Journal of Infrastructure, Policy and Development 2024, 8(16), 10082.
https://doi.org/10.24294/jipd10082

Article

Overcoming the digital divide: A conceptual framework

Roland Zsolt Szabó

Department of Corporate Leadership and Marketing, Széchenyi István University, 9026 Győr, Hungary; roland.szabo@sze.hu

CITATION

Szabó RZ. (2024). Overcoming the digital divide: A conceptual framework. Journal of Infrastructure, Policy and Development. 8(16): 10082. https://doi.org/10.24294/jipd10082

ARTICLE INFO

Received: 4 November 2024
Accepted: 29 November 2024
Available online: 27 December 2024

Abstract: The digital divide is one of the biggest challenges of our time. There are significant differences in the digital maturity of individuals, organizations/companies and regions/countries, which increase the inequalities between them and result in a persistent and growing digital divide. The digital divide can be attributed to a number of factors, and its scientific definition is constantly evolving. It was first attributed more to technological factors, such as internet speed. Today, economic and social factors, such as the ability to use technology, are increasingly important, both at the individual, organizational and governmental levels. The causes and opportunities of digital divide are explored through this theoretical paper. Different indicator systems have been developed over the last decades to measure digital divide, and their logic can be used to identify the factors of digital divide and to propose a way to bridge the gap. By creating a conceptual framework, the causes of the digital divide can be grouped into three dimensions; (1) structural, (2) cognitive and (3) motivational. Along these three dimensions, proposals can also be made to overcome the digital divide at individual, organizational/company and regional/country levels.

Keywords: digital transformation; fourth industrial revolution; inequalities; skill gap; technology management

1. Introduction

Digitalization is transforming our everyday lives. There are many opportunities for digital transformation, but not everyone, not every company, region or country can develop at the same pace. This leads to a digital divide, the question is how to overcome it?

Digitalization is a major challenge in all parts of the world, but the European Union (EU) and the Association of Southeast Asian Nations (ASEAN) are much more fragmented than the United States (US) and China, making digital investments that require significant commitment more difficult. As these regions are not homogeneous, coordination between the countries requires considerable effort, and this affects the speed of digital transformation. The EU lags in the digital race, therefore, a sustained and coordinated effort is essential to strengthen the EU's digital technological leadership, as a key factor in enhancing its competitiveness (European Commission, 2024). Supporting EU-wide digital ecosystems and scaling up innovative enterprises, and strengthening cybersecurity are crucial actions. Besides, putting people at the center of the digital transformation of the EU's societies and economies is at the core of the Digital Decade. Furthermore, digital transformation is a tool for smart greening, too (e.g., a variety of sensors are used to monitor plant growth information for data display and management operations) (Li et al., 2024). However, EU policies overlook many factors, processes and opportunities.

The main aim of the study is to provide a conceptual framework of the causes and possible solutions to the phenomenon of digital divide. In order to be successful

in overcoming the digital divide at macro or micro level, it is necessary to understand what factors (individual, organizational/company and regional/country level) are driving it and what inequalities are at the root of it.

A novelty of the study that it gives a comprehensive conceptual framework to understand the digital divide. The study identified both macro (global and regional economic, technological, social, educational, political/legal) and micro (corporate/organizational, individual) inequalities. They can lead to structural, cognitive, and motivational digital divide, which is a new approach in examining the causes of digital divide. In addition, the measurement practices and the conceptual framework developed are used to make some suggestions for overcoming the digital divide. Furthermore, the study points to the need to improve the measurement scales currently used to identify digital divide.

The structure of the paper is as follows: after the introduction, the digital divide and the inequalities that contribute to it are presented. This is followed by methodological section and a theoretical classification of the causes of digital divide along three dimensions, and then an overview of popular indicators that can be used to measure it. Then, some solutions for overcoming the digital divide are identified on the basis of four popular international measurement indicators. The Discussions chapter highlights the novelties of the study compared to previous research. The paper concludes by stating that the paper provides an adequate conceptual framework for the study of digital divide and lays the foundations for the empirical studies that follow.

2. Methodology

Following the methodology of Shapira (2011), the paper seeks to develop a coherent and meaningful conceptual framework that help to better understand the digital divide phenomenon and how to overcome it. Such a framework makes sense of the field and understand its boundaries, major findings, and challenges. Thus, the later described conceptual framework (1) provides a structure to organize observations, and (2) describes the structure in a clear and precise manner.

3. Digital divide and inequalities

The digital divide refers to the disadvantage experienced by individuals (households), companies, regions, or countries in terms of access to and use of digital services, as well as the impact of information and communication technologies (Aissaoui, 2021; OECD, 2001; Van Dijk-Hacker, 2003).

The digital divide can be traced back to various inequalities (Hsein et al., 2008; Manduna, 2016; Rogers, 2016):

- Global and regional economic inequalities: Significant differences exist between countries and regions, urban and rural places, and more attention should be paid to within-country differences (Sharp, 2024). The price of internet varies from country to country, in many low-income countries the price of internet is higher than in many high-income countries, making it less affordable, and this increases the digital divide (Numbeo, 2024).
- Technological inequalities: Access to both basic and cutting-edge technologies varies. Differences in digital infrastructure (like 5G coverage) or advanced

technologies (like industry 4.0 technologies, or artificial intelligence related technologies) increases digital divide (Krishnatri and Vellakkal, 2024).

