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LENNART HAMMERSTRÖM

HUNGARIAN UNIVERSITY OF

AGRICULTURE AND LIFE SCIENCES

DOCTORAL (PhD) SCHOOL FOR MANAGEMENT AND

ORGANIZATIONAL SCIENCE

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AGRICULTURE AND LIFE SCIENCES

DEVELOPMENT OF A RESOURCE-BASED INVESTMENT METHODOLOGY FOR DIGITALIZATION

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ORGANIZATIONAL SCIENCE

The head of the Doctoral (PhD) School

Imre Fertő, DSc

Hungarian University of Agriculture and Life Sciences, Kaposvár
Member of the Hungarian Academy of Sciences

Supervisor

Ferenc Csima, PhD

Hungarian University of Agriculture and Life Sciences, Kaposvár
Associate Professor

....	....
Approval of the Head of Doctoral School	Approval of the Supervisor

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2 BACKGROUND OF THE WORK AND ITS AIMS

The Era of Industrialization was driven by the hope and enthusiasm of inventors, scientists, engineers and audacious investors who possessed the radical idea of enhancing permanently established technologies and contending with competitors. Hope and enthusiasm have been changing the economic environment since the beginning of the modern age, but the speed of change has never been so fast.

The economic environment in which organizations operate today is becoming more volatile, uncertain, complex and ambiguous (VUCA; Bennis & Nanus, 1985) than ever before. Today, this perception is much more significant. Companies need to develop strategies to cope with these challenges if they want to remain contenders. Besides VUCA, industry changes are accelerating, driven by the 4th Industrial Revolution[1] - *digitalization and artificial intelligence*. The 4th Industrial Revolution is creating an environment of disruption and conversion in which companies are required to react appropriately in order to ensure their economic success. Macroeconomic lectures deal with three industrial revolutions, stating that this endeavor started two centuries ago.

The first industrial revolution was driven in its beginnings by the economic utilization of natural forces such as water and hydrodynamic power, and required the knowledge and potential of *mechanization*. This revolution peaked when humankind learned how to utilize the energy produced by a steam-engine. Alongside our growing knowledge of chemistry, the understanding of electricity produced novel technologies that resulted in the worldwide use of electrical power and is termed as the 2nd industrial

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[1] Although the phrase *Industrial Revolution* has been used before (Shigenobu, 1900; Cunningham, 1907), it was popularized after its use by Arnold Toynbee in an article on industrial and agrarian revolution (Toynbee, 1908).

revolution – it denoted the rise of mass production. With further progress in science, especially in chemistry, physics and natural science, the foundation of the 3rd industrial revolution, relating to electronics and information technology, was laid. Every industrial revolution changed people's perception of the world, space, and time, and each came with great social upheavals.

It is likely that our successors will refer to our times as the period in which the 4th industrial revolution was reaching its peak. Today's agents for creative destruction are digitalization and artificial intelligence, and we have only begun to fathom where this path is leading the human race.

2.1 Introduction to the research field

Disruption in the context of this dissertation is used in a broader sense than the strict definition for innovations given by Christensen, Raynor, & McDonald (2015). It focuses on the nature of conversion and advancement of technologies, deliberately leaving aside the stepwise, evolutionary development of technologies and focusing on the particular difficulties of planning and making strategic decisions. The conversion of industries and businesses, and being aware that an industrial revolution is likely to happen (the first three industrial revolutions were termed retrospectively), results in the attempt of firms to integrate the upcoming inventions and innovations into current business models to strengthen the corporate stratagem and enable further growth, profitability and the long-term viability of the company. Already today, digitalization is a wide field of applications and technologies, and it is likely that it will keep expanding as it continues to develop.

Nevertheless, changing environments and disruption are not new to management science as will be explicated in the literature review.

The adaptation of innovation, the element of human capital and knowledge, the company's current position, its processes and its future paths that lay within the realms of the firms' present business model to generate a shrewd strategic planning method is the idea explored in this dissertation. Framing the future digitized business model and carving out the right digitalization strategy today will be an important factor for tomorrow's business success. Even before the age of the internet, it has been recognized that that which is ahead tends to stay ahead; in other words, a 'winner takes it all (or the lion's share)` practice became veritable. The digital area does not reward the penny pincher. But it will reward companies that invest their scarce budgets into a digitalization strategy that fits the company's product portfolio, its corporate strategy, its processes and knowledge, and into a shrewd course of action when it comes to utilizing the new technologies within operations and services.

A company aims to gain the most benefit from the investments it makes; from an abstract point of view, growth, differentiation and profitability are often considered the main goal. On an operational level, conceptional ratios such as economic efficiency, revenue, return on invested capital, productivity, rentability and liquidity are employed. The lowest level of the ratios, such as in- and output parameters, scrap rates, changeover time, occupancy time and so forth, form a wide range of different ratios. Digitalization technologies interfere at this level and influence different ratios, depending on the company's conception. Finding a set of digital technologies that supports the company's long-term goals and aspirations for the future is an optimization problem that will be examined in this dissertation.

Action is an offshoot of reason; investment into digitalization is made clear through pure ratiocination and is following the company's strategy. Robust competitiveness builds on a complementary mix of low-, medium-, and high-technology with conjoint reinforcing impacts. Therefore, the research question is to investigate whether a framework for a digitalization-model can aggrandize the competitive advantage for individual firms that are not the inventors of groundbreaking technologies but their applicants. The dissertation does not focus on developing digital technologies and their improvement; the dissertation's focus is on the combination of digital technologies that is accessible for all market participants and is not a unique selling proposition on its own.

This dissertation's focal point is to recognize the technologies within digitalization that are of proper use for the company, to seize those adequate technologies and the suitable integration into the companies processes while devising a culture to transform and adjust rapidly. The impact affects the "micro" level (individuals, teams, sectors) of the firm predominantly. Still, due to the character of the industries' digital change, the "meso" level (industries, firms, cross-sectoral cooperation) is directly and indirectly affected. The firm's ability to make strategic decisions is constrained by its current position, paths and current processes. The options of what a firm can do and where it can go are therefore not as comprehensive as may seem in the first place. The factors of position, paths and processes limit possibilities for the firm to a greater extent for the decision-makers. The dynamic capability approach provides a structure and a procedure to cope with that incalculability.

2.2 Intellectual origin of the dissertation

The motivation for this dissertation's fundament originates from the ardent work of David John Teece, Gary Pisano & Amy Shuen and the eminently compelling article by Rebecca Marta Henderson & Kim Bryce Clark dedicated to architectural innovation. There is a conceptual connection

between both theories, and its joint application can contribute to gaining new insights into the strategy of digitalization. It can pave the way to a new understanding of digitalization in the tactical framework of firms.
Teece is a Professor in Global Business at the University of California, Berkeley's Haas School of Business. Teece pioneered the dynamic capabilities perspective[2], defined as the "ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments". Henderson is the John and Natty McArthur University Professor at Harvard University, she holds a joint appointment at the Harvard Business School in the General Management and Strategy units[3].
The intellectual exchange with the professional council of the Hungarian University of Agriculture and Life Science, the disputes with the student body and the discussions at several research conferences with other scientists about macro- and microeconomy, economic development and stability, sustainability and individual responsibility has strengthened my decision to conduct further research in this field.

