Vol. 9, No. 2, 19-36
doi:10.17708/DRMJ.2020.v09n02a02

Dynamic Relationships Management Journal

REGIONAL DEVELOPMENT IN THE ERA OF INDUSTRY 4.0

Avigdor Zonnenshain, Gilead Fortuna, Eithan Adres, and Ron S. Kenett
The Samuel Neaman Institute for National Policy Research, Center for Industrial Excellence, Technion, Haifa, Israel

Abstract

Regional development is a complex challenge for policymakers in government, business, and industrial leadership. The Fourth Industrial Revolution, labeled Industry 4.0, has created integrated opportunities for a circular economy involving actors from different society strata. This paper presents an integrated approach that combines conventional strategic planning methods with tools adapted to the Fourth Industrial Revolution. The regional development methods discussed here are demonstrated with a real-life case study from a major regional development project initiated by policymakers. The integrated approach presented here lists opportunities and challenges in regional development applications with interest to both researchers and policy makers. The case study is from the North of Israel, which also is called the Galilee. The Galilee is considered a geographical and social peripheral region in Israel, and, as such, it creates significant complexities and challenges for regional development policymakers. As a peripheral region, the Galilee suffers from major weaknesses such as low income, low productivity, poor services, and negative migration, especially of young populations. The paper presents the theoretical foundation of an integrated approach which includes an assessment using the Industrial Maturity for Advanced Manufacturing (IMAM) tool developed at the Samuel Neaman Institute, Technion, Israel. The IMAM scale assesses the maturity and ability of industrial companies to adapt and implement innovative and advanced manufacturing technologies and processes. We suggest that an integrated approach combining a strategic plan and an IMAM assessment can be replicated in other industrial zones.

Keywords*: fourth industrial revolution, strategic program, industrial maturity, regional development, SWOT analysis, innovation and productivity*

1. INTRODUCTION

As value and production chains become more trans-territorial in the era of globalization and Industry 4.0, the regional development level of analysis gains more salience. Regional development is a complex challenge that needs to address multiple interrelated goals. Traditionally, the main economic measures driving regional development, at both the national and the regional levels, are the GDP and GDP per capita. In contemporary developed societies characterized by growing income inequality, these measures may not provide an accurate assessment of the situation in which most people find themselves and of societal well-being (Stiglitz, Sen, and Fitoussi, 2010). This observation also applies to regional disparities which lead to the resurgence of regional economics, processes of development, growth, and sustainability. Consequently, careful attention should be given to long-term factors such as education, health services, welfare, and research and development (R&D) investments at the regional level. Advanced technologies also may play a major role in bridging the interregional well-being gap by advancing proximity – physical and virtual (Capello and Nijkamp, 2009). An essential vehicle for regional development is proper policy measures, such as moving jobs to region with high unemployment; indirect measures, including better infrastructure, stimulating R&D and innovations, improving education, and providing an attractive environment (housing, recreation, sport, culture); direct measures such as financial compensation, soft loans, low land prices, favorable energy con-

tracts, etc.; and strict direct measures such as relocation of governmental institutions (van Dijk, Folmer, and Oosterhaven, 2009).

Recent directions in theories of regional economics shed light on two main approaches: more realism, and more dynamics (Capello, 2008). We stress the following trajectories: understanding endogenous factors that support regional competitiveness (industrial specialization, infrastructure, location, entrepreneurship, realistic economic clusters, agglomeration economies, transportation costs, human resources, etc.); knowledge, which is embedded in human capital, as an endogenous driving force to development; and nonlinear trajectories of development (Krugman, 1991; Romer, 1986; Lucas, 1988; McCann and van Oort, 2009; Minerva and Ottaviano, 2009; Faggian and McCann, 2009).

Due to measurability difficulties, general modelling logic entails static assumptions. The focus on the "representative" firm and on pecuniary economies, while ignoring dynamic nature of externalities such as human capital and technological spillovers, underpins the critique of models (McCann, 2005; Fingleton and McCann, 2007; McCann and van Oort, 2009). Moreover, careful attention should be given to institutions and their relationships with knowledge. The role of institutions, and more specifically efficient institutions, in economic development is paramount (North, 1990; Aghion and Howitt, 1998, Helpman, 2004). Considering the dynamic environment of the 21st century and the Fourth Industrial Revolution, the breaking down of barriers between national economies make the region a fundamental basis of economic and social life (Fischer and Nijkamp, 2009). Therefore, the variance among regions should be considered, and for better assessment of potential regional development, it should be recommended to critically use generalizable predictions based on representative models. Hence, geographical thinking should be intertwined with economic analysis, and pinpointing the need for dynamic measuring tools is unquestionable. This dynamism gives central importance to entrepreneurship among processes affecting regional growth. Entrepreneurship encourages innovative activity and always involves economic risk taking, which nonlinearly leads to development and growth (Acs, 1994; Audretsch, 2004; de Groot et al., 2004).

To bridge gaps between theories and practice, we follow Cuadrado-Roura (2001), who identified seven attributes of succeeding regions in terms of development and growth:

1. The presence in a region of a group of medium-sized cities together with a large city.
2. The presence of medium- to high-educated labor, preferably with moderate wages.
3. Physical proximity to major markets and large urban centers together with access to new ideas.
4. Availability of business services such as consulting, advertising, financing, etc.
5. A facilitating local authority with well-developed strategies and leadership.
6. A positive social environment facilitating cooperation among institutions and organizations.
7. Many small and medium-sized industries easily enabling knowledge spillovers, as opposed to the dominance of a few large firms.

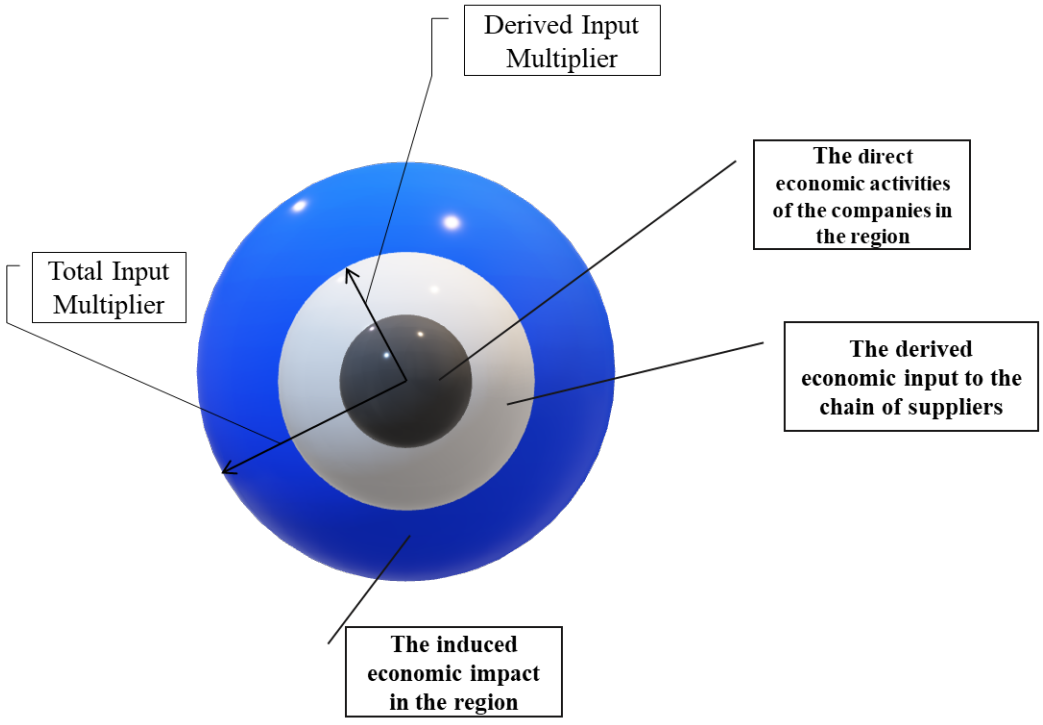
This article introduces a comprehensive integrated methodology for regional development and implements it in a case study. The article is structured as follows: Section 2 presents a survey of different models, the third section introduces the integrated methodology for regional development, Section 4 discusses the case study of Northern Israel, and the last section concludes with a discussion.

