

Assessing the Impact of Information Systems on the Sustainable Development Goals within the Middle Eastern Countries Using Core Digital Sustainability Integration Index (Core DSII)

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Abstract: This paper is showing the correlation between digital transformation and sustainable development in the Middle East countries, which is the basis for developing the Core Digital Sustainability Integration Index (Core DSII). The primary research gap this study aims to overcome is the lack of a combined framework to assess the integration of digital infrastructure, digital economic activity and development goals related to sustainability in the Middle East region. To fill this, we have created the Core DSII with six indicators in two dimensions: Digital Infrastructure (DI) and Digital Economy (DE), and in particular the World Bank and the International Telecommunication Union. The empirical analysis is based on 271 observations, and shows that there are significant variations in the digital performance of the countries analyzed. The findings reveal that the overall level of digital integration (based on the study's classification) is a moderate average Core DSII score of 0.401. The most significant result is the large difference between Digital Infrastructure Index (DI) (0.387) and Digital Economy Index (DE) (0.148). This disparity provides some indication of the lack of a corresponding development of digital economic activity as a result of connectivity and digital infrastructure development.

Keywords: Information systems, Sustainable Development Goals, Core Digital Sustainability Integration Index (Core DSII), MENA, e-government, ICT.

I. INTRODUCTION

The use of ICTs and the growing digital economy are shaping economic and social outcomes in Arab economies [1, 2]. This impact is not just in terms of growth, as the digital economy also has direct and indirect effects on sustainable development and therefore is one of the pillars of the long-term development strategies in the region [3]. The existing literature reveals that the effects of digital economy are not equal to the Arab countries but rather varying [2, 3]. A higher level of performance of the digital economy is linked to higher levels of sustainable development in higher income and upper middle income Arab countries, but is less positive in lower middle-income countries and not present in the lowest income countries.

The paper has three contributions. First, it defines 'sustainable digital integration' as a multi-dimensional phenomenon and connects it with four other related elements: 'digital access', 'digital use', 'digital governance' and 'environmental performance'. Second, it describes a suite of basic indicators and methodology to build the Core DSII for

Middle Eastern countries. Third, it places the index in the current body of work in the field of digitalization and sustainability, highlighting its contribution to existing knowledge, which has been largely focused on individual aspects of the digitalization process (e.g., the environmental impact of ICTs or the performance of e government) and not on how both are contributing to sustainable development.

II. REVIEW OF PRIOR SEARCH

The first stream highlights the overall contribution of digital transformation to the SDGs. These studies show that digital transformation and the use of information's systems also enhances the efficiency, accessibility, sustainability and the capacity to solve problems such as poverty, inequality, infrastructure deficits and energy problems [4,5]. This stream also highlights the fact that digital technologies are tools that can be powerful if used in an inclusive manner, with strategic partnerships and ethical policy frameworks to ensure fair development outcomes [6].

The second stream is on localization and implementation. The evidence presented indicates that digital transformation can be an effective enabler for SDG localization, which involves incorporating planning and budgets to meet community needs into local government frameworks. In order to be successful, good data systems, institutional capacity to manage the information and sufficient funding of the development program [6] must exist. The findings are aligned with the SDG research on this implementation view, as it characterizes the 2030 Agenda as transformative, yet still weaker actors have less capacity to implement, and there are missing mechanisms in practice [7].

The third stream looks at evidence on a regional and sectoral basis in the Middle East. Recent research reveals that digital transformation in the region is link with the concepts of smart cities, sectoral innovation and improved health and education provision [8]. Digital engagement has been found to be associated with higher involvement in SDG related university initiatives in Jordan and thus digital communication can be used to aid in the sustainability awareness [9]. Jordan's banking sector supports [10] by leveraging AI, big data analytics, and green digital infrastructure to facilitate their organizations' digital transformation, thereby enhancing SDG practices. Looking at the case of Egyptian postal services, there is a statistically significant positive relationship between digital transformation and outcomes in economic, social, and technological development [11], and between digital transformation and organizational performance.

The fourth stream emphasizes constraints and limitations in research. The digital divide, cybersecurity issues, privacy concerns, inadequate infrastructure capabilities, and low institutional readiness are some of the challenges that can hinder digital transformation as identified in several studies [4, 5]. The weakness in Egypt is not a lack of digital initiatives, but the lack of integration of digital capacity with the sustainable development plans under the Vision 2030 [12]. The same challenge seen in the broader region of the Middle East in terms of fragmented regulation, advanced capabilities and unequal human capital development [8].

In general, the findings of these previous studies indicate that digital transformation and the application of information's technologies is beneficial for sustainable development, and it is contingent on the institutions, skills, infrastructure and digital technologies' connectivity with development targets. This calls for a deeper understanding of the role of the specific dimensions of digitalization in supporting SDG attainment in Egypt and the

Middle East, to go beyond general discussion and go towards specific dimensions.

Combined in the literature these strands suggest that the Core SDII seeks to overcome three core constraints. These strands of literature collectively indicate three key areas of constraint that the Core SDII addresses.

First, many studies focus exclusively on the environmental or economic impacts of ICT, but do not include social, governance dimensions relevant for sustainability [13, 14].

Second, many digital integration indices do not have a sustainability dimension; they focus on connectivity, services and/or competitiveness [15, 16].

Third, there is much work specific to MENA which is based on very general innovation or ICT indicators, but that do not directly reflect the contribution (or lack of) that digital systems make to sustainable development outcomes (SDOs) [17,18]. The Core SDII is develop to fill these gaps by bringing together:

- Digital health literacy and skills indicators, derived from the ability to access and use digital information; digital capability and usage measures that reflect the actual use of a technology by people, firms and governments;
- Environmental and sustainable digitalization metrics related to ICT energy consumption, emissions and e waste.
- Data security, privacy, and trust issues.

