketing-innovation/>, accessed 12 May 2015.

Yin, R. K. 2009. *Case Study Research: Design and Methods*, Sage Publications: London, 563p.

Yin, R. K. 2012. *Applications of Case Study Research*, Sage Publications: London, 453p.