2. THEORETICAL BACKGROUND

2.1 Competitive advantage and the clusters approach

The importance of connections among branches of businesses and industries gained the interest of economists in the 1970s (Czamanski, 1974, 1976). These connections among manufactures are called "value chains" and the geographic concentration of manufactures which are creating and operating relationships among them are called "geographic clusters." Analysis of these networks among businesses and manufacturers is used to build and to calculate matrices which are the basis for conventional analysis methods such as "input–output," the gravity model (Haynes and Fotheringham, 1984), and the Diamond Model (Porter, 2000, 2003; Delegdo, Porter, and Stern, 2014).

Figure 1: The Input–Output Model

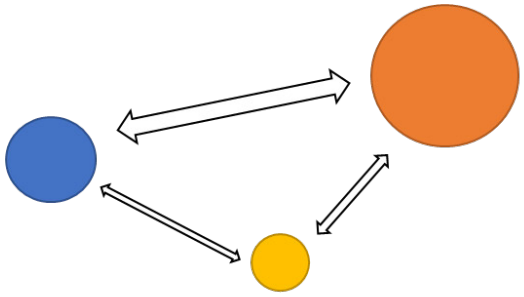


Adapted from Leontief and Strout, 1963

The "input–output" model (Figure 1) developed by Leontief and Strout (1963), represents the flow of money in an economy, primarily through connections between industries, i.e., the extent to which different industries are buying from and/or selling to one another in a geographic region. An "input–output" model also accounts for such factors as government spending, housing spending, investments, imports, and exports, all of which help provide a full picture of what is happening in an economy. This model was used to assess the economic impact of Teva and Intel on the economy of Israel (Fortuna, Neev, and Freeman, 2014; Fortuna et al, 2018).

The gravity model (Figure 2) demonstrates the general form of spatial interaction encompassing any movement over space that results from a human process. It includes journeys to work, migration, information and commodity flows, student enrolments and conference attendance, the utilization of public and private facilities, and even the transmission of knowledge. Gravity models are the most widely used types of interaction models. They consist of mathematical formulations used to analyze and forecast spatial interaction patterns. The gravity model as a concept is of fundamental importance to modern scientific geography because it makes explicit and operational the idea of relative as opposed to absolute location.

Figure 2: Illustration of the Gravity Model

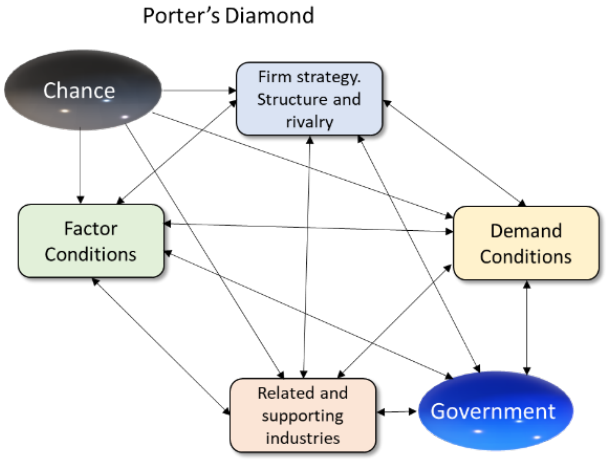


The shorter the distance between two locations, and the greater the mass of either or both locations (like size of population or attractive economy), the greater the economic pull and economic attraction between the locations

Adapted from Haynes and Fotheringham, 1984

The strategic analysis based on Porter's (1990) Diamond Model (also known as the Theory of National Competitive Advantage of Industries) is a diamond-shaped framework (Figure 3). It explains why certain industries are competitive internationally, whereas others are not, and why some companies perform consistent innovations, compared to others. Porter argues that any company's ability to compete in the international arena is based mainly on an interrelated set of location advantages that certain industries in different countries possess, namely firm strategy, structure and rivalry, factor conditions, demand conditions, and related and supporting industries.

Figure 3: The Porter Diamond Model for Cluster Development



Adapted from Porter, 2018

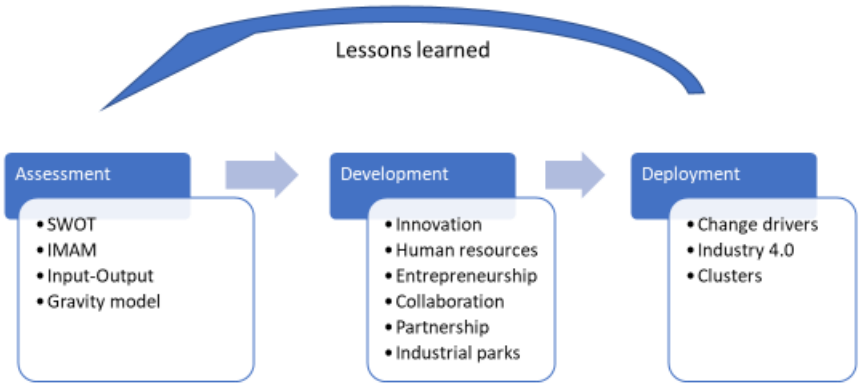
The Diamond Model of Porter describes the main benefits of the regional clusters to the competitiveness of the businesses in the clusters and to the economic growth of the region:

- Productivity can be improved through the availability of common resources such as an experienced workforce, shared knowledge, and information.
- Innovation can be nurtured through sharing ideas and innovative technologies.
- New businesses can be created through promoting the business environment and ecosystem.
- Positive spillovers across complementary economic activities can provide an impetus for agglomeration: the growth rate of an industry within a region may be increasing in the "strength" (i.e., relative presence) of related industries.
- Industries located in a strong cluster register higher employment and patenting growth. Regional industry growth also increases with the strength of related clusters in the region and with the strength of similar clusters in adjacent regions.
- There is evidence of complementarity between employment and innovation performance in regional clusters: both the initial employment and the patenting strength of a cluster have separate positive effects on the employment and patenting growth of the constituent industries.
- New regional industries emerge where there is a strong cluster. These findings are consistent with multiple types of externalities arising in clusters, including knowledge, skills, and input–output linkages.

3. AN INTEGRATED METHODOLOGY FOR REGIONAL DEVELOPMENT

The model described in the case studies is an integrated framework for policy making in regional development. The framework is depicted in Figure 4. This framework includes four stages: assessment, development, deployment, and lessons learned. The assessment stage can combine quantitative methods such as the gravity model, the input–output model, IMAM (see Section 4.4), and qualitative models such as SWOT (see Section 4.2). The development stage includes several elements of regional development like innovation and entrepreneurship, human resources development, collaboration and partnerships, and industrial parks. The deployment stage consists of several initiatives such as developing infrastructure change drivers and growth driver engines, deploying Industry 4.0, advanced manufacturing and engineering technologies, and supporting economic clusters. These initiatives are presented in the context of case studies.

Figure 4: Integrated Framework for Regional Development



3.1 The Role of Entrepreneurship in Regional Development

Entrepreneurship is a dynamic, ever-changing entity in constant interaction with its ecosystem. It begins with an idea sparked by the identification of an opportunity within the abilities of the business team. The main challenge lies in identifying an opportunity and approaching the matching market by materializing this idea into business success in which the outcome may be different from the initial idea. The essence lies in finding that opportunity, exciting the market and raising demand, planning the scenario, and delivering a winning solution, while managing the risk presented by uncertainty. This entity exists in a challenging ecosystem consisting of highly competitive market conditions and requirements, such as the need for faster development and delivery of new and differentiated products, services, value, and ever-growing customer expectations.