2.2.1 The resource based approach

Knowledge is a recurring theme throughout economists' work, constantly examined from different angles. In his trailblazing article "A Contribution to the Theory of Economic Growth," Solow (1956) proposed his theory that technological progress, not capital accumulation and investments, is the source of long-term growth. His article "Technical Change and the Aggregate Production Function" further supported his theory (Solow, 1957). Linking the concept of competitive advantage with competencies was

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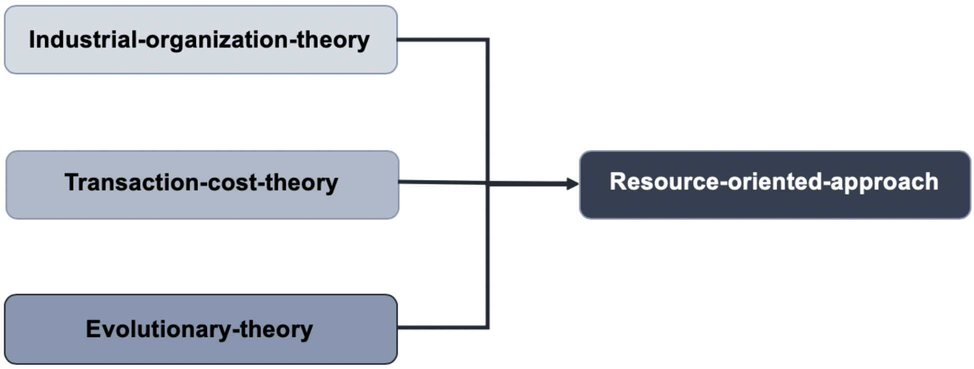
[2] https://www.davidjteece.com/biography

[3] https://www.hbs.edu/faculty/Pages/profile.aspx?facId=12345&facInfo=custom&pageId=903

established by Selznick (1957). Penrose (1959) widened the perspective by integrating the element of internal resources of a company into the scientific discussion. The work of Penrose received relatively little formal attention due to the unpleasant modeling of technological skills that do not obey the law of conservation and do not exhibit declining returns to sale, as in the traditional theory of factor demand (Wernerfelt, 1982). Kuznets considered the essence of modern economic growth to be an increasing stock of knowledge and its proper application to the industry (Kutznets 1966). Porter (1980) combined the traditional strategy concepts (Andrews, 1971) of a firm's strengths and weaknesses with the economic tools of the market and the rivalry among existing firms. Wernerfelt (1982) attempted to look at firms in terms of their resources rather than their products. He emphasized the balance between the exploitation of existing resources and the development of new ones. With his contribution, he is often considered to be the founding father of the modern resource-based perspective. Wernerfelt proposed an analytical tool to evaluate a firm's position from the resource side rather than from the product side to derive strategic options and visualize what he called a resource-product matrix. Solow's growth model was further enhanced by Mankiw, Romer and Weil (1992) by introducing the element of human capital. In the Romer model, growth is driven by technological change induced by investments that are made intentionally and that the stock of human capital determines the rate of growth. Knowledge leads to new technologies; new technologies foster technological progress, and this leads to economic growth. Thus, knowledge and new ideas are the keys to growth. The economic models before Romer considered technological progress as something outside of their models. Romer is regarded therefore as the originator of the endogenous theory of growth, since he incorporated it into the economic growth model. Hitt and Ireland

(1986) explored the specific relationships between corporate-level distinctive competencies, performance and their normative character. They were able to show that the strategic business units that applied distinctive competencies gained a competitive advantage over other strategic business units that had the same assignment. Prahalad and Hamel (1990) presented the distinction of portfolio competencies versus a portfolio of businesses and the need to identify, cultivate and exploit the core competencies as a strategic advantage of firms to make growth possible. The specificity in a firm's skills and resources as an enabler to raise barriers to imitation was contributed to the discussion by Reed and DeFillippi (1990). Still, the types of competencies are not further specified in their article. The important fact that an employee's firm-specific know-how has a different value for different firms has been outlined by Mahoney and Pandian (1990). Langlois (1992) made a link between the firm's capabilities view, the cost that the building of competencies necessitates long-term and the cost that occurs with the transformation of knowledge. Under 'dynamic' governance cost, he cited cost for persuading, negotiating, coordinating with and teaching others. Langlois (1992) understood the dynamic costs as "the cost of not having the capabilities you need when you need them" (p. 99). The connecting elements of the theories in industrial-organizational theory, the transaction-cost theory and the evolutionary theory have been realized, and a resource-based approach was developed upon those theories.



The sources of the resource-oriented approach. Adopted from Foss, N. J., Knudsen, C., & Montgomery, C. A. (1995). An exploration of common ground: Integrating evolutionary and strategic theories of the firm. Resource-based and evolutionary theories of the firm: Towards a synthesis. Boston, MA.

In the 90s of the last century, the resource-based approach flourished and gained a lot of attention in many industries. When the resource-based perspective prevailed, a paradigm shift from the outside perspective of a firm (market orientation) to the inner perspective (competence orientation) took place. Scientists specified that the resource-based approach and its practicability improved. The resource based approach the dissertation is based upon is the concept that was developed and introduced by Teece, Pisano, & Shuen in the very renowned article Dynamic Capabilities and Strategic Management in 1997. Even though the concept is more than 2 decades old, it is still valid and can be applied to areas of application that it has not bee applied before.

2.2.2 Dynamic Capabilities

Building competitive advantages in an environment of rapid technological change requires dynamic capabilities (Teece, Pisano, & Shuen, 1997; Teece, 1998). Technology and technological change are something that can be designed, influenced, controlled and managed by a company. Therefore, it should be made part of the planning process of a company (endogenous) and consequently become calculable. Technology, therefore, transforms from being an exogenous event into an endogenous one. A company can develop the ability to integrate, build and reconfigure internal and external competencies to address digitalization's disruptive nature. Teece (2007, 2010) defined Dynamic capabilities in the following way:

> Dynamic capabilities operate on ‘organizational skills, resources, and functional competencies. They are higher-level competencies that determine the firm’s ability to integrate, build, and reconfigure internal and external resources/competencies to address and possibly shape rapidly changing business environments. They determine the speed and degree to which the firm’s particular resources can be aligned and realigned to match the business environment's requirements and opportunities to generate sustained abnormal (positive) returns.