- Social inequalities: Not everyone has access to complete information, although, may enjoy internet access but have limited incomes and participation in larger political and economic processes (Tewathia et al., 2020)
- Educational inequalities: The quality of educational environments differs. Many researchers have already pointed out that a lack of digital skills increases the digital divide (Antoun et al., 2023)
- Political/legal inequalities: Practices of e-government and e-citizenship vary across regions. E-Government initiatives have the potential to increase equality of access (Zulmasyhur and Sugiyanto, 2024), thus reducing digital divide.
- Corporate/organizational inequalities: Companies vary greatly in their integration of digital technologies. While many companies are still trying to understand and apply some digital technologies, others have already gained considerable experience and digitally transformed themselves, giving them a significant competitive advantage. (Hortoványi et al., 2023)
- Individual inequalities: Personal characteristics differ significantly in terms of demographics (age, gender, education, income), attitude, cognitive abilities, and motivational factors. Cultural differences in technology adoption, especially for older generations, lead to digital divide (Zulmasyhur and Sugiyanto, 2024).

Digitalization presents both opportunities and risks; it can either increase or decrease the social or economic capital of individuals and can include or exclude them from social and economic life (Ragnedda, 2017). Previous research (Tátrai and Szabó, 2020) has shown a correlation between the level of digitalization and quality of life, as well as purchasing power. Already developed economies are better able to exploit the opportunities offered by digitalization, which in turn increases the digital divide.

The different inequalities also reinforce each other. For example, societies with high levels of economic and social inequality tend to have higher levels of educational inequality. This is reflected in political and individual inequalities, which also affect corporate inequalities. Significant development of digital infrastructure is ineffective if social inequalities are high, which means that the digital divide is not actually being overcome (Tewathia et al., 2020). Digital inclusion may solve class, gender and rural digital divide (BBVA Research, 2022).

4. The causes of the digital divide

The digital divide can be traced back to the inequalities discussed in the previous chapter, which can cause digital divides along three dimensions. The dimensions are detailed below. In addition, in **Table 1** the causes of the digital divide and exemplary research questions are presented.

One factor contributing to the digital divide is the structural lack of access. This can stem from technological or economic reasons, with fast internet access often being affordable only for a small segment of the population. According to Speedtest (2024), in July 2024, the United Arab Emirates had the fastest internet speeds for both mobile (359.85 Mbps) and fixed internet (291.85 Mbps), while Hungary ranked 47th in mobile (54.61 Mbps) and 22nd in fixed (176.87 Mbps). At the bottom of the global

rankings for mobile internet are Yemen (111th, 7.26 Mbps) and Afghanistan (162nd, 3.56 Mbps).

Table 1. The causes of the digital divide and exemplary research questions.

Inequality	Structural dimension	Cognitive dimension	Motivational dimension
Global and regional economic	Is the DS affordable?	Is society advanced enough to embrace DS?	How does DS help to escape the low and middle income trap?
Technological	Is the DS accessible?	Is the DS understandable?	What are the benefits of DS?
Social	What DS can a particular social group access?	Does DS fit into a particular social subculture?	How does DS help break down social barriers?
Educational	What DS is available for education?	Can a wide range of people be taught the skills needed to use DS properly?	How can DS help you learn more effectively?
Political/legal	What DS is allowed under a given regime?	How able are citizens to understand and use e-Government and e-Participation specific DS?	How does DS contribute to more efficient governance?
Corporate/organizational	What DS does a company provide or allow?	Are the necessary training available for employees to use DS properly?	How does the use of DS contribute to a competitive advantage?
Individual	What DS is available to the individual?	Is DS smart enough to be easy to learn how to use?	How enjoyable is it to use DS?

DS: A digital solution(s) (DS) may include a wide range of internet, communication and other digital technologies, tools, and contents such as industry 4.0 solutions, or artificial intelligence solutions, or social media.
Source: Author's own elaboration.

Another aspect of structural access includes restrictions in certain countries due to political or legal reasons, limiting access to specific content. This can lead to significant social inequalities by reducing the free flow of information, typically affecting already marginalized groups who have less access to information and opportunities. Persons in rural or remote areas, frequently the elderly, have even fewer access options due to infrastructure concerns and high fees (World Bank, 2022). On the other hand, such restrictions can be beneficial if they limit the spread of misleading or false information, similar to how a good spam filter operates.

In the age of artificial intelligence (AI), structural access disparities will likely increase, as major AI developments are concentrated in a few countries and large tech corporations, raising numerous ethical and legal issues (Boncz and Szabó, 2021).

Another factor contributing to the digital divide is the cognitive dimension, meaning a lack of understanding of technology. This is influenced by individual skills and the availability of education and training opportunities. Older people, for example, often struggle more to adapt to and embrace new technologies. Additionally, a country's human development level often reflects its digital development, and without improving human development, it is challenging to close the digital divide. Lack of digital literacy from educational inequalities also hinder job opportunities for new graduates. Higher skill and middle-level employment typically pay higher than lower-skilled ones. People without digital skills are deprived of career opportunities. A certain level of digital competency is required for over 80 percent of middle-skill employment (IEEE, 2024). Besides, education and learning are increasingly shifting towards on-the-job learning, much of which is experiential or training-based (Hortoványi and Ferincz, 2015).