The ecosystem, and its regional cultural support and empathy for innovation, are key factors in the emergence of entrepreneurships. If it forms a sustainable local ecosystem, it can accept, absorb, and nourish exceptional and nonconservative concepts, approaches, and operations. This tendency, combined with the practice of appreciating calculated risk-taking and tolerance to failures, forms an encouraging incubator for various initiatives. These are only a handful of the issues to be considered. A mindset of dealing with a complex situation in a dynamic ecosystem is required, and often timing is of the essence. One should not disregard all relevant aspects of all factors involved, including human factors. Reasoning the main systemic components and carefully planning how to use a systemic concept may vastly increase the chances for the success of entrepreneurship initiatives in the region, which supports and advances entrepreneurship at the system level and the practical level. Entrepreneurship in system development was discussed in detail by Katz (2020).

3.2 The Role of Innovation and Creativity in Regional Development

Managing the innovation and creativity process also demands a holistic approach at the regional level. The idea generation lifecycle includes the following major milestones: focus selection, ideas generation, harvesting, assessing ideas, treatment, and ideas implementation. As indicated in Porter's model (Porter, 2000, 2003) innovation is nurtured through the sharing of ideas and innovative technologies in the cluster ecosystem. It happens on the micro level through personal connections and communications, and on the macro level through collaborations of companies and institutes. As mentioned subsequently, the theory of the strength of weak ties (Granovetter, 1973; Bakshy et al, 2011) explains the barriers to and the enablers of innovating and sharing ideas in regional periphery, through connections on the micro level.

3.3 The Role of Human Resources in Regional Development

The main source for successful regional development is the human resources who act and work in the region. There is a need for businesspeople, man-

agers, engineers, and workers who have the knowledge and expertise which fit the jobs of the businesses in the region. This may be called the regional intelligence. In addition, the regional institutes for training, such as academia and vocational programs, can fill the gaps of knowledge in the region through life-long training. The managers and workers not only should have knowledge for the jobs in the region, but also should have leadership and creativity skills. Creative workers have been shown to have a direct and an indirect impact on regional innovation (Sleuwaegen and Boiardi, 2014). Creative workers have an impact on innovation that is differentiated from the presence of regional intelligence, as measured by the availability of human capital. In addition, in peripheral regions it is important to create regional loyalty and identification with the regional vision and goals. Such regional human resources development programs may be created.

3.4 The Role of Collaboration, Partnership, and Industrial Parks in Regional Development

Collaboration and partnership among peoples, companies, and institutes in the region are essential drivers for successful regional development. This happens through the spreading and sharing of ideas and innovations. Industrial parks are excellent place for collaboration and partnership of the companies located in the park, through the leadership of the industrial park management.

4. CASE STUDY FOR REGIONAL DEVELOPMENT: DATA AND APPLICATION OF THE INTEGRATED METHODOLOGY

4.1 Background data

Following the proposed integrated methodology for regional development, a real case study of a strategic initiative to advance the geographical area of Northern Israel was conducted. The initiative involved a major strategic regional planning program followed by a focused assessment of organizational maturity in terms of Industry 4.0 implementation. The assessment was based on the IMAM scale described in Section 4.4 (Adres, Kenett and Zonnenshain, 2020). The methodologies and approaches described here can be adapted to other regions and industrial zones, and therefore provide a generic approach to the development of regions with industrial parks.

The first step was to collect and assess relevant data on Northern Israel, which is a heterogeneous area in terms of industrial activity, population structure, socioeconomic status, and educational aspects. Table 1 compares employment and salaries levels in this region to those of other regions in Israel.

Table 1 shows that 16.5% of Israel's population lives in the North, and 14.7% of the employees in Israel work in the North. The unemployment rate in the North region is the highest in Israel, 8%, compared to the average of 6.2%. In addition, salaries

Table 1: Employment and Salaries in the North Region Relative to Other Regions in Israel

Region	Percentage of population	Employment rate	Participation rate	Unemployment rate	Average compensation per job in the industry
Central District	24.2%	27.5%	70.2%	5.1%	115.6%
Tel Aviv District	16.4%	18.9%	67.3%	5.2%	94.1%
North District	16.5%	14.7%	58.0%	8.0%	79.7%

Adapted from Central Bureau of Standards, 2013

in the North are relatively low, only 79.7% of the national average.

The Northern region of Israel is home to a large portion of Israel's industry – about 34%. However, most of this industry is traditional, and its productivity and export rates are relatively low.

Industry in the North is strong in metals (38%), electronics (35%), and food (35%) (Figure 5).

There is migration from the North to the central regions of Israel, with high rates of migration among young people. The Israeli Ministry of Economy, in a joint program with the Samuel Neaman Institute, identified five strategic goals for improving the economic conditions in Northern Israel (Israeli Ministry of Economy, 2014). These goals are:

1. Growth of the economic system in the North;
2. Improvement of the socioeconomic status of the population in the North;
3. Advancing the joint economy of the Arab and Jewish populations in the North;
4. Exploiting the potential of the Arab population as a growth advantage; and
5. Reversing the negative migration from the North and attracting strong populations.

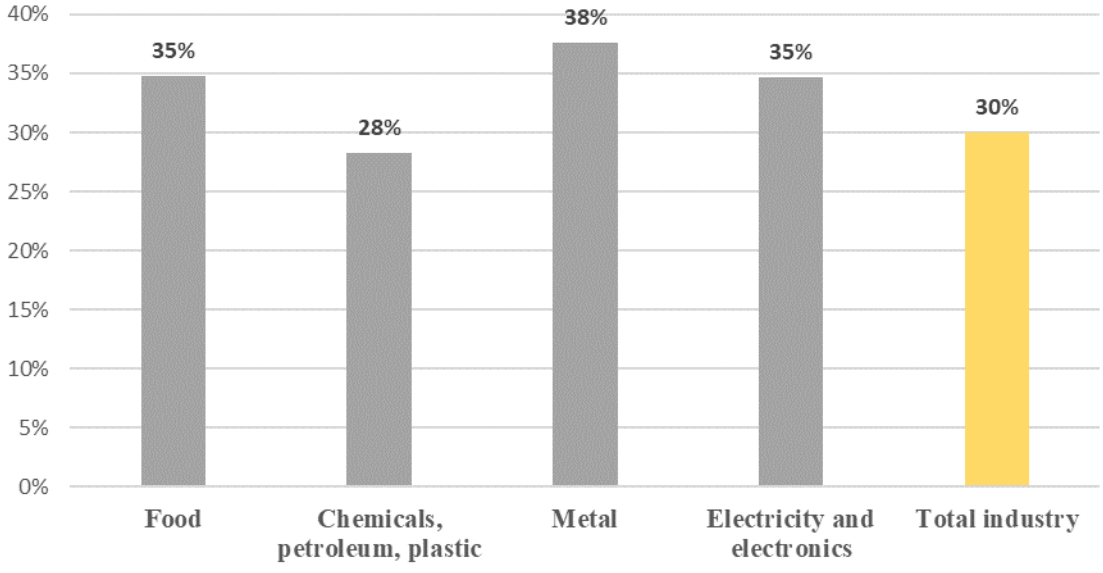
The first two goals relate to the entire population in the North of Israel. Goals 3 and 4 relate to the Arab population and its potential for the growth of the North. The fifth goal presents a challenge to achieve better employment figures, a better business environment, higher industrial productivity, and improved quality of life indicators. This aims at reversing the migration trends and attracting a stronger and younger population to the North.

4.2 SWOT Analysis and Assessment of the North

The SWOT (strengths, weaknesses, opportunities, threats) assessment and analysis of the Northern region was driven by the data collected and based on inputs solicited from 80 individuals with leadership positions in different areas, representing various positions within the government, industry, municipality, education, healthcare, academia, and NGOs. On-site visits were organized to several industrial plants and municipalities in order to receive first-hand impressions of and information about opportunities and barriers in the North.