There are 3 types of dependency that are essential for dynamic capabilities, those are:

2. **Process-dependency:** Teece and Pisano (2003) refer to the way things are done in a firm, to 'routines' or patterns of current practices and learning when outlining managerial and organizational processes, and understand those as a reflection of distinctive organizational or coordinative capabilities. The way production is organized by management inside the firm is the source of differences in firms' competence in various domains (Teece & Pisano, 2003). Performance drivers, such as quality, seem to be less dependent on assets in an accounting sense and are neither directly related to capital investment nor the degree of automation of the production processes, as studies have shown (Garvin, 1988; Johanson,

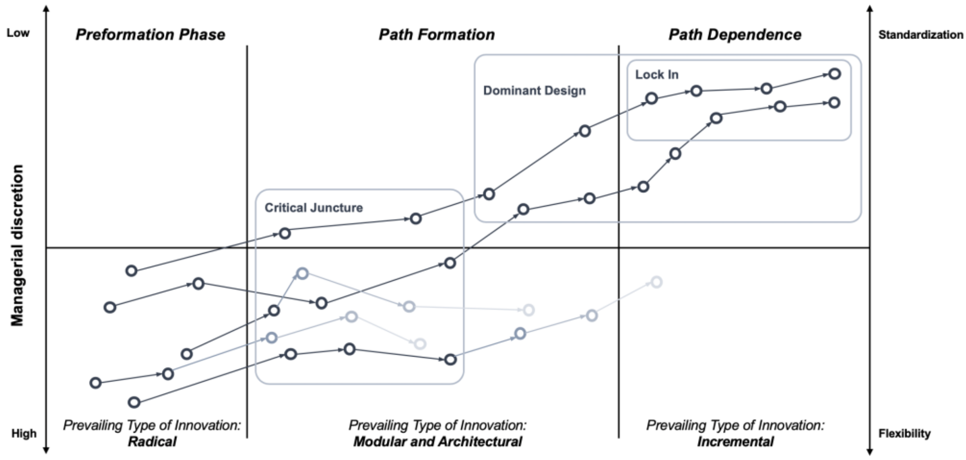
Mårtensson, & Skoog, 2001; Marr, Schiuma, & Neely, 2004). The subfield of process-dependency within the dynamic capabilities approach focuses not only on processes related to production output but also on an integrated vision of all the firms' processes. To further disintegrate the entrepreneurial and orchestration processes, Teece (2007, 2012, 2017) proposes the following three activities:

    1. **Sensing**: The identification and the assessment of an opportunity (at home and abroad).
    2. **Seizing**: The mobilization of resources to address an opportunity and to capture value from doing so, based on managerial competencies for devising and refining business models.
    3. **Transforming**: Continued renewal.

2. **Position-dependency:** According to scientists that work on the field of evolutionary economics, the current stock of a firm's "assets" at a certain point in time is influenced and determined by decisions made by management in the past (Nelson & Winter, 2002; Helfat & Peteraf, 2003; Nelson 2008; Clark, Feldman, Gertler & Wójcik 2018). It's the legacy of a firm related to its difficult-to-trade knowledge assets, less regarding its fixed assets such as machines, manufactured goods, or production facilities. Therefore, the current stock of capabilities constrains the ability to change the future repertoire of capabilities (Pisano, 2016). Scholars have found that a strong position is supportive of a firm's dynamic capabilities (Danneels 2008; Anand, Oriani & Vassolo 2010; El Akremi, Perrigot & Piot-Lepetit, 2015).
3. **Path-dependency:** The dynamic capabilities approach is taking into account the company's history by considering path dependencies.

The paths are the strategic alternatives available to the firm and the attractiveness of the opportunities that lie ahead (Teece & Pisano, 2003). Path dependencies are underrepresented when a strategy is worked out and are unintentionally excluded from the strategic decision process. Existing processes, learned behavior, and core capabilities influence the decision processes and, thus, the paths ahead. The result is that the strategic process decisions are biased and do not follow the value maximation criteria. The same is true for technologies that have a similar starting position and compete with each other in a market of adopters. The technologies often have no significant differences in the returns they provide. One experience is that the one technology that is more widely adopted gains more experience, scale effects, and a reduction of cost for implementation and purchasing over time. Insignificant events may, by chance (e.g., the unexpected success of a prototype's performance) give one of them an initial advantage (Arthur, 1989). Based on this slight advantage, technology gains an early lead and develops a dominance in the market. In an advanced state and after many consecutive optimizations of the technologies, it can reach the property of inflexibility and the exclusion of renewal and adaptability; the costs for changes become too high. Hence, technology has reached a 'locked-in' status. There are three different stages of the path-dependency:

1. Preformation phase, the undirected search process.
2. Path formation phase, the narrowing process.
3. Path dependency, the lock in.



From preformation phase to path dependence – prevailing innovations and the final lock in. Adapted from "Constitution of a technological or institutional path - the classical model", by J. Sydow, G. Schreyögg, and J. Koch, 2005. 21st EGOS Colloquium, June 30 – July 2, Berlin, Germany, p. 9.

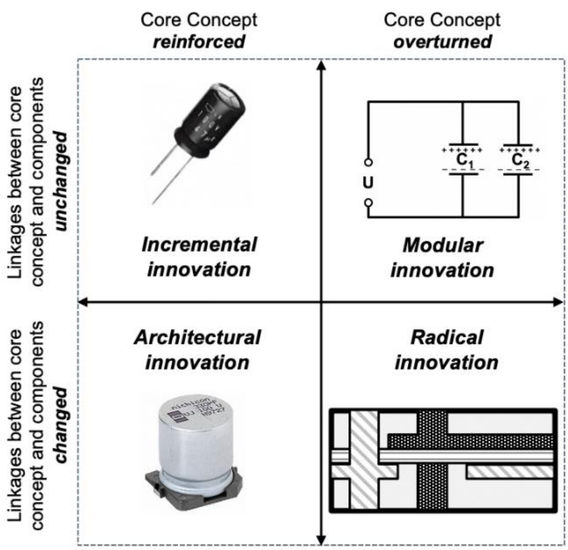
When radical technology innovations have been made, and the direction of change is heading towards critical junctures, innovations tend to shift towards modular and architectural innovation. Critical junctures are hypothesized to produce distinct legacies, triggered by their antecedent conditions, the cleavage (or crisis) that emerges from the antecedent conditions, its mechanisms of production, preproduction, and the stability of the legacy's core attributes (Collier & Collier, 1991). It is the phase of the modular and architectural innovations that punt a piece of technology in one direction or the other, predetermining its path to become a dominant design, to be relegated to a niche application, or to perish. After attaining the dominant design, incremental innovations are novated to be the appropriate means to further improve the technology.