Moreover, digital tools are gaining more prominence in both workplaces and online educational platforms (MOOC list, 2024). While theoretically, more knowledge is accessible at lower costs through (open) online education platforms, cognitive limitations often prevent full exploitation of these resources. The development of generative AI may help overcome some of these cognitive barriers, but in professional or specific fields, current solutions still frequently produce errors.

The third factor, which might be the most important, is the motivational dimension, explaining why there is still a significant digital divide between countries, regions, organizations, and individuals. Despite COVID-19's push towards digital development, the divide has widened rather than narrowed.

The motivation to adopt digital technologies can be caused by several factors, such as perceived usefulness, enjoyment, or openness to trying new things. On an individual level, this could mean someone is willing to switch to a 5G-capable phone and subscription if it genuinely reduces lag in online gaming, giving them a competitive advantage.

At the corporate level, motivation quickly develops if a key customer demands the adoption of digital technologies. For example, in a manufacturing company, if key retail customers set quality standards that can only be met with new Industry 4.0 technologies, the perceived need becomes strong enough to justify investment before losing competitiveness.

Motivation is also relevant at the government level, as seen in many countries' national strategies. The world's leading digital economies (like Singapore) are now implementing their second-generation digital strategies (MDDI, 2024), while the lagging countries (like Hungary) still see digitalization as only a sub-strategy for competitiveness (cf. Hungary's competitiveness strategy (Kormány, 2024)). The Hungarian strategy is significantly behind and much smaller in scale than the digital benchmark countries. For example Singapore committed SGD 3.8 billion (€2.6 billion) towards digital initiatives, amounting to 0.80% of its €326 billion GDP in 2020 (Smart Nation and Digital Government Office, 2024). This includes projects such as the National AI Strategy, which received SGD 500 million (€345 million) to develop AI capabilities and applications in key sectors like healthcare and transportation (National AI Office, 2024). Nowadays, more than 17% of the value-added in Singapore's economy can be attributed to digital-related activities. Their digital economy amounted is to SGD 113 billion (€80,5 billion) in 2023, larger than the financial services and insurance sector and comparable with the manufacturing sector (MDDI, 2024).

Governments have several tools to reduce the digital divide. While companies can improve the digital development of individual supply chains, governments (including public administration organizations) can impact the digital development of entire industries.

Identifying and accurately measuring digital divide is not a simple task, and there is currently no single agreed indicator to capture all the factors of this complex phenomenon. Nevertheless, a number of indicators have emerged in recent decades and are presented in the next chapter.

5. Indicators for measuring the digital divide

As shown in the previous chapters, digital divide is a complex phenomenon that can be attributed to a number of inequalities, at structural, cognitive and motivational levels. Being able to identify and measure it accurately will help to overcome the digital divide. Progress can also be well monitored through appropriate indicators.

In the beginning, digital divide was measured by a simple binary variable of having or not having access to the Internet. Later on, the speed of the Internet became more important and we are now talking about a complex, multidimensional phenomenon (CruzJesus et al., 2012, Vassilakopoulou and Hustad, 2021).

Various organizations have developed measurement scales over the past decades to define the level of digitalization (see **Table 2**). These indicators capture some elements of digitalization, providing insight into only parts of the digital divide. While they have improved over the years, none of the indicators fully captures all aspects of the digital divide. Therefore, a combination of multiple indicators is currently necessary to assess a country's digital development, although resolving contradictions between indicators remains a challenge in drawing conclusions.

Table 2. Popular indicators of the digital economy, in chronological order of introduction.

Introduction	Short	Full name	Organization	countries	indicators
1997	ISI	Information Society Index	IDC	53	< 20
2000	ERI	E-Readiness Index	EIU	70	< 100
2001	TAI	Technology Achievement Index	UNDP	72	< 10
2002	EGDI	E-Government Development Index	UNPAP	182	< 10
2002	IDI	ICT Development Index	ITU	154	< 20
2002	NRI	Networked Readiness Index	WEF	148	< 80
2003	DAI	Digital Access Index	ITU	178	< 10
2003	IS	Infostates	ORBICOM	183	< 20
2005	KEI	Knowledge Economy Index	KEI	140	< 20
2005	DOI	Digital Opportunity Index	ITU	181	< 20
2005	ICT-OI	ICT Opportunity Index	ITU	183	< 20
2006	ICT-DI	ICT Diffusion Index	UNCTAD	180	< 10
2014	DESI	Digital Economy and Society Index	EU	28	< 40
2019	DiGiX	Digital Index	BBVA	100	20
2019	GCI 4.0	Global Competitiveness Index 4.0	WEF	141	103
2020	DII	Digital Intelligence Index	Fletcher	90	160
2021	ADII	ASEAN Digital Integration Index	ASEAN	15	30
2022	GII	Global Innovation Index	WIPO	132	81
2022	WDC	World Digital Competitiveness Ranking	IMD	63	54

Source: Compiled from Moroz (2017), with additional research.

Duda et al. (2024) concluded that there are few attempts to build a common index for measuring the digital economy. Developing a common framework for measuring the digitization of economies remains a challenge. Every index is build using different methodology, taking into account different indicators. Only few are published

regularly and only two of them have source data available (DII, DESI). Besides their components may change over time, as may their methodology.