This provided both quantitative and qualitative data that were combined with past programs and reports that discussed the economic and social con-

Figure 5: Percentage of Israel's Employees Who Work in the North and Haifa in Several Industrial Sectors



Adapted from Central Bureau of Standards, Industrial Review, Board 29, 2013

ditions in the North of Israel. All this information led to several discussions and roundtable brainstorming sessions that produced the SWOT of the North. The main findings of the SWOT were as follows.

Strengths:

- Large portions of the traditional industries are located in the North, and they have significant growth potential.
- The population in the North is diversified, with good qualities and historical connections to the North.
- The Arab population in the North is well educated.
- The basic relationships among the different cultures are good.
- The North of Israel is green, beautiful, and holy to Christians; hence it attracts both local and foreign tourism.

Weaknesses:

- The North lacks large vertically integrated companies with effective human resources growth.
- The North lacks sufficient professional work force.
- The North is a periphery far from the nation's decision makers.
- Many municipalities lack substantial cooperation.
- The city of Haifa is not perceived as and is not acting as the capital city of the North.
- The Jewish and Arab economies in the North lack integration.
- Investment in innovation in the North is relatively low.

Opportunities:

- There are many traditional and classical industries in the North with a potential for growth through innovation and productivity improvement.
- There is a good basis for life science clusters with many active companies (more than 290), eight hospitals with research capabilities, and several good research institutes in tes area.
- The Arab population in the North has a growing number of experts, workers, and students in the area of life sciences.
- There is a good basis for clusters that focus on water, with many active companies (more than 300) and several research institutes.
- The daily relationship between Arabs and Jews is good and offers an opportunity for joint development.
- Recent substantial government investments in public transportation and roads in the North, as well as roads connecting the North to the Center, may promote businesses development and housing opportunities.
- The new deep-water seaport in Haifa presents an opportunity to develop the economy of the North.
- There is potential for an international airport in the North, which may positively impact the economy of the North.
- The ultra-orthodox population in the North is growing as a community, with good qualities of work and study.
- The North is green and attracts ethnic and nature tourism.

Threats:

- The absence of substantial economic growth in the North in the next few years will encourage the young population's tendency to leave the region.

4.3 A Strategic Analysis of Northern Israel

A strategic analysis of the Northern region of Israel was conducted in "The North Project" (Zonnenshain, Fortuna and Dayan, 2015). The program studied the economic system of the North from various facets – industry, services, academia, municipalities, education, healthcare, transportation, large companies, small companies, different sectors of the population, etc. This also was based on the systemic approach of the Systems Engineering methodology (Zonnenshain and Shtauber, 2015) The program followed the integrated framework for regional development presented previously: assessment, development, and deployment. The assessment stage included the SWOT analysis and the IMAM scale (Adres, Kenett, and Zonnenshain, 2020). The development stage included identifying infrastructure change drivers and developing

growth drivers' engines. In the deployment stage, practical plans for deployment were prepared with the relevant partners and stakeholders.

4.3.1 Identifying infrastructure change drivers

This study proposes four change drivers designed to impact the infrastructure in the North in nonlinear paths:

1. Moving specified technological industries and plants of the Israeli Defense Forces (IDF) from the central part of Israel to the North. This move can add at least 2,000 job opportunities for technical and logistic staff. In addition, it will create 10,000 jobs for suppliers and subcontractors.
2. Deepening and upgrading the port in Haifa so that it can accommodate large modern containers ships. The government is investing about NIS 6 billion through 2021 to build this port. It is planned that this port will employ about 7,000 people in various positions in various industries.
3. Building an international airport in Ramat David. This move will create thousands of employment opportunities, both for the construction and the operation of this airport. This airport can change the status of the North region for international business and tourist communities.
4. Leveraging the transportation revolution in the North to develop new business and housing areas along the recently constructed railroads and along the new major routes in the North. Based on the transportation-oriented development (TOD) methodology, we propose several suggestions for developing businesses and housings centers.

4.3.2 Developing growth drivers' engines

The study also proposes several growth drivers that do not represent "business as usual." These growth drivers, aimed at creating employments opportunities, are:

1. Building and advancing an industrial scientific cluster in the area of life sciences. This cluster includes a full ecosystem of manufacturing plants, academic institutions, research institutes, start-ups, incubators, hospitals, and labs, all with advanced capabilities in life sciences. In the North region and in the Haifa area, there are impressive assets of manufacturing plants (representing more than 300 companies) and research institutes that use state-of-the-art technology in the life sciences. In addition, an impressive number of the Arab population have knowledge, experience, and expertise in this area. The North Project program proposes that there should be a national policy in Israel to advance the life sciences in the North of Israel. Furthermore, it is proposed that this policy should include support for international medical tourism in the North.
2. Building and advancing industrial-scientific water cluster. Similar to the life sciences cluster, it is proposed to build in the North an industrial-scientific ecosystem in the field of water. The North also has assets of manufacturing plants and research institutes. The Arab sector also can be integral in this cluster, with engineers, researchers, technicians, workers, and laboratory assistants.
3. Advancing innovation and productivity in the classical industry in the North. The North has a relatively large numbers of classical and traditional industries (34% of all classical industry sales, and about 115,000 employees), but the productivity, salaries, and export rates are relatively low. Innovation and excellence are recommended to improve productivity. The North Project program proposed specific tools for productivity and competitiveness improvements, such as investing in research and development, advancing automation, introducing advanced manufacturing, developing industrial parks that are oriented toward innovation and entrepreneurship, etc.
4. Better integrating the Arab sector in the Northern economy to create a common economy. Upgrading the economy of the Arab sector is one of the most important and crucial challenges in the North Project program. It is proposed to improve the Arab sector by creating a common economy with the Jewish population. This program includes specific steps for creating the common economy, such as improving the socioeconomic situations of Arabs in the North,

including initiating dialogue among the two populations to advance trust, create collaborative industrials parks, advance the employment of Arabs with academic degree in quality roles, encourage Arabs to join high tech organizations, and integrate Arabs into the life sciences and water cluster initiatives. This part of the program is prepared with representatives of the Authority for Economic Development of Minorities in the Prime Minister Office.

5. Advancing tourism in the North. Annual tourism revenue in the North is about NIS 10 billion. The tourism industry offers various employment and businesses opportunities to different populations. The North Project program explored several alternatives for developing tourism in the North and chose ethnic and cultural tourism, which demonstrates the highest possible revenue and future opportunities for sound investment. Furthermore, as mentioned previously, it is proposed to advance medical tourism as part of the life sciences cluster. As mentioned previously, it relates to building an international airport in the North to further advance tourism development.
6. Integrating the ultra-orthodox population in the North economy. Currently, 130,000 ultra-Orthodox Jews live in the North. This population may double in 15 years through natural growth and immigration. The North Project program proposed several tools and steps for developing a productive and quality ultra-Orthodox population in the North. These steps include, for example, academic and technical education, and integrating this community into the life sciences and water clusters.
7. Advancing innovation in the North. As mentioned previously, introducing innovation through industry and other enterprises in the North is a key factor for the success of the economy system. The Innovation Center in the Technion proposed, as part of this project, a holistic program to introduce innovation in the North. The program will include specific steps, such as education of leadership for innovation, teaching processes for innovation, creating collaboration between academia and industry, initiating pilot projects for innovation in the industries through advanced manufacturing, etc.
8. Advancing small and medium enterprises (SME) in the North. Small and medium enterprises are an important part of the North's economy. Through meetings with SME owners, and through national reviews, it was found that there are a significant number of barriers to the development and the success of SME in the periphery of the North. The theory of the strength of weak ties (Granovetter, 1973; Bakshy, Rossen, Marlow and Adamic) explains the barriers to innovating and sharing ideas in the periphery. It is very difficult for SMEs to survive in the economic and business environment of the Northern periphery. Therefore, special government and municipal help and support for the SMEs in the North are proposed, such as offering special loans, providing business-consulting services, lowering the burden of unnecessary regulations, and providing accessibility for purchase by government and public institutions.