2.2.3 Architectural Innovation

Architectural innovations derive from the research on technical innovations and conclude that an exclusive distinction between radical and incremental innovations is incomplete. The article about the then unnoticed architectural innovation from Henderson and Clark (Henderson, & Clark, 1990), that is based on an earlier working paper from Henderson (1990) when she was an assistant professor at the MIT Sloan School of Management, lead to a new thinking about technological innovations. Henderson and Clark define architectural innovation in the following manner:

We define innovations that change how product components are linked together while leaving the core design concepts (and thus the basic knowledge underlying the components) untouched. … It destroys the usefulness of a firm's architectural knowledge but preserves the usefulness of its knowledge about the product's components (Henderson & Clark, 1990).

The architecture of a product determines the interaction of the product's single components and the architectural knowledge, the knowledge about how components are linked together, creating completely new interfaces, into a coherent whole, define its performance. With this differentiation, it is possible to distinguish between radical, incremental, modular, and architectural innovation.



Four types of innovation in the automotive supplier industry, displayed on a capacitor. Inspired by Henderson, R. M. & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing. Administrative Science Quarterly.

(1) **Incremental innovation:** The through-hole-technology for capacitors (formerly called condensers) with a liquid dielectric is more than 100 years old. It was patented by Elihu Thomson, who was working at the time for General Electric (United States Patent Office, 1921). It requires a hole within the PCB to be assembled and soldered, in order to establish an electrical connection with the other components. The original design underwent a great number of incremental improvements, such as improvements in the weight of the case (which today is mainly made from aluminum), the characteristics of the paper spacer, or the capacitors' cover, nowadays often built from tantalum. Incremental innovations typically result in an increasingly specialized system in which the productive unit loses its flexibility and economies of scale are extremely important (Abernathy & Utterback, 1978).

(2) **Radical innovation:** Radical innovation is to forgo some parts of the capacitor and to integrate it completely into the PCB. By doing so, it becomes a fixed component of the PCB and must be integrated into the PCBs manufacturing process. This approach economizes the PCB's surface and leaves more freedom for the design of the PCB, and saves space within the final product. Under normal conditions, radical innovation attempts to produce more failures than successes and is highly time-dependent (Leifer, McDermott, O'Connor, Peters, Rice, & Veryzer, 2000).

(3) **Modular innovation:** The example of modular innovation focuses on the extension of the use case; the capacitor is used in a different way to create a new type of utilization. Capacitors are used as devices to create a low-resistance path for electric currents (shunts) to pass around other points in the circuit in high-frequency applications. Modular innovation calls for specialization and co-ordination over

organizational boundaries as a managerial response (Magnusson, Lindström, & Berggren, 2003).

(4) **Architectural innovation:** A significant architectural innovation was the advancement of the through-hole-technology to the surface-mounted-technology. It required very little change in the mechanical construction of the capacitor. Still, the ‘capacitor-PCB-system’ architecture was dramatically changed. The interface is completely different (soldering on the surface instead by means of a soldering hole), and the components are linked together in a new way. The cost for the assembling process dropped significantly, the design options for the PCB and the available space for designers improved, and further incremental innovations of the production process were made possible.

Henderson and Clark (1990) emphasize that the distinctions between radical, incremental, modular, and architectural innovations are matters of degree and that innovations cannot always be divided clearly into four quadrants.

2.3 Concatenation of the 2 theories

The overall goal of the dissertation is to develop a structural concept that enables companies to work out recommendations and strategies for the implementation of IIoT technologies from a financial point of view. Such a concept cannot be of a collective nature; it works on an individual basis and has to consider the different characteristics of a company and the differences of each industry in which such a company is operating. The dissertation is likely to help the engineering and the finance departments come to a common agreement for investments, evaluate those spending, and measure the long-term success of the investments.

3 MATERIALS AND METHODS

To give the research a credible footing, a survey was conducted within the automotive supplier industry with an extensive questionnaire. Corresponding to the research questions, the survey was structured in such a manner as to provide insights both into the architectural framework as well as the dynamic capabilities, and to then convey recommendations for action within a specific firm. The survey was conducted within the automotive industry at a supplier for the OEMs for automobiles. The investigated company employs more than 33,000 staff members and is running more than 125 locations worldwide. The company was chosen because it fits perfectly into the framework conditions of the object of investigation. The firm does not develop or produce digitalization technologies that can be applied in the value creation process by itself. Rather the firm is a user and applicant of the digitalization technologies that are readily accessible and operates those within its value stream.

All 142 participants of the survey work within the automotive supplier industry. The larger portion possess higher education qualification, such as a bachelor's or a master's degree. 4 of them have a Ph.D. A small portion of the expert group in Germany underwent vocational training but were considered experts due to their position and accountability. The majority of the participants are male, only a low number of participants are female (< 12%). A basic condition of the survey was strict confidentiality; hence a distinction between the male and female respondents is not possible and cannot be displayed. The participants of the survey come from Asia, Europe and the Americas. The majority of the participants come from Germany, where the company has its headquarters.

The survey was sent out to 142 participants that were classified into three main groups. Managers with a leadership position, senior experts with extensive technical know-how in a dedicated field and vast experiences in their field, and experts with less long-standing experience. The survey was answered fully by 93 participants, and this produced a participation rate of 65.5%.

	Asia		Europe		North- and South America		
	China	India	Romania	Germany	USA	Mexico	Brazil
Leadership position	3	2	4	9	6	7	2
Senior expert	6	2	6	19	6	7	2
Expert	8	0	7	26	6	14	0
Sum	**17**	**4**	**17**	**54**	**18**	**28**	**4**

After cleaning the survey, a multidimensional data-set with a number of 3,000 lines, comprising of the sections, the technologies, and the individual ratings remained. To analyze the data-set, the statistics software Minitab® (version 18) was used.

3.1 Principal component analysis

Principal component analysis (PCA) refers to the problem of fitting a low-dimensional affine subspace S of dimension $d \ll D$ to a set of points $\{x_1, x_2, \ldots, x_n\}$ in a high-dimensional space $\mathbb{R}^D$ (Vidal, Ma & Sastry, 2016) and is likely to be introduced at first by Pearson (1901) as a new approach to statistics.

Independent from Pearson, Hotelling (1933) developed a similar approach to the standard algebraic derivation and a solution for the same problem, discussing a different geometric interpretation from that given by Pearson (Jolliffe, 1986).

If not the most, PCA today is a popular, multivariate statistic technique used by almost all scientific disciplines. It is a multivariate statistic technique used to structure, simplify and exemplify extensive datasets. Many variables are approximated by a smaller number of ideally descriptive and meaningful linear combinations (the principal components). The PCA has four goals when applied to a dataset (Abdi & Williams, 2010):

1. Extract the most important information from the data-set
2. Compress the size of the data-set by keeping only the important information
3. Simplify the description of the data-set
4. Analyze the structure of the observations and the variables

New variables, the principal components, are computed and are obtained as linear combinations of the original variables. The first principal component is required to have the largest possible variance and this component will explain the largest part of the data-set's inertia. The second component is computed under the constraint of being orthogonal to the first component and having the largest possible inertia. The other components are computed likewise. The values of these new variables for the observations are called factor scores; these factor scores can be interpreted geometrically as the projection of the observation on the principal component (Abdi & Williams, 2010).