A more detailed analysis of the indicators shows that the earliest measurements of the digital divide primarily focused on access to and the cost of technological factors, including broadband internet. Nowadays, economic and social dimensions are becoming increasingly important, as they represent the main divide between moderately and highly developed countries. **Table 2** presents popular indicators in chronological order of their introduction.

Most indicators are global, though there are regional ones, such as the DESI (the EU's key digital "compass") and the ADII, a digital development and comparison indicator for the Association of Southeast Asian Nations (ASEAN). It's important to note that not only are the number of indicators changing—new ones are emerging, and others are disappearing—but the methodology and indicators themselves also evolve every few years, as digital technologies and their use continue to introduce innovations.

Two regional and two global indicators were selected for more detailed analysis. Both the EU and ASEAN countries have made economic development through digital development an important policy objective, and therefore the DESI and ADII indicators are used for a more detailed analysis. DESI focuses more on the EU context, while ADII is specific to ASEAN. Besides, the two overarching indicators DII and DiGiX have been selected because of their broad geographical and thematic coverage of digitalization.

The Digital Economy and Society Index (DESI) (European Commission, 2022) measures the digital divide along the following dimensions: (1) human capital, (2) connectivity, (3) integration of digital technology, and (4) digital public services. The Digital Index (DiGiX) (BBVA Research, 2022) has a slightly different approach by having the following dimensions: (1) users' adoption, (2) enterprise adoption, (3) government adoption, (4) affordability, (5) regulations, and (6) infrastructure. The Digital Intelligence Index (DII) (Fletcher, 2020) has the most indicators along four dimensions: (1) supply conditions, (2) demand conditions, (3) institutional environment, and (4) innovation and change. The ASEAN Digital Integration Index (ADII) (ASEAN, 2021) has six pillars, namely (1) digital trade and logistics, (2) data protection and cybersecurity, (3) digital payments and identities, (4) digital skills and talent, (5) innovation and entrepreneurship, and (6) institutional and infrastructural readiness.

Szabó (2024), in a detailed analysis of the indicators, concludes that usage, network and security are common to the indicators. Different focus among the regional indicators can be identified, with DESI being interpreted in the context of a single market, countries with relatively close development, high levels of legal harmonization and the removal of digital barriers, while ADII can be interpreted in the context of a cooperative markets, countries with significantly different levels of development, low levels of legal harmonization and the exploitation of synergies. A number of differences can also be identified between the regional and global indicators. DiGiX and DII provide a broad, global perspective, with a global scope, covering different economic and technological environments, using a standardized approach to compare countries. Both DiGiX and DII assess digitalization, but with different emphases. DiGiX provides a comprehensive picture of digital demand, supply and

institutional environments worldwide. The DII focuses more on the development and sustainability of digital ecosystems, with an emphasis on factors such as digital adoption, institutional support and the development of digital trust. DII's approach is more dynamic, as it also looks at how digital capabilities evolve and develop over time, while DiGiX provides a static snapshot of current digital development.

Table 3. How indicators help to capture the barriers that leads to digital divide?

Indicator	Dimension	Structural barrier (direct measure)	Cognitive barrier (direct measure)	Motivational barrier (indirect measure)
DESI	(1) human capital		Internet user skills Advanced skills and development	
	(2) connectivity	Fixed broadband coverage Mobile broadband Broadband prices		Fixed broadband take-up
	(3) integration of digital technology			Digital Intensity Digital technologies for businesses e-Commerce
	(4) digital public services			e-Government
DiGiX	(1) users' adoption		Digital skills among population	Active Mobile-broadband subscriptions Fixed (wired)-broadband subscriptions Individuals using the internet
	(2) enterprise adoption	Innovation ecosystem components		Growth of innovative companies
	(3) government adoption			E-participation Index
	(4) affordability	Low-usage data and voice basket High-usage data and voice basket Data-only mobile-broadband basket (2GB) Fixed-broadband basket (5G)		
	(5) regulations	Phishing attacks Legal framework's adaptability to digital business models Burden of government regulations Efficiency of legal framework in challenging regulations Judicial independence Efficiency of legal framework in setting disputes Conflict of interest regulation		
	(6) infrastructure	3G or more mobile network coverage Secure internet services		
DII	(1) supply conditions,	Access infrastructure Fulfilment infrastructure Transaction infrastructure		
	(2) demand conditions	State of the human condition*	Literacy rate, adult total* Human Development Index*	Digital inclusion Digital payment uptake
	(3) institutional environment	Institutional effectiveness and trust Institutions and business environment Institutions and the digital ecosystem**		Government procurement of advanced tech**
	(4) innovation and change	Inputs Output Process		

Table 3. (*Continued*).