4.3.3 Deployments plans

The aforementioned joint strategic program was developed during 2014–2015 and concluded with several practical deployment's plans (Israeli Ministry of Economy and Samuel Neaman Institute, 2015). These plans were the basis for several major decisions and actions of the Government of Israel for upgrading the North of Israel. Some of the actions were already initiated, such as building a new port in Haifa with deep water, improving the transportation system in the North of Israel, upgrading the economy of the Arab sector, and advancing innovation in the industries through advanced manufacturing (see Section 5).

4.4 Industry 4.0 – Maturity Assessment Model Development

During the last decade, industry in advanced economies has experienced significant changes in its engineering and manufacturing practices, processes, and technologies. These changes have the potential to create a resurgence in the engineering and manufacturing activities. This phenomenon is often referred to as the Fourth Industrial Revolution or Industry 4.0. It is based on advanced man-

ufacturing and engineering technologies, such as massive digitization, big data analytics, advanced robotics and adaptive automation, additive and precision manufacturing (e.g., 3D printing), modeling and simulation, artificial intelligence, and the nanoengineering of materials (Pai, 2014). This revolution presents challenges and opportunities for the systems, manufacturing, and process engineering disciplines. Several authors have discussed approaches to assess organizational readiness to advanced manufacturing challenges (McKinsey & Company, 2016; President's Council of Advisors on Science and Technology, 2014; PwC, 2016; Shuh et al., 2017). Under Industry 4.0, systems have access to large types and numbers of external devices, and to enormous quantities of data, which must be analyzed through advanced data analytics (Kenett and Shmueli, 2016; Kenett, Zonnenshain, and Fortuna, 2018).

To help companies make progress on the roadmap toward Industry 4.0, we developed a questionnaire-based tool that assesses the current maturity level of a specific or a group of industrial companies and highlights a set of focused areas for the companies to pursue in an effort to deploy Industry 4.0 methods. We call this the model of Industrial Maturity for Advanced Manufacturing (IMAM). The next section is an introduction to IMAM. More details were given by Adres, Kenett, and Zonnenshain (2020) and Zonnenshain et al. (2018).

The IMAM scale helps companies to assess their strengths and weaknesses and to prepare an improvement plan. It also provides companies with a tool for evaluating their actual improvements and achievements and serves as an effective benchmarking tool. The IMAM framework consists of an assessment tool based on the Software Engineering Institute's Capability Maturity Model Integration (CMMI) approach. It is specifically designed for assessing the maturity level of a company in the area of advanced manufacturing and engineering. The CMMI maturity level assessment in systems and software development was presented by Kenett and Baker (2010). The IMAM scale was established and validated using an accepted methodology (De Winter, Dodou, and Wiernga, 2009; De Vellis, 2012; Adres, Vashdi, and Zalmanovitch, 2016). The content of the IMAM was validated by an international experts' survey. The IMAM is a multidimensional latent construct constructed at the basic level with 14 identified application areas (subdimensions) which are relevant for advanced manufacturing and engineering. For each subdimension, we developed a self-report questionnaire, based on statements (items) measured on a five-point Likert-type scale. The 11th subdimension concerns information and knowledge management and builds on the information quality framework presented in Kenett and Shmueli (2016) and Reis and Kenett (2018). We added a concluding item stating, "It may be said that in general that the advanced manufacturing status of our company is in level…" (1–5 on a Likert scale). The dimensions are:

1. Strategy and long-term planning for advanced manufacturing
2. Human resources for advanced manufacturing
3. Communication with customers and the market
4. Processes in manufacturing
5. Processes in engineering
6. Business processes
7. Processes in maintenance
8. Logistics processes
9. Processes in the supply chain
10. Processes in product life cycle
11. Information and knowledge management
12. Processes in cyber assurance
13. Investment in infrastructure and equipment
14. Actual improvement outcomes and results

In each area, several possible actions and activities can be considered by companies aiming at the advanced maturity level. Statistical analysis of these 14 subdimensions showed that they converge into four higher-level dimensions: (1) value chain; (2) infrastructure; (3) monitoring and control processes; and (4) engineering processes. These four dimensions statistically converge to the IMAM scale, which is an individual-level characteristic that can be understood as a single industrial organizational construct, reflecting the competence and maturity for advanced manufacturing implementation. More details on the IMAM model are given in Chapter 22 of Kenett, Swarz, and Zonnenshain (2020).

4.4.1 Analysis of IMAM assessments from companies in Northern Israel

Self-assessment and IMAM scores of 15 industrial companies in Northern Israel are presented in Figure 6. We approached the industrial companies in the North of Israel based on our efforts and experience from the North Project.

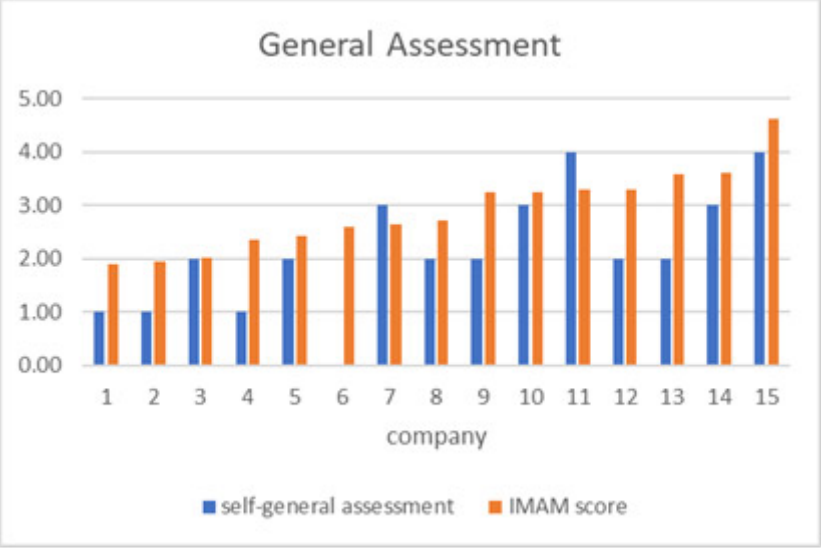
Figure 7 shows the subdimensions of the Infrastructure dimension.

Figure 8 shows the value chain subdimensions.

Figure 9 shows the subdimensions of monitoring and control processes.

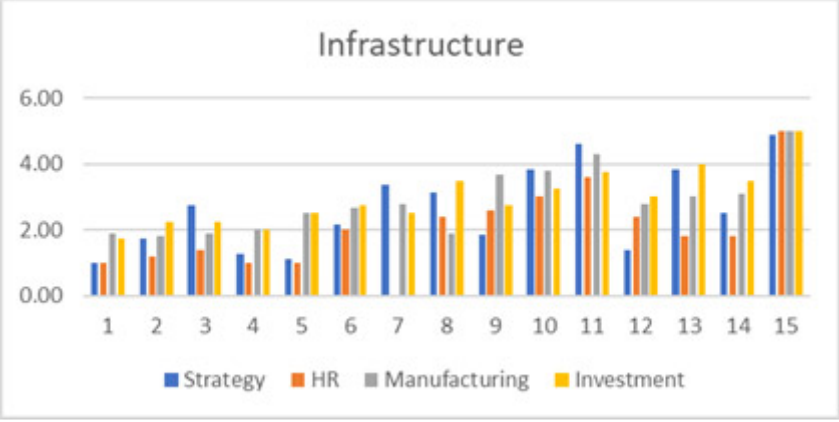
Figure 10 shows the engineering scores.