4 RESULTS AND DISCUSSION

The results of the analysis in this chapter are categorized according to the analysis of the data into Architectural Innovation and Dynamic Capabilities. For the analysis of the Architectural Innovation, a reduction of the dimensionality had to be performed, using the principal component analysis (PCA). The second part for the Dynamic Capabilities was analyzed by sorting the data and displayed by means of histograms. Later, the results of both parts were re-combined.

4.1 Analyzing the data-set for Architectural Innovation

The principal component analysis was selected to simplify the first part of the dataset, which is looking into architectural innovations. This practice was done to expose the significant variables and to deduce the key activities.

Eigenanalysis of correlation matrix

The first principal component accounts for 43.9% of the total variance.

Eigenvalue	2.6352	1.1885	0.8440	0.5454	0.4500	0.3370
Proportion	0.439	0.198	0.141	0.091	0.075	0.056
Cumulative	0.439	0.637	0.778	0.869	0.944	1.000

The table *Eigenanalysis of correlation matrix* presents the PCA's result of the variables strategic relevance, current priority, current maturity, invest/disinvest, complexity, and readiness (of the firm). The eigenvectors (which are comprised of coefficients corresponding to each variable) are used to calculate the principal component. The coefficients indicate the relative weight of each variable in the component. In these results, the first principal component has large positive associations with current priority

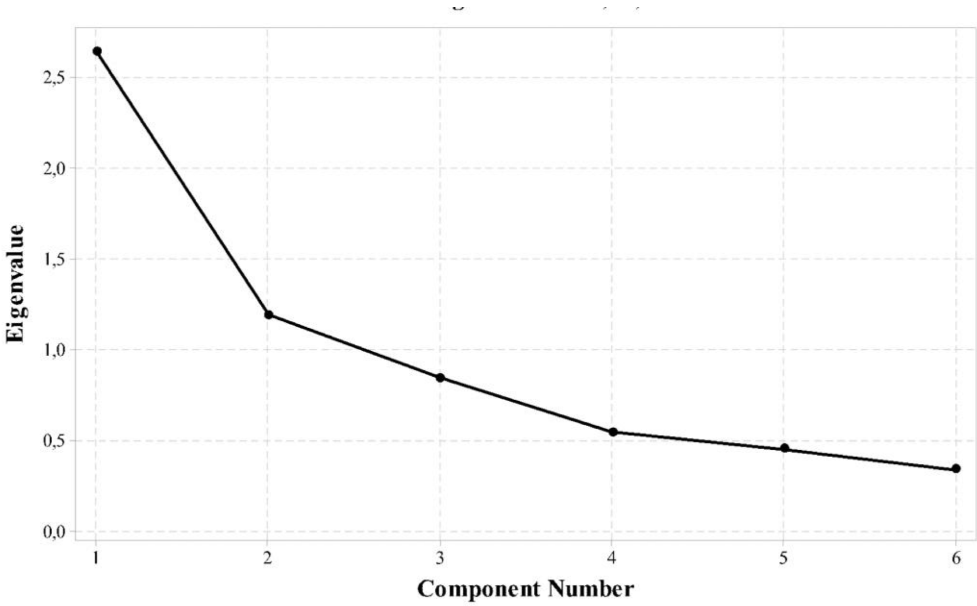
(0.487), strategic relevance (0.473), current maturity (0.436), and readiness (of the firm) (0.402). The first principal component in this analysis is interpreted as being primarily a measurement of the firm's (current and future) competitiveness and expresses the concern of the participants of the survey to guarantee the firm's sustained viability. On the other hand, the second principal component can be interpreted as the negligence of the current maturity and financial impact due to the blatant need to invest in digitalization.

Eigenvectors

The variables that correlate the most with the first principal component (PC1) are current priority (0.487).

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
Strategic relevance	0.473	0.378	-0.222	-0.068	-0.062	0.758
Current priority	0.487	0.065	0.181	-0.516	0.619	-0.278
Current maturity	0.436	-0.342	0.318	-0.308	-0.699	-0.093
Invest/ disinvest	-0.428	-0.324	0.495	-0.341	0.193	0.559
Complexity	-0.068	0.697	0.675	0.158	-0.133	-0.104
Readiness	0.402	-0.380	0.340	0.702	0.265	0.123

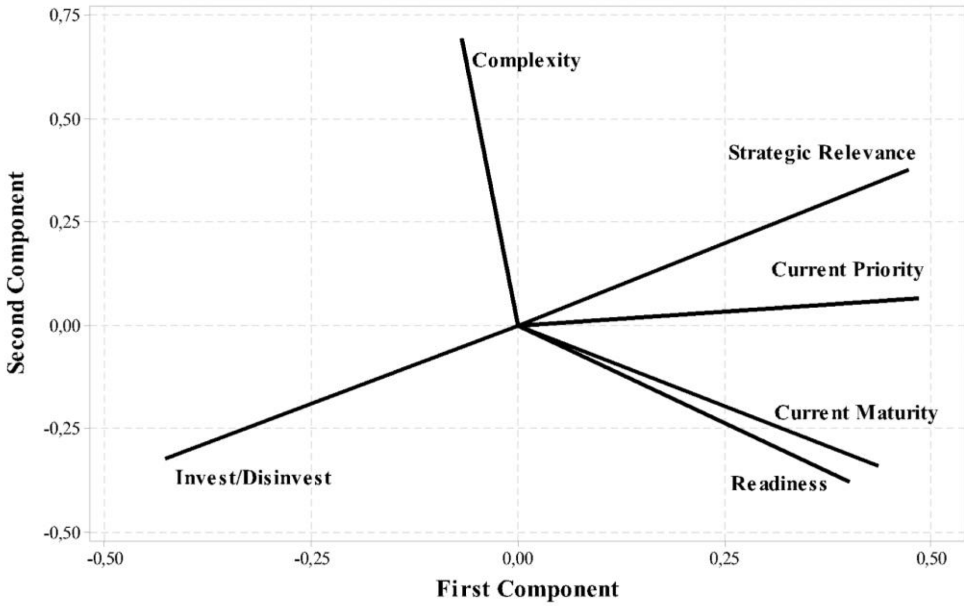
The scree plot displays the number of the principal components versus its corresponding eigenvalue. It is reasonable to select the number of components based on the eigenvalues. The first two components form a steep curve, followed by a bend, and are therefore relevant for further analysis.



Scree plot of strategic relevance, current priority, current maturity, invest/disinvest, complexity and readiness (of the firm).