Indicator	Dimension	Structural barrier (direct measure)	Cognitive barrier (direct measure)	Motivational barrier (indirect measure)
ADII	(1) digital trade and logistics,	Trade and transport infrastructure Logistics services	Certificates and signatures International standards for trade documents	Support for trade/customs processes
	(2) data protection and cybersecurity	Data protection measures	Legislative cybersecurity capabilities Institutional cybersecurity capabilities Technical cybersecurity capabilities	International cooperation
	(3) digital payments and identities	Frameworks for transactions National identity cards Digitalized ID system		Banking platforms users Financial transactions users
	(4) digital skills and talent		Graduates in STEM Employment in knowledge-intensive services Active population skills Graduates' skills	Collaboration in R&D
	(5) innovation and entrepreneurship	Venture Capital R&D expenditure Innovative companies Starting business Intellectual property protection		
	(6) institutional and infrastructural readiness	Responsive government Legal framework		Mobile users Internet users Availability of government services

Note: The indicators are analyzed at the following levels: DESI: subdimension, DiGiX: indicator, DII: component, ADII: indicator.
* Literacy rate, adult total and Human Development Index are sub-indicators of the State of the human condition component, however, they are related to the cognitive barrier category, while other sub-indicators of that component belong to the structural barrier category.
** Government procurement of advanced tech is a sub-indicator of the Institutions and the digital ecosystem component, however, it is related to the motivational barrier category, while other sub-indicators of that component belong to the structural barrier category.
Source: Author's own elaboration.

A comparison of the indicator items (**Table 3**) with the previously defined barriers reveals how each dimension of the indicators measures structural, cognitive and motivational barriers. Furthermore, while the structural and cognitive elements are measured directly, motivation is measured indirectly: the indicators measure the uptake and use of certain digital solutions, which can be interpreted as a measure of motivation.

In the next chapter, the dimensions of these indices will be used to identify possible pathways bridging the digital divide.

6. Tools for bridging the digital divide

Addressing the digital divide requires a variety of measures and approaches. It is not enough to focus on a single indicator; cross-effects should also be considered. Furthermore, developing the least developed areas often yields the most visible results.

Based on the indicators and the background processes associated with them (**Table 3**), here are several methods that may help:

1. Eliminating structural barriers:

- Improving access (cf. DESI (2), DiGiX (6), DII, (1), ADII (6)): Enhancing access to digital devices and the internet is key. This includes developing infrastructure in rural or underdeveloped areas, expanding broadband internet access, and increasing the availability of smartphones or other digital devices. Vishnu et al. (2024) fund regional disparities in digital infrastructure and suggested areas to focus to strengthen digitally enabled higher education. They recommended to reduce the digital divide by improving digital infrastructure and designing policy interventions, particularly in developing countries.
- Reducing costs (cf. DiGiX (4), DII (1)): Lowering the cost of digital devices and internet services can also help reduce the digital divide. Governments and non-profit organizations may offer support or discounts to low-income families and those in rural areas, making these tools and services more affordable. For example Krishnatri and Vellakkal (2024) argue that affordable Internet promote maternal and child healthcare access.
- Government and civil society actions (cf. DII (3)): Programs and initiatives developed through government and civil society partnerships can help reduce the digital divide. These may include subsidized access programs, educational initiatives, or infrastructure development. For example Zhang et al. (2023) conclude that targeted incentive to digital is necessary to prevent digital disparity from becoming health outcomes disparity.
- Private sector partnerships (cf. DiGiX (4), (5)): Collaborating with the private sector can create opportunities for low-income or underserved communities to access digital tools and the internet at lower costs or for free. Popiel and Pickard (2022) pointed out that Philadelphia's COVID-19 digital inclusion efforts faced challenging logistics, limited data on the unconnected, funding concerns, and sometimes pushback from Internet service providers. The latter failed to address basic digital access gaps without significant public and governmental pressure.
- Innovative technological solutions (cf. ADII (6)): Developing and implementing technological solutions to bridge the digital divide, such as community mesh networks or public Wi-Fi in areas with low bandwidth or technical limitations. Improved social and technical outcomes for connectivity may be possible with these innovative technological solutions, especially when catalyzed by supportive policies (Stover et al., 2021)
- Developing workplace digital infrastructure (cf. DESI (3)): Companies need to enhance internal digital infrastructure so that employees can easily access information and communicate with each other, regardless of their location. This could include the introduction of cloud services, virtual workstations, video conferencing options, etc. For example during COVID-19 delivering previously in-person public programs through video conferencing formats was bridging the digital divide (Real, 2021).
- Ensuring access to digital platforms (cf. DESI (3)): Companies must provide employees with access to digital platforms, including business applications, internal communication tools, and other necessary software. This is particularly important for remote work (Soga and Bolade-Ogunfodun, 2024).
- Providing digital workplace tools (cf. DiGiX (2)): Companies need to provide employees with the appropriate digital tools and software to effectively perform

their tasks. This includes smartphones, laptops, software licenses, etc. Properly equipping employees with digital tools can help reduce the digital divide between workers. In the business environment, advanced digital devices often reach critical mass later than in the household (Peng, 2010).

- Rethinking organizational processes (cf. ADII (5), DII (4)): For example, removing human intervention where it's not necessary and replacing it with automated (robotized) processes (Schlegel and Kraus, 2023). This can address both cognitive and motivational problems, redirecting human labor toward other critical activities. The digital divide can also be addressed by limiting tasks exclusively to human activity without the use of digital aids.