Figure 6: General Self-Assessment and IMAM Score



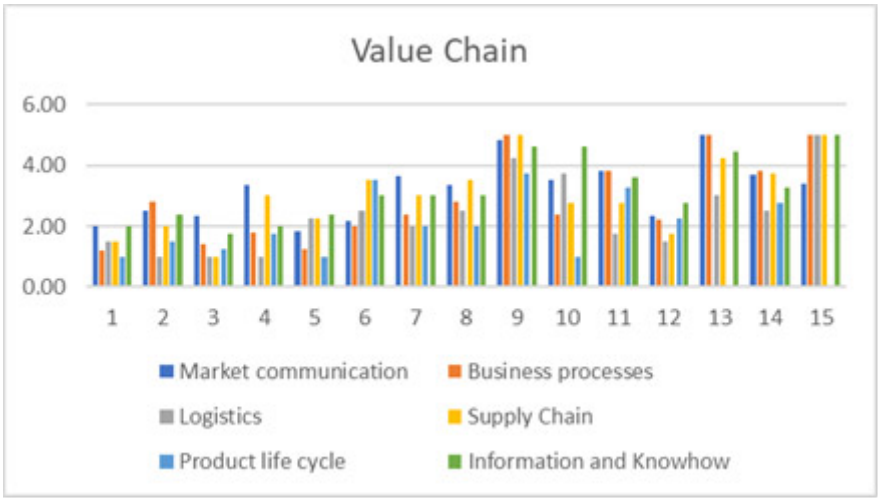
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 7 : Infrastructure Subdimension Scores



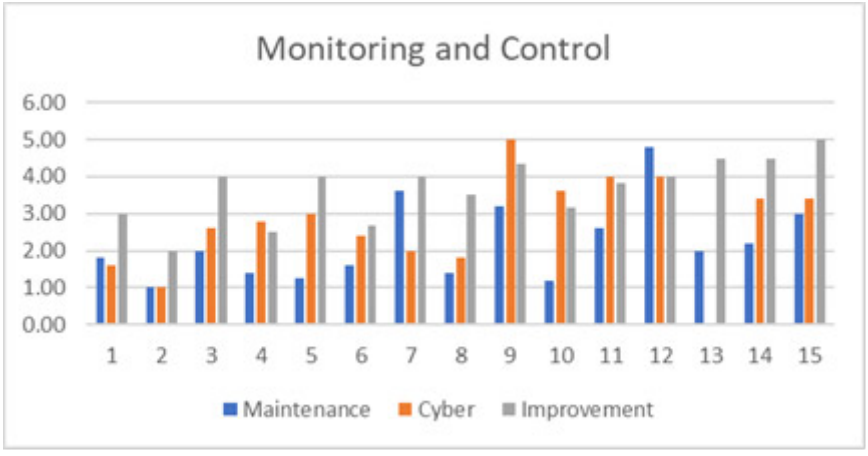
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 8 :Value Chain Subdimension Scores



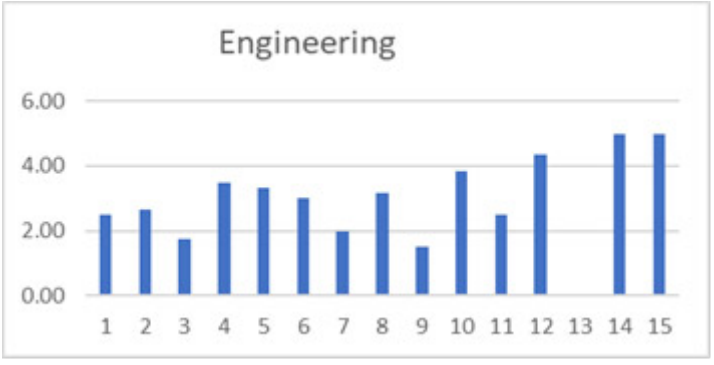
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 9: Monitoring and Control Subdimension Scores



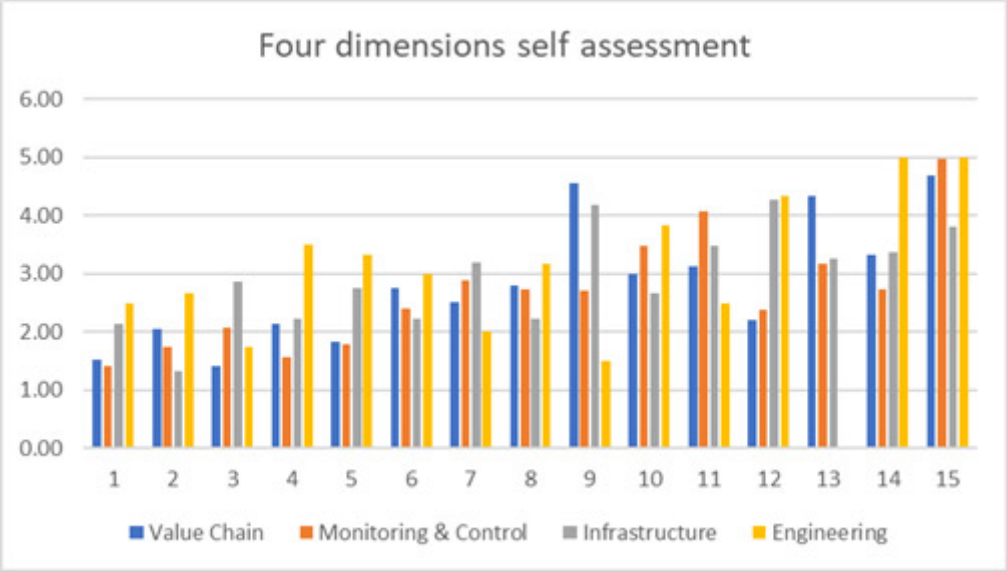
Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 10: Engineering Scores



Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 11: Scores of the Four Dimensions of the Self-Assessment



Adapted from Zonnenshain, Adres, Fortuna, and Kenett, 2018

Figure 11 compares the four dimensions for the 15 companies.

The means, medians, and standard deviation for the general self-assessment; IMAM score; and the four dimensions are presented in Table 2. Self-assessment may be affected by overcriticism on the one hand, and by social desirability on the other hand.

However, all means, and medians were less than the mid-point, 3, except for engineering. This indicates a need for general improvement in the industry; hence, this finding calls for planning a national policy.

To analyze the data, we used a methodology and tools developed to highlight areas for improvement and areas of excellence (Kenett and Salini, 2011). A basic element in this analysis is the computation of the proportion of 1 and 2 ratings, labelled Bot1+2, and the proportion of 5 ratings, labelled Top5. The analysis shown subsequently builds on two standard statistical methods, control charts for proportions (p-charts) and analysis of variance (ANOVA) with Student's *t*-tests for paired comparisons, controlled for multiple comparisons. More details of this analysis were given by Kenett and Zacks (2014).

Table 2: Descriptive Statistics of IMAM Responses

		General self-assessment	IMAM score	Value Chain	Infra-structure	Monitoring and control	Engineering
N	Valid	14	15	15	15	15	14
Mean		2.29	2.8998	2.8174	2.6728	2.9311	3.1488
Median		2.00	2.7328	2.7500	2.7125	2.8667	3.0833
Std. Deviation		0.994	0.74718	1.04668	0.96802	0.82522	1.10852
Range		3	2.72	3.27	3.56	2.93	3.50
Minimum		1	1.89	1.41	1.41	1.33	1.50
Maximum		4	4.61	4.68	4.97	4.27	5.00

Based on this analysis of 15 respondents, representing industry in Northern Israel, overall strengths and weaknesses were identified for the companies which participated in the survey (Table 3).

Table 3:Strengths and Weaknesses of Industrial Group with Respect to Industry 4.0 Implementation

Strengths	Weaknesses
Communication with the customers and the market	Strategy and long-term planning for advanced manufacturing
Engineering processes	Human resources for advanced manufacturing
Processes in the supply chain	Processes in maintenance
Information and knowledge management	Processes in product life cycle

The IMAM maturity level assessment helps to achieve two major goals in efforts to implement advanced manufacturing.