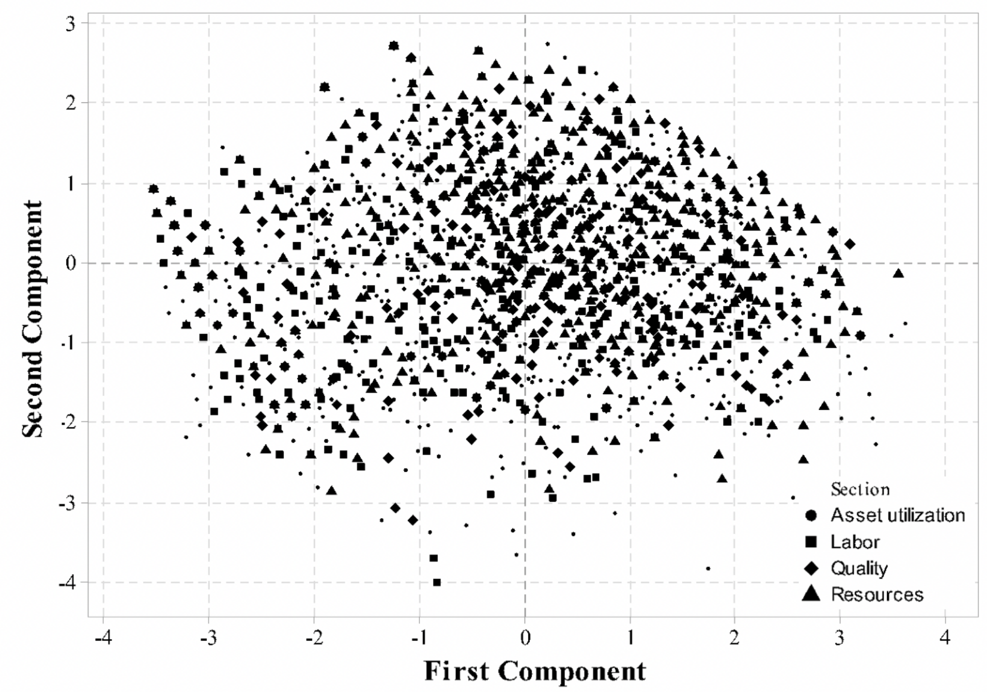
The loading plot displays each variable's coefficients for the first component versus the coefficient for the second component. The loading plot is used to identify which variables have the largest effect on each component. Loadings close to 0 indicate that the variable has a weak influence on the component.

The PCA loading plot shows that current priority, strategic relevance, current maturity, and readiness (of the firm) have large positive loadings on component 1. Invest/disinvest, readiness (of the firm), and current maturity have large negative loadings on component 2 and confirm the statement made earlier.



Loading plot of strategic relevance, current priority, current maturity, invest/disinvest, complexity and readiness (of the firm).

The score plot graphs the scores of the second principal component versus the scores of the first principal component and is used to detect outliers, clusters and trends. In the survey's PCA, very few outliers stand out; groupings can be assumed for resources and quality even though the overlap is obvious.



Score plot of the 4 sections showing the scores of the second principal component versus the scores of the first principal component.

The results of the score plot are not as easy to interpret, the groupings of the data are not apparent, and therefore separate distributions in the data are unlikely. The points are randomly distributed around zero; therefore, the data is highly likely to follow a normal distribution.

Once the most important variables have been detected, the data-set is used to determine which technologies are most important from the participants' perspective.

The analysis found that there are top-5-technologies with highest rating. Those are:

1. Automated, real-time feedback to process experts/specialists
2. Parameter adjustment on premise
3. Advanced planning (and scheduling)
4. Intelligent lot sizes
5. Big Data & Analytics

The ulterior motives behind the survey participants' ratings of the technologies are that they thought about the main problems on the shop-floor. Those are mainly downtimes (which would explain the ratings for number 1 and number 2), problems with the supply chain (which would explain the ratings for number 3 and number 4) or sustainability (which would explain the rating for number 5). Sustainability is increasingly important; as well as avoiding a cost driver (reduction of scrap cost), or as a precondition by customers who ask for less and less CO_2 emissions in production processes.

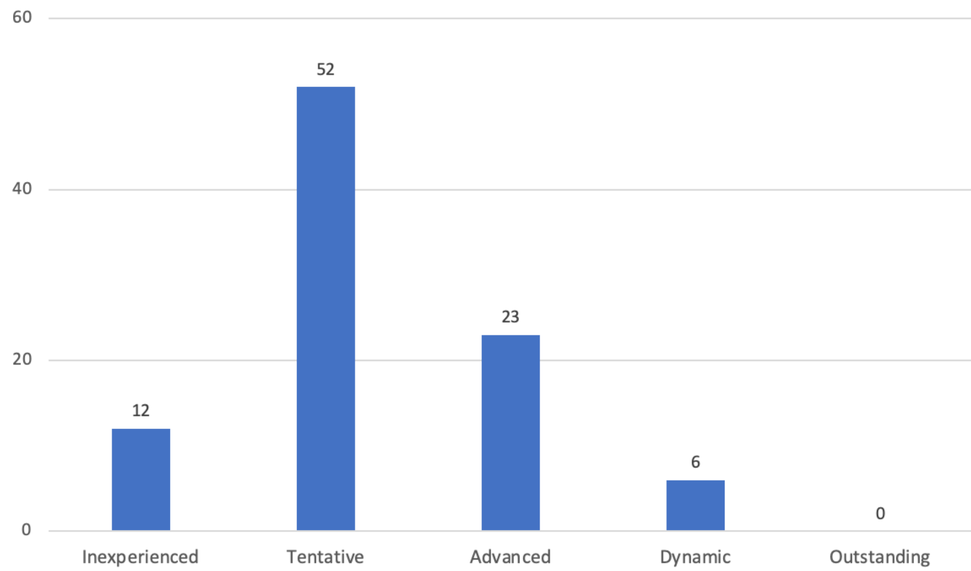
4.2 Analyzing the data-set for Dynamic Capabilities

The second part of the data-set refers to the dimension of dynamic capabilities. It is a detailed examination of the working levels that have to integrate digital technologies; in other words, make the digital technologies run on the shop-floor, disseminate good practice examples, advocate the achievements and captivate the users for their benefits. The working levels that were recognized as being decisive for the survey (middle management, engineers, technical experts, and line operators) are consequently the subject of the survey. For each group a dedicated analysis of the following 6 questions was done:

1. "Do you agree or disagree that further training and education is necessary to meet the IIoT challenges?"
2. "How do you rate the current priority of training and education within operations?"
3. "How do you rate the current training level for IIoT within operations?"
4. "Do you agree or disagree that further training and education is necessary to meet the IIoT challenges?"

5. “How do you rate the current priority of training and education within operations?”
6. “How do you rate the current training level for IIoT within operations?”