2. Addressing cognitive barriers:

- Developing digital culture (cf. DESI (1), DII (2), ADII, (2)): Education and the development of digital competencies are key factors. Teaching the use of digital tools and the internet, especially basic skills (e.g., searching, safe browsing, evaluating information), can help people use these tools more efficiently and safely (Ragnedda, 2017).
- Enhancing digital skills (cf. DiGiX (2)): Organizations should provide opportunities for employees to develop their digital skills. This can include online courses, training, and workshops on the use of digital tools and applications, as well as effective information management. A good example for this is the case of the skills and competences needed for the implementation of robotic process automation (Schlegel and Kraus, 2023).
- Social innovation and grassroots initiatives (cf. ADII (4)): Supporting and encouraging grassroots initiatives based on community or voluntary work. For example, creating community internet centers where people can learn from each other and help one another develop digital skills. Establishing and running such community centers is especially important for marginalized groups (which requires not only technology but human expertise as well) (Tirad-Morueta et al., 2023).
- Developing smarter digital tools and solutions (cf. ADII (2)): The example of the tablet shows that it's much easier to facilitate people's digital transition if smarter tools and solutions are provided—meaning people don't need to learn the language of machines but can use thoughtful, more "human" devices and solutions (Faith and Hernandez, 2024).
- Promoting the use of collaborative digital tools (cf. ADII (4)): Many collaborative digital solutions are already available, which can efficiently support human activities. However, even built-in smart assistants on mobile phones are only utilized by a smaller portion of potential users. Song urges (2024) to improve AI literacy among Higher educational institutions' (HEIs) students and faculty, as it ensures that everyone has equal access to technology, preventing a digital divide. Besides, proactive education on the ethical use of AI is vital for HEIs to prepare students for the AI-driven future of education and maintain academic integrity.

3. Overcoming motivational barriers:

- Developing content and applications tailored to local segments (cf. DiGiX (1), ADII (5)): Creating digital content and applications that meet the needs and

cultural characteristics of local communities or target segments. This can encourage people to participate actively in the digital world and contribute to the development of digital skills (Priyadharma, 2024).

- Breaking down cultural barriers (cf. DII (2)): Sometimes, cultural barriers are behind the digital divide. It's essential to understand and address these barriers by involving representatives of the respective cultures and communities in education and the design of tools (Priyadharma, 2024).
- Data protection and security (cf. ADII (2)): Data protection and digital security are important factors in resolving the digital divide. People need to be provided with a safe environment for their online activities to prevent misuse of personal data and cyberbullying, which can be hindering factors to entering the digital world (Meier and Krämer, 2024).
- Leadership support and cultural shift (cf. DESI, (3), DiGiX (2)): Organizational leaders must pay special attention to reducing the digital divide and support the implementation of necessary measures. Moreover, creating a corporate culture that supports the use of digital tools and platforms and encourages employees to develop their digital skills is important (Loglo, 2024).
- Cross-supply chain collaboration (cf. ADII, (1), (3), DiGiX (2)): The latest generation of enterprise management systems can already manage the entire supply chain collectively, resulting in significant cost savings. The main obstacle to their spread is conflicting business interests, but aligning these interests can yield substantial savings for all parties. Besides, in most of the cases there is a digital divide among partner firms (Sharma et al., 2024).
- Strengthening digital governance (cf. ADII (6), DESI (4), DiGiX (3)): In some cases, activities can only be carried out digitally, which often provides "enough motivation" for digital transition. Moreover, the creation of a unified data platform across subsystems of government could significantly assist in administration and motivation to use digital systems. Moreover, the development of digital government services is an important public interest (Zulmasyhur and Sugiyanto, 2024)

7. Discussions

Several researchers have attempted to explore the causes of digital inequalities (Hsein et al., 2008; Manduna, 2016; Rogers, 2016), but the current study is considered the most comprehensive. The identified inequalities include both macro (global and regional economic, technological, social, educational, political/legal) and micro (corporate/organizational, individual) inequalities.

Also, the identification and conceptual framework of structural, cognitive and motivational causes of digital divides based on inequalities is a novel approach. On this basis, new research directions can be initiated, for which **Table 1** contains a number of sample research questions.

An analysis of four international indicators (DESI, ADII, DiGiX, and DII) for measuring digital inclusion has shown that currently measurement systems assess the structural and cognitive dimensions directly, while the motivational dimension is only indirectly measured, which highlights the need to extend them. Based on the

conceptual framework presented in **Table 3**, in addition to the categorization of indicator measures, the directions for overcoming some of the barriers are outlined, and a number of possible solutions are presented. This new approach is significantly more complex than previous research, but also contributes to a deeper understanding of the causes of digital divide and the directions for overcoming it.

8. Conclusion and future research

The main aim of the study was to provide a conceptual framework of the causes and possible solutions to the phenomenon of digital divide. The causes were identified along three dimensions (structural, cognitive, and motivational) and possible solutions were presented along these dimensions. The possible solutions were identified on the basis of four contemporary international indicators (DESI, DiGiX, DII, and ADII) measuring digital divide. There are a number of opportunities to extend the research. For one, a number of additional indicators have been identified to measure the phenomenon and further empirical studies are expected to complement the results. Moreover, the conceptual framework developed allow for a more in-depth analysis of specific digital divide measures and policies.

Funding: Co-funded by the European Union. This outcome was prepared in the framework of the project Overcoming Digital Divide in Europe and Southeast Asia "ODDEA" Project No. 101086381 Call: HORIZON-MSCA-2021-SE-01-1. Views and opinions expressed are however those of the author only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them. This research was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences. Grant Nr.: BO/00305/23. The APC was funded by Széchenyi István University.

Acknowledgments: The author would like to thank the anonymous reviewers for their detailed comments and suggestions, which greatly helped in the preparation of the final version of the paper.