Goal 1: Assessing the organizational maturity level of a specific company and positioning its level on a 1–5 maturity ladder. IMAM also helps companies design an advanced manufacturing program based on its strengths and weaknesses, and it helps the company assess progress along the maturity ladder.

Goal 2: Identification of regional strengths and weaknesses in the dimensions of advanced manufacturing. This can be done at the regional level, but also at the national level and for different industrial sectors.

Based on the findings of this survey, there is awareness in the industrial companies in North of the importance of advanced manufacturing for the success of these companies. However, previously this awareness did not drive most of the companies in the region to develop a strategy and long-term planning for advanced manufacturing. We claim that this conservative attitude may risk the survivability of traditional companies in the North of Israel. It is proposed that the integrated framework for regional development can support and promote the Industry 4.0 implementation in the industries in the region.

5. DISCUSSION AND CONCLUSION

This paper introduced an integrated framework for regional development. This framework includes four main components: assessment, development, deployment, and lessons learned.

As a case study for this framework, we presented a joint strategic program for the growth of the Northern region of Israel which was conducted for the Ministry of Economics during 2014–2015. This program proposes four change drivers, designed to change the infrastructure in the North in nonlinear paths. This study also proposes several growth drivers that do not present "business as usual" and that are aimed at creating employment opportunities. It led to several decisions and actions of the Government of Israel; some of these actions already have been initiated.

The additional component of the integrated methodology for regional development addresses the Industry 4.0 implementation efforts which were conducted in industrial companies in Northern Israel. It is based on the Industrial Maturity for Advanced Manufacturing scale, which assesses the maturity and ability of industrial companies to adapt and implement innovative and advanced manufacturing technologies and processes. The findings from 15 companies from the North of Israel are presented. These findings were used to validate the IMAM scale, and to reveal the strengths and weaknesses of the industries in the north of Israel.Both case studies demonstrated the framework for regional development in Northern Israel.

The combination of a strategic program, which gave a wide and long-term perspective, with the Industry 4.0 implementation based on IMAM assessment, which is focused on a mid-term perspective, represent the proposed integrative methodology approach. It helped to pool together stakeholders from government, business, industry and academia, including various associations and NGOs. The IMAM assessment gave individual managers of industrial organizations specific feedback that can impact their annual plan.

The combination of a strategic program and an Industry 4.0 implementation based on IMAM assessment can be replicated in other regions. It can

be combined with deployment planning initiatives and middle-of-the-road pulse-taking evaluations.

This paper demonstrated successful implementation of four theoretical approaches and practical tools: the input–output model, through the direct economic activities of the companies in the region, through the derived economic input in the chain of suppliers and the induced economic impact in the region; the gravity model, by journey-to-work, migration of families and peoples, and flows of information and commodity; Porter's Diamond Model for developing clusters in the areas of life sciences and water engineering by productivity improvement through the availability of common resources, nurturing innovation through sharing advanced ideas and technologies, and creating and supporting new businesses through promoting doing business environment and friendly ecosystem; and applying SWOT by advancing the strengths of the region like the traditional industries and the well-educated Arab population. These four approaches are integrated through four practical stages of an integrated framework for regional development: assessment, development, deployment. and lessons learned. These approaches were successfully applied for the case study of the Northern region of Israel. The implementation process includes elements such as innovation, creativity, and entrepreneurship, such as the Industry 4.0 initiative; infrastructure change drivers and growth engines; and promotion of the human resources. All are important for the development and execution of improvement program in the Northern region of Israel.

The program for developing the North of Israel presents initiatives which demonstrate the bridging of gaps between theories and practice for the benefits of this region, such as the presence of a large city (Haifa) with a group of medium sized cities; the presence of medium- to high-educated labor; positive social and economic environment facilitating collaboration among peoples, institutions, and organizations; etc.

EXTENDED SUMMARY/IZVLEČEK

Regionalni razvoj predstavlja kompleksen izziv za oblikovalce politik na vodilnih vladnih, poslovnih in industrijskih položajih. Četrta industrijska revolucija oziroma Industrija 4.0 je ustvarila integrirane priložnosti za razvoj krožnega gospodarstva, ki vključuje akterje iz različnih družbenih slojev. Raziskava predstavlja celostni pristop, ki združuje običajne metode strateškega načrtovanja z orodji četrte industrijske revolucije. Obravnavane metode regionalnega razvoja so prikazane s pomočjo študije resničnega primera razvojnega projekta, katerega namen je spodbuditi regionalni razvoj. V raziskavi predstavljeni integriran pristop navaja priložnosti in izzive regionalnega razvoja, zanimive tako za raziskovalce kot oblikovalce politik. Študija primera izhaja iz področja na severu Izraela, imenovanega Galileja. Galileja velja za geografsko in socialno obrobno regijo v Izraelu in kot taka predstavlja izziv za oblikovalce politik regionalnega razvoja. Kot obrobna regija Galileje trpi zaradi mnogih pomanjkljivosti kot so nizki dohodki, nizka produktivnost, slabe storitve in negativne migracije zlasti mladega prebivalstva. V raziskavi so predstavljena teoretična izhodišča celostnega pristopa ter ocena slednjega, pridobljena na podlagi orodja Industrial Mat mature for Advanced Manufacturing (IMAM), razvitega na Institutu Samuel Neaman, Technion, Izrael. Lestvica IMAM ocenjuje zrelost in zmožnost industrijskih podjetij za vključevanje in izvajanje inovativnih in naprednih proizvodnih tehnologij in procesov. Avtorji predlagajo, da se celostni pristop, ki združuje strateški načrt in oceno IMAM, uporabi tudi v drugih industrijskih conah.

REFERENCES

Acs, Z. (ed) (1994), Regional Innovation, Knowledge and Global Change, London: Frances Pinter.

Adres, E., Kenett, R. S., and Zonnenshain, A. (2020). Developing and Validating an Industry Competence and Maturity for Advanced Manufacturing Scale. In R. S. Kenett, R. Swarz, and A. Zonnenshain (Eds.), Systems Engineering in the fourth industrial revolution: Big data. novel technologies, and modern systems engineering. New Jersey: John Wiley and Sons.

Adres, E., Vashdi, D, and Zalmanovitch, Y. (2016). Developing and validating the new individual's level of globalism (ILG) scale. Public Administration Review, Puar 12424 S1.

Aghion, P. and P. Howitt (1998), Endogenous Growth Theory, Cambridge, MA: MIT Press.

Audretsch, D.B. (2004), 'Sustaining innovation and growth: public policy support for entrepreneurship', Industry and Innovation, 11(3), 167-91.

Bakshy, E., Rossen, I., Marlow, C., and Adamic, L. (2011). The Role of Social Networks in Information Diffusion.

Capello, R. (2008), 'Regional economics in its fifties: recent theoretical directions and future challenges', Annals of Regional Science, 42(4), 747-67.

Capello, R., and P., Nijkamp (2009), 'Introduction: regional growth and development theories in the twenty-first century – recent theoretical advances and future challenges', in R. Capello, and P. Nijkamp (eds.), Handbook of Regional Growth and Development Theories. Cheltenham, UK and Northampton, MA: Edward Elgar, 1-16.

Cuadrado-Roura, J.R. (2001), 'Regional convergence in the European Union: from hypothesis to the actual trends', Annals of Regional Science, 35, 333-56.

Czamanski,S (1974). Study of Clusters of Industries, Halifax, Nova Scotia: Institute of Public Affairs

De Winter J. C. F., Dodou D., and Wieringa, P. A. (2009). Exploratory factor analysis with small sample size. Multivariate Behavioral Research, 44, 147-181.

Delgado, M., Porter, M. and Stern, S., (2014) Clusters, convergence, and economic performance, Research Policy 43, 1785–1799.

De Vellis, R. F. (2012). Scale Development: Theory and Applications. Newbury Park, CA: Sage.