In the following figure one example of the graphical display of the results is presented:



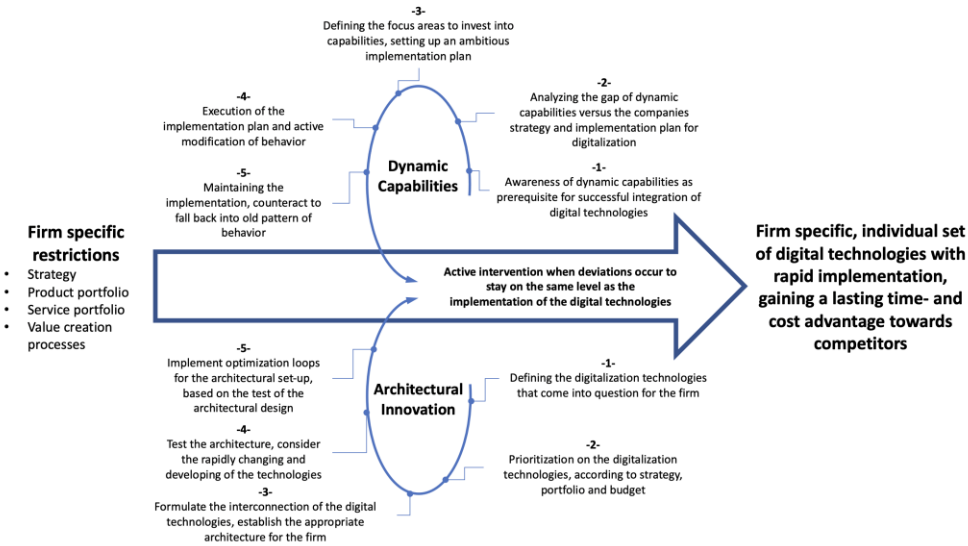
Histogram for the current training level, representative example

The survey participants almost entirely agreed to the questions addressing training and education as necessary to cope with digitalization and the new technologies. The question regarding the current priority of training and education notwithstanding is rated as medium by most participants of the survey. The enquiry about the current training level of the four groups received the most mixed views, with the main emphasis on a low training level. The survey results for the dynamic capabilities would be utilized in the framework to highlight to the firm that the need for the development of dynamic capabilities exists and that the company is aware of that need. The firm is also aware that the four investigated groups' training and education levels are mainly inexperienced to tentative - action to take countermeasures are necessary to be prepared for the digitalization. Nevertheless, the participants of the survey rated the current priority for training and education mainly as ‘medium’. For the framework, this is a finding of the highest interest due to the fact that a blocking point for the implementation of digital technologies is becoming obvious.

5 CONCLUSION AND RECOMMENDATIONS

The thesis statements combine the two suppositions that a firm that is bound for digitalization often oversees a) *the mutual reinforcement between the digital technologies* and b) th*e need for people-know-how to implement and to run those new technologies*. By overseeing the two effects, the firm cannot achieve the best outcome possible. It will lack the right architectural set-up for its technologies and will not be able to build the necessary dynamic capabilities to exploit the new technologies to their full potential. Both the architecture and the dynamic capabilities need to be firm-specific from the authors' point of view and cannot be generalized. Therefore, the research question was to investigate how the two theories can be brought into one edifice of ideas, how a firm specific analysis can look, and how the findings can be brought to life through the employment of a real-life application.

The firm that was investigated in this survey is a company within the automotive supplier industry facing the challenges of digitalization. The course of actions has to be based on two directions, both integrating the selected technologies and building dynamic capabilities. The frameworks systematic is to integrate available technologies into a company that is not producing digitalization technologies on its own. Therefore, the presented framework's contribution here is to work out the top 3 to 7 technologies that are of the utmost value for a firm and then focus the spare capacities (time to implement and capital expenditures) on those. Alongside, the actions to build and strengthen the necessary dynamic capabilities and ensure that a real competitive advantage can be worked out, based on the outcome of the analysis, must be undertaken. The company must be aware of the need for training and education, and the willingness to invest in this area must be given and must be scrutinized by management. The following figure displays the mesh of the buildup of dynamic capabilities and the concurrent integration of digital technologies.



Synchronization between dynamic capabilities and the development of a digital architecture requires a constant and active intervention to assure that the buildup of DC is consistent with the development of the architecture.

A firm would have to set up and adapt an implementation plan according to the individual survey findings, their prioritization of the single measures, and the number of optimization loops that the integration will require. With transparency over the dedicated technologies, the firm can set up focused purchasing- and integration plans for each individual technology, appoint implementation teams, organize the necessary implementation support from the individual supplier, and ensure that the equipment is available at the right time. Creating an innovative architectural structure that can make a difference to its competitors, the firm now has the chance to map out in detail the full range of each technology, to establish the optimal interconnection between the different technologies, and fully scale each individual technology. This is only possible having the right dynamic capabilities.

6 NEW SCIENTIFIC RESULTS

A new way of strategizing to gain an edge in the industry took off when Teece, Pisano, and Shuen published their research in 1990, which led to employing Dynamic Capability in various fields of the business economy. Henderson and Clarks' work, released in the same year, gave new insights that enriched the process of innovation by another degree. Joining the Dynamic Capability approach with the Architectural Innovation's concept into a mutual framework, a methodology that can be pivotal for the economic superiority of one firm over another becomes conceivable. The research produced the following new scientific results.

1. **Unification of the strengths of Dynamic Capability and Architectural Innovation**
   The combination of the Dynamic Capability approach, together with the systematic of Architectural Innovation, enhances a firm's opportunities to compete successfully. Combining both concepts creates a robust approach to respond to the fast-changing field of digitalization.
2. **Pointlessness of general digitalization strategies**
   The digital strategy must be customized to fulfill the expectations of the overarching firms' competitive strategy. It must support the other policies, processes, and methods of a firm or replace them with superior ones. It has to support the decision process of not digitizing instead of applying more than the firm needs and applying in practice.

3. **Synergies between Architectural Innovation and Dynamic Capabilities**
   The concepts of Architectural Innovation and Dynamic Capabilities can interact and create synergy effects, especially within the economies of scope and the chaining effect. The reasons for this are broad, such as the complementarity of digital technologies, boosting effects of one technology when implementing another, and features of digital technology that are useful but were not incorporated so far.
4. **Factual basis for a digitalization strategy**
   The core findings of the dissertation are the companies' main directions in digitalization. Hidden in the data-set, this information was disclosed with the principal component analysis (PCA). The company is now making decisions based upon facts and independent of individuals. Unarticulated and concealed knowledge about the context in which digitalization is connected with the firms' products, production processes and logistics is recognized and considered in the digitalization strategy.
5. **Averting cognitive biases**
   A large number of survey participants helps to prevent (or at least minimize) effects such as the Dunning-Kruger effect (Dunning, 2011), the mere exposure effect, or the system justification bias. The data discloses hidden patterns within the firm that can be considered part of its collective intelligence and would have remained undetected.
6. **A concept to structure the digitalization process**
   The hallmark of digitalization is that nearly everyone believes in its capability to create a competitive advantage, but a) the risk to invest into a pointless technology or b) not to gain the full capabilities of a

digitalization technology and c) to discount on the advantages of the interaction of the digitalization technologies is preventing firms from investing sufficiently. The proposed DCAI concept is a guideline for a firm to invest in its digitalization. The concept assures that a) the right technologies that are of utmost need for the firm will be chosen and b) that those technologies are applied to their total capacity and become effective to their full potential.