Conflict of interest: The author declares no conflict of interest.

References

Aissaoui, N. (2021). The digital divide: a literature review and some directions for future research in light of COVID-19, Global Knowledge, Memory and Communication, https://doi.org/10.1108/GKMC-06-2020-0075

Antoun, J., Lapin, J. &Beck, D. (2023). Efficacy and efficiency of information retrieval of community family physicians at the point of care: exploring the associations with information and computer literacy. Journal of the Medical Library Association, 111 3, 677-683. https://doi.org/10.5195/jmla.2023.1539

ASEAN (2021). ASEAN Digital Integration Index 2021. https://asean.org/wp-content/uploads/2021/09/ADII-Report-2021.pdf

BBVA Research (2022). Digital Index 2022. https://www.bbvaresearch.com/en/publicaciones/digix-2022-update-a-multidimensional-index-of-digitization/

Boncz, B & Szabó, Z. R. (2021). Ethical and Safe Artificial Intelligence (Hungarian), Magyar Tudomány 182, 9, 1203–1209 https://doi.org/10.1556/2065.182.2021.9.5

Cruz-Jesus F., Oliveira T. & Bacao F. (2012). Digital divide across the European Union, Information & Management, 4, 278–291. https://doi.org/10.1016/j.im.2012.09.003

Duda, J., Duda, J. & Muhimmah, I. (2024). Measuring the digital economy in Europe and Southeast Asia. Is it possible to develop a common indicator? Zenodo. https://doi.org/10.5281/zenodo.8383819

European Commission (2022). DESI 2022. https://digital-strategy.ec.europa.eu/hu/policies/desi

European Commission (2024). 2030 Digital Decade. https://digital-strategy.ec.europa.eu/en/policies/2024-state-digital-decade-package

Faith, B. & Hernandez, K. (2024). Smartphone- and Tablet-Reliant Internet Users: Affordances and Digital Exclusion, Media and Communication, 12, 8173. https://doi.org/ 10.17645/mac.8173

Fletcher (2020). Digital Intelligence Index 2020. https://digitalintelligence.fletcher.tufts.edu/dei

Hortoványi, L. & Ferincz, A. (2015). The impact of ICT on the learning on-the-job, The Learning Organization, 22, 1, 2-13, https://doi.org/10.1108/TLO-06-2014-0032

Hortovanyi, L. Morgan, E.R., Vuksanovic Herceg, I., Djuricin, D., Hanak, R., Horvath, D., Mocan, L. M., Romanova, A. & Szabo, Z.R. (2023) Assessment of digital maturity: the role of resources and capabilities in digital transformation in B2B firms, International Journal of Production Research, 61, 23, 8043-8061, https://doi.org/10.1080/00207543.2022.2164087

Hsein, J. J. P-A, Rai, A. & Keil, M. (2008). Understanding Digital Inequality: Comparing Continued Use Behavioral Models of the Socio-Economically Advantaged and Disadvantaged, MIS Quarterly, 2008, https://doi.org/10.2307/25148830

IEEE (2024). IEEE Connecting the Unconnected: An IEEE Future Networks Program. https://ctu.ieee.org/impact-of-the-digital-divide-economic-social-and-educational-consequences/

Kormány (2024). Hungary's Competitiveness Strategy 2024-2030 (Hungarian). https://cdn.kormany.hu/uploads/document/9/92/92a/92a4fab01312d48d0390441f4389c44dc7699620.pdf

Krishnatri, V. & Vellakkal, S. (2024). Does affordable Internet promote maternal and child healthcare access? Evidence from a post-telecommunication market disruption period in India, Telecommunications Policy, 48, 10, 102872, https://doi.org/10.1016/j.telpol.2024.102872.

Li, Y., Li, C., Wang, Y., & Teng, G. (2024). Design and development of immersive 3D virtual simulation experiment teaching platform for internet of things. Multimedia Tools and Applications, 1-15. https://doi.org/10.1007/s11042-024-20209-8

Loglo, F. S. (2024). Towards Digital Transformation of Selected Ghanaian Public Universities: Leadership Enablers, Challenges, and Opportunities, Open Praxis, 16, 3, 374-395.

Manduna, W. (2016). Empirical study of digital poverty: a case study of a University of Technology in South Africa, Journal of Communication, 7, 2, 317-323. https://doi.org/10.55982/openpraxis.16.3.700

MDDI (2024). Smart Nation 2.0 A Thriving Digital Future for All. https://file.go.gov.sg/smartnation2-report.pdf

Meier, Y. & Krämer, N. (2024). Differences in access to privacy information can partly explain digital inequalities in privacy literacy and self-efficacy, Behaviour and Information Technology. https://doi.org/10.1080/0144929X.2024.2349183

MOOC list (2024) Online Courses. https://www.mooc-list.com/

Moroz, M. (2017). The level of development of the digital economy in Poland and selected European Countries: A comparative analysis, Foundations of Management, 9, 175-190. https://doi.org/10.1515/fman-2017-0014

National AI Office (2024). https://www.smartnation.gov.sg/nais/

Numbeo (2024). Price Rankings by Country of Internet (60 Mbps or More, Unlimited Data, Cable/ADSL) (Utilities (Monthly)) https://www.numbeo.com/cost-of-living/country_price_rankings?itemId=33

OECD (2001). Understanding the digital divide, OECD Digital Economy Papers, No. 49, OECD Publishing, Paris.