Faggian, A., and P., McCann (2009), 'Human capital and regional development', in R., Capello, and P., Nijkamp (eds.), Handbook of Regional Growth and Development Theories. Cheltenham, UK and Northampton, MA: Edward Elgar, 133-151.

Fingleton, B. and P. McCann (2007), 'Sinking the iceberg? On the treatment of transport costs in new economic geography', in B. Fingleton (ed.), New Directions in Economic Geography, Cheltenham, UK and Northampton, MA: Edward Elgar, 168-203.

Fischer, M.M. and P. Nijkamp (2009), 'Entrepreneurship and regional development', in R., Capello, and P., Nijkamp (eds.), Handbook of Regional Growth and Development Theories. Cheltenham, UK and Northampton, MA: Edward Elgar, 182-198.

Fortuna, G., Neev,Y., Freeman D. (2014). Assessment of the Contribution of TEVA Company to the National Economy of Israel, The Neaman Institute for National Policies Researches

Fortuna, G., Neev,Y., Freeman D., Zonnenshain, A., Werner M., Naveh, R., Dayan, T. (2018). Estimation of Intel Israel's contribution to the Local Economy, The Neaman Institute for National Policies Researches

Granovetter, M. S. (1973). The strength of weak ties. The American Journal of Sociology, 78(6), 1360-1380.

Groot, H.L.F. de, P. Nijkamp and R. Stough (eds.) (2004), Entrepreneurship and Regional Economic Development, Cheltenham, UK and Northampton, MA: Edward Elgar.

Haynes K.E. and Fortherngham, S.A. (1984), Gravity and Spatial Interaction Models, Sage Publications

Helpman, E. (2004), The Mystery of Economic Growth, Cambridge, MA: Harvard University Press.

Israel Ministry of Economy and Industry. Strategic Plan for Advanced Manufacturing in Industry, 2018. https://-www.gov.il/he/Departments/publications/reports/national-strategic-plan-for-advanced-manufacturing

Israeli Central Bureau of Standards (2013). Annual Reports.

Israeli Ministry of Economy (2014). Upgrading the Economy System in the North of Israel, Interim Report. Samuel Neaman Institute, Technion, Israel.

Kenett, R. S., and Baker, E. (2010). Process Improvement and CMMI for Systems and Software. Taylor and Francis: Auerbach CRC.

Katz, A. (2019). Entrepreneurship as a Multidisciplinary Project, in R. S. Kenett, R. Swarz, and A. Zonnenshain, A. (eds.), Systems Engineering in the Fourth Industrial Revolution: Big Data. Novel Technologies, and Modern Systems Engineering. New Jersey: John Wiley and Sons.

Kenett, R. S., and Raanan, Y. (2011). Operational Risk Management: A Practical Approach to Intelligent Data Analysis. John Wiley and Sons: Kindle Edition.

Kenett, R. S., and Salini, S. (2011). Modern Analysis of Customer Surveys: With applications using R. New Jersey: John Wiley and Sons.

Kenett, R. S., and Shmueli, G. (2016). Information Quality: The Potential of Data and Analytics to Generate Knowledge. New Jersey: John Wiley and Sons.

Kenett, R. S., Zonnenshain, A., and Fortuna, G. (2018). A road map for applied data sciences supporting sustainability in advanced manufacturing: The information quality dimensions. Procedia Manufacturing, 21, 41-148.

Kenett, R.S., and Zacks, S. (2014). Modern Industrial Statistics: With applications in R, MINITAB and JMP. New Jersey: John Wiley and Sons.

Knesset Research and Information Center, Personal Communication (2014).

Krugman, P. (1991), Geography and Trade, Cambridge, MA: MIT Press.

Leontief W., Strout A. (1963) Multiregional Input-Output Analysis. In: Barna T. (eds) Structural Interdependence and Economic Development. Palgrave Macmillan, London.

Lucas, R. (1988), 'On the mechanics of economic development', Journal of Monetary Economics, 22, 3-42.

McCann, P. (2005), 'Transport costs and new economic geography', Journal of Economic Geography, 5(3), 305-18.

McCann, P., and F., van Oort (2009), 'Theories of agglomeration and regional economic growth: a historical review', in R., Capello, and P., Nijkamp (eds.), Handbook of Regional Growth and Development Theories. Cheltenham, UK and Northampton, MA: Edward Elgar, 19-32.

McKinsey & Company. (2016). Industry 4.0 at McKinsey's Model Factories: Get ready for the disruptive wave. Retrieved from https://capability center.mckinsey.com-/files/mccn/2017-03/digital_4.0_model_factories_brochure_2.pdf.

Minerva, A. G., and G. I.P., Ottaviano (2009), 'Endogenous growth theories: agglomeration benefits and transportation costs', in R., Capello, and P., Nijkamp (eds.), Handbook of Regional Growth and Development Theories. Cheltenham, UK and Northampton, MA: Edward Elgar, 86-97.

North, D.C. (1990), Institutions, Institutional Change and Economic Performance, Cambridge: Cambridge University Press.

Pai, J. C. (2014). Industry 4.0: From the Internet of Things to Smart Factories, MSME. https://www.slideshare.net-/jcterspai/industry-40-pai.

Porter, M. (2000), Locations, clusters and company strategy, in G.L. Clark, M. Feldman and M. Gertler (eds) The Oxford Handbook of Economic Geography. Oxford: Oxford University Press.

Porter, M. E. (1990). The competitive advantage of nations. Harvard Business Review.

Porter, M.E. (2003). The economic performance of regions. Regional Studies 37, 549–578.

Porter, M.E. (2018), Porter's Diamond Model: Why Some Nations Are Competitive and Others Are Not, Industrial Analysis. Retrieved from https://www.business-to-you.com/porter-diamond-model/.

President's Council of Advisors on Science and Technology (2014). Accelerating U.S. Advanced Manufacturing [Report to the President]. Retrieved from https://www.manufacturingusa.com/sites/prod/files/amp20_report_final.pdf.

PwC (2016). Industry 4.0: Building the digital enterprise [White chapter]. Retrieved from https://www.pwc.com-/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf.

Reis, M., and Kenett, R. S. (2018). Assessing the Value of Information of Data-Centric Activities in the Chemical Processing Industry 4.0. AIChE, Process Systems Engineering.

Romer, P. (1986), 'Increasing returns and long-run growth', Journal of Political Economy, 94(5), 1002-37.

Sleuwaegen,L. and Boiardi,P. (2014). Creativity and regional innovation: Evidence from EU regions, Research Policy, V. 43, issue 9, Nov. 2014.

Schuh, G., Anderl, R., Gausemeier J., ten Hompel, M., and Wahlster, W. (Eds.) (2017). Industrie 4.0 Maturity Index: Managing the Digital Transformation of Companies [acatech study]. Munich: Herbert Utz Verlag.

Stiglitz, Joseph E., Sen, Amartya, and Fitousi, Jean-Paul (2010). Mis-measuring Our Lives, Why GDP doesn't Add Up. New York, NY: The New Press.

The Research and Information Center, Knesset (2014). A special report on the socioeconomic status of the North region.

Van Dijk, J., H. Folmer and J. Oosterhaven (2009), 'Regional policy: rationale, foundations and measurement of its effects', in R., Capello, and P., Nijkamp (eds.), Handbook of Regional Growth and Development Theories. Cheltenham, UK and Northampton, MA: Edward Elgar, 461-478.

Zonnenshain, A., and Shtauber, S. (2015). Managing and Engineering Complex Technological Systems. New Jersey: John Wiley and Sons.

Zonnenshain, A., Fortuna, G., and Dayan, T. (2015). Upgrading the economic system in the North of the country.

Zonnenshain A., Adres E., Fortuna G. and Kenett R. (2018). Assessing the Maturity Level of the Industry for Advanced Manufacturing: The IMAM Model Haifa Israel: Samuel Neaman Institute.