7. **Risk-free knowledge transfer between competitors**

   Another research finding came up late when the firm decided to become involved in the subsidy program *Long-term future investments vehicle manufacturer and supply industry as well as research and development (clause 35c)*. This program was launched by the Federal Ministry of economics and energy (for further details, please read *Chapter 11 Outlook and further exploitation of the research*). A non-transferable, firm-specific framework for digitalization was already recognized at the beginning of the research and formulated as hypothesis number 3. Evidence of this hypothesis was shown in the research process; but the effect became even more evident when the firm started to think about working in the subsidy program. The decision process was simplified, and the anxiety to share information and new findings with other program participants was sharply reduced.

7 PROPOSALS FOR THEORETICAL AND PRACTICAL USE

Understanding the interrelation and close connection of Dynamic Capabilities and Architectural Innovation was the impetus behind establishing a concept to model the connections and build a common framework which can be used for practical use. The model must consider both theories and present each theory's subfields, which is essential for a combined framework. The two theories of Dynamic Capabilities (DC) and Architectural Innovation (AI) can be drawn together into the DCAI concept.

7.1 Architectural innovation in the DCAI concept

The DCAI concept addresses the architectural setup of technologies, the junction of digitalization technologies and dynamic capabilities with the effect of an architectural framework. If a company identified the digital technologies it is going to implement, buying technologies (that are considered as radical innovations) is not sufficient. To make the architecture of new technologies reach its full potential, the company must prepare itself to handle the technologies. The company must learn how to work with each technology; therefore, it requires dynamic capabilities or it will not be able to harvest the advantages of new technologies to the full.

7.2 Dynamic capabilities in the DCAI concept

A firm must prepare a comprehensive set of dynamic capabilities, and the participants of a than to be conducted survey must be selected cautious. The following table summarizes a certain range of dynamic capabilities; these must to be specified for each particular company.

Example of the selection of dynamic capabilities

Matrix for the selection of dynamic capabilities a company requires before it is capable to harness the full advantages of an architectural set-up of certain digitalization technologies and to move between the different phases.

Dynamic Capabilities *"Rapid and flexible innovation with a timely response"*					
Sensing *"Identify and create business opportunities"*		***Seizing*** *"Mobilize internal resources to address those opportunities and to utilize it for the company"*		***Transforming*** *"Align all resources and activities to address those opportunities"*	
Capability to recognize mega-trends, trends, shifts in the market		Capability to reconfigure internal capabilities		Capability to align the resources and activities to manage the transformation	
YES ✓	NO	YES ✓	NO	YES ✓	NO
Capability to evaluate trends for the company		Capability to reconfigure external capabilities		Capability to transform the organizational structure	
YES ✓	NO	YES ✓	NO	YES ✓	NO
Capability to classify trends		Capability to build internal competencies		Capability to enable/support the transformation process	
YES ✓	NO	YES ✓	NO	YES ✓	NO
Capability to realistically estimate the own position in the market		Capability to integrate external competencies		Capability to build an innovation strategy that leads to commercialization	
YES ✓	NO	YES	NO ✓	YES ✓	NO
Capability to recognize disruption (in industry, economy, ecology, politics)		Capability to attract external competencies		Capability to proactively shape change	
YES ✓	NO	YES	NO ✓	YES ✓	NO

Based on the findings of a firm specific survey the company can deploy a gap analysis and establish a plan to close this gap. In this example the firm fulfills nearly all requirements with regards to dynamic capabilities, with only two lacking. Being aware of having a gap within the dynamic capabilities is the baseline to counteract and to close the gap.

8 THE PUBLICATIONS OF THE AUTHOR

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2. Hammerström, L., Zwerenz, D. (2019). Maturity-model for the evaluation of investments into IIoT. *European Journal of Economics and Business Studies*. DOI: 10.26417/ejes.v5i1.p126-140
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6. 1st Joint Research Conference on Economic Science. Presentation: *Evaluation of the impact of big data & analytics on the energy consumption within the automotive industry and its contribution to corporate social responsibility*. 23rd of February 2018. Venue: Hungarian University of Agriculture and Life Science, faculty of economic science, Kaposvar, Hungary. Chairman: Prof. Dr. Sándor Kerekes

7. 16th International Conference on Social Sciences. 23-24 November 2018. Venue: Mercure Paris Centre Eiffel Tower, Paris, France. Chairman: Prof. Dr. Rodica Sirbu
8. 2nd Joint Research Conference on Economic Science. Presentation: *Success-factors in data-driven optimizations.* Venue: Hungarian University of Agriculture and Life Science, faculty of economic science, Kaposvar, Hungary. Chairman: Prof. Dr. Sándor Kerekes
9. 17th International Conference on Social Sciences. 8-9 March 2019. Venue: Campus de la Merced, Universidad Murcia, Spain. Chairman: Prof. Dr. Ahmet Ecirli
10. Making Industry 4.0 real. Fourth international industry 4.0 conference. Presentation: *Steering the transformation process – IIoT applications in the automotive supplier industry*. Park Inn Hotel, Kaunas, Lithuania. Chairman: Florian Schröder, CEO German-Baltic Chamber of Commerce
11. 3rd Joint Research Conference on Economic Science. Presentation: *Measuring the impact of IIoT devices on global networks*. Venue: Hungarian University of Agriculture and Life Science, faculty of economic science, Kaposvar, Hungary. Chairman: Prof. Dr. Imre Fertö
12. 20th International Conference on Social Sciences. 6-7 September 2019. Venue Zurich University of the Arts, Switzerland. Chairman: Prof. Dr. Rodica Sirbu
13. AutoDigital 2019. Organized by WESER KURIER. Presentation: *Digitalization in the automotive-supplier industry*. December 2019, Bremen, Germany.
14. 4th Joint Research Conference on Economic Science. Presentation: Maturity-model for the evaluation of investments into IIoT. Hungarian

University of Agriculture and Life Science, faculty of economic science, Kaposvár, Hungary. Chairman: Prof. Dr. Imre Fertö

15. International Conference on Sustainable Economy and Agriculture. Presentation: Data analytics as a sustainable customer loyalty tool. Hungarian University of Agriculture and Life Science, faculty of economic science, Kaposvár, Hungary. Chairman: Prof. Dr. Imre Fertö