Peng, G. (2010). Critical mass, diffusion channels, and digital divide, Journal of Computer Information Systems, 50, 3, 63 – 71

Popiel, P. & Pickard, V (2022). Digital Redlining and the Endless Divide: Philadelphia's COVID-19 Digital Inclusion Efforts, International Journal of Communication, 16, 3329 – 3353.

Priyadharma, S. (2024). "Periphery-Centric" Approach as a Tactic for Everyday Digital In- and Exclusion of Indonesian Villages, Media and Communication, 12, 8162. https://doi.org/ 10.17645/mac.8162

Ragnedda, M. (2017). The Third Digital Divide: A Weberian Approach to Digital Inequalities, Abingdon: Routledge.

Real, B. (2021). Bridging Digital Divides during COVID-19: Findings from the 2020-2021 Connecticut State Library Digital Inclusion Survey, Public Library Quarterly, 40, 4, 283-309. https://doi.org/10.1080/01616846.2021.1938918

Rogers, S.E. (2016). Bridging the 21st century digital divide, TechTrends, 60, 3, 197– 199.

Schlegel, D. & Kraus, P. (2023). Skills and competencies for digital transformation – a critical analysis in the context of robotic process automation, International Journal of Organizational Analysis, 31, 3, 804 – 822. https://doi.org/ 10.1108/IJOA-04-2021-2707

Shapira, Z. (2011). "I've Got a Theory Paper—Do You?": Conceptual, Empirical, and Theoretical Contributions to Knowledge in the Organizational Sciences. Organization Science 22, 5, 1312-1321. http://dx.doi.org/10.1287/orsc.1100.0636

Sharma, P., Gunasekaran, A. & Subramanian, G. (2024). Enhancing Supply Chain: Exploring and Exploiting AI Capabilities, Journal of Computer Information Systems. https://doi.org/10.1080/08874417.2024.2386527

Sharp, M. (2024).Revisiting the Measurement of Digital Inclusion, The World Bank Research Observer, 39, 2, 289–318, https://doi.org/10.1093/wbro/lkad007

Smart Nation and Digital Government Office (2024) https://www.smartnation.gov.sg/

Soga, L. R. & Bolade-Ogunfodun, Y.(2024). Exploring flexible working practices and the digital divide in a post-lockdown era, European Journal of Management and Business Economics, 33, 4, 445 – 465. https://doi.org/10.1108/EJMBE-08-2023-0247

Song, N (2024). Higher education crisis: Academic misconduct with generative AI, Journal of Contingencies and Crisis Management, 32, 1, e12532, https://doi.org/10.1111/1468-5973.12532

Speedtest (2024) Speedtest. https://www.speedtest.net/global-index

Stover, S., Riedl, M. J. & Dickey, S. (2021). Scoping new policy frameworks for local and community broadband networks, Telecommunications Policy, 45, 10, 102171, https://doi.org/10.1016/j.telpol.2021.102171

Szabó, Z.R. (2024). Comparison of international indicators to identify digital divide (Hungarian). Tér-Gazdaság-Ember, forthcoming

Tátrai, M. & Szabó, Z. R. (2020) Digitalization, Quality of Life and Purchasing Power, Theory, Methodology, Practice, 16, 2, 97-102. https://doi.org/10.18096/TMP.2020.02.10

Tewathia, N., Kamath, A., & Ilavarasan, P. V. (2020). Social inequalities, fundamental inequities, and recurring of the digital divide: Insights from India. Technology in Society, 61, 101251. https://doi.org/10.1016/j.techsoc.2020.101251

Tirado-Morueta, R. Rodríguez-Martín, A. Álvarez-Arregui, E., Ortíz-Sobrino, M. Á. & Aguaded-Gómez, J. I. (2023). The digital inclusion of older people in Spain: technological support services for seniors as predictor, Aging and Society, 43, 6, 1409-1435. https://doi.org/10.1017/S0144686X21001173

Van Dijk, J. & Hacker, K. (2003) The digital divide as a complex and dynamic phenomenon The Information Society, 19, 4, 315–326.

Vassilakopoulou, P. & Hustad, E. (2021). Bridging digital divides: a literature review and research agenda for information systems research, Information Systems Frontiers, 25, 955–969. https://doi.org/10.1007/s10796-020-10096-3

Vishnu, S., Tengli, M.B., Ramadas, S., Sathyan, A. R. & Bhatt, A. (2024). Bridging the Divide: Assessing Digital Infrastructure for Higher Education Online Learning, TechTrends. https://doi.org/10.1007/s11528-024-00997-4

World Bank (2022). Digital inclusion and barriers in Laos: The cost of broadband and its impact on older adults. https://www.worldbank.org

Zhang, J., Gallifant, J., Pierce, R.L., Fordham, A., Teo, J., Celi, L., & Ashrafian, H. (2023) Quantifying digital health inequality across a national healthcare system. BMJ Health and Care Informatics, 30,1, e100809. https://doi.org/10.1136/bmjhci-2023-100809

Zulmasyhur Z. & Sugiyanto E. (2024). Toward equal access to public services through enhanced e-Government in Semarang City. Theoretical and Empirical Researches in urban Management, 19, 1, 89-109. https://www.jstor.org/stable/27283032