The Core SDII places these dimensions in the context of the broader literature on digitalization and sustainability, and builds on empirical evidence on the (dis)functionality of digital technologies and information systems in Middle Eastern countries to provide a more holistic approach to evaluating whether and how these support the achievement of the SDGs in the Middle East.

III. RESEARCH METHODOLOGY

The Construction of the Core Digital Sustainability Integration Index (Core DSII)

The Core Digital Sustainability Integration Index (Core DSII) has been created as a generic composite index to measure the extent of digital transformation in the countries of the Middle East. The index combines six digital metrics to capture two complementary aspects of digital development – Digital Infrastructure (DI) and Digital Economy (DE). The construction

process was based on the OECD Handbook on Constructing Composite Indicators (2008).

3.1 Data Collection

All selected countries of the Middle East were chosen and their annual data was taken from 2010 to 2024. The indicators were drawn from the most widely used national and international indicators, mainly from the World Development Indicators (World Bank) and International Telecommunication Union (ITU).

Table 1: Indicators of the Core DSII

Dimension	Indicator
Digital Infrastructure	Internet Users
Digital Infrastructure	Fixed Broadband Subscriptions
Digital Infrastructure	Mobile Cellular Subscriptions
Digital Infrastructure	Secure Internet Servers
Digital Economy	ICT Goods Exports
Digital Economy	ICT Service Exports

Data

- <https://datacatalog.worldbank.org/search/dataset/0067055/it-u-data-hub>
- <https://sdghelpdesk.unescap.org/data-portals>
- <https://databank.worldbank.org/source/world-development-indicators>

3.2 Global Min-Max Normalization

All indicators are measure with different measurement units and scales, so they were converted to be dimensionless using the Global Min–Max Normalization method.

This study differs from traditional normalization methods by computing the min and max of the panel data (all countries and all years), instead of the minimum and maximum for each year. This is done to guarantee the same interval for the composite index during the study period.

Normalization was calculated for indicators for which higher scores represent higher digital performance as follows:

$$N_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (1)$$

Where:

- N_{ij} : is the normalized value of indicator j for country i ;
- X_{ij} : is the original value;

- $X_{j\min}$: is the global minimum value of indicator j ;
- $X_{j\max}$: is the global maximum value of indicator j .

Consequently,

$$0 \leq N_{ij} \leq 1$$

Where larger values indicate better digital performance.

3.3 Construction of the Sub-indices

Following normalization, the indicators were aggregated into two sub-indices using the arithmetic mean and equal weighting.

3.3.1 Digital Infrastructure Index (DI)

The Digital Infrastructure Index was computed as in (2)

$$DI = (\text{Internet Users} + \text{Fixed Broadband} + \text{Mobile Cellular} + \text{Secure Internet Servers}) / 4 \quad (2)$$

Where:

- I_{Internet} = normalized Internet users;
- $I_{\text{Broadband}}$ = normalized fixed broadband subscriptions;
- I_{Mobile} = normalized mobile cellular subscriptions;
- I_{Secure} = normalized secure Internet servers.

3.3.2 Digital Economy Index (DE)

The Digital Economy Index (DE) was calculated by the (3)

$$DE = (ICT \text{ Goods} + ICT \text{ Services}) / 2 \quad (3)$$

Where:

- $ICT \text{ Goods}$ = normalized ICT goods exports;
- $ICT \text{ Services}$ = normalized ICT service exports.

3.4 Construction of the Core DSII

The final Core Digital Sustainability Integration Index was obtained by combining the two sub-indices using equal weights with the (4).

$$\text{Core DSII} = (DI + DE) / 2 \quad (4)$$

This aggregation assumes that Digital Infrastructure and Digital Economy contribute equally to overall digital.

Alternatively, the index can be expressed using the general composite indicator formulation as given in (5) (6)

$$\text{core DSII} = \frac{\sum_{i=1}^n w_i l_i}{\sum_{i=1}^n w_i} \quad (5)$$

Where:

- l_i denotes the normalized indicator;
- w_i represents the indicator weight.

Since equal weighting was adopted,

$$w_i = 1$$

Thus,

$$\text{core DSII} = \frac{1}{n} \sum_{i=1}^n l_i \quad (6)$$

Where $n = 6$.

Prior to index construction, missing values were evaluated for each indicator and country. Missing observations were handled according to the following rules:

- Missing values below **10%** within a country's time series were estimated using **linear interpolation**.
- Data was forward-filled at the start of the series and back-filled at the end of the series, if missing values were present.
- There is no estimation bias if a country had more than 40% missing observations for a particular indicator, so these countries were not included in the calculation of that indicator.

Interpretation of the Index

Table 2: The Core DSII ranges between 0 and 1

Core DSII	Interpretation
0.80–1.00	Very High Digital Sustainability
0.60–0.79	High Digital Sustainability
0.40–0.59	Moderate Digital Sustainability
0.20–0.39	Low Digital Sustainability
0.00–0.19	Very Low Digital Sustainability

The higher the score for more developed the digital infrastructure, digital economy and readiness to support SDGs.

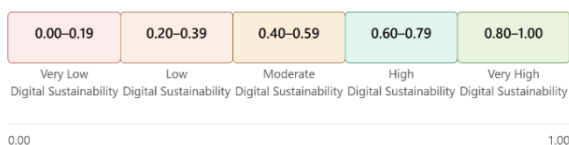


Figure 1: The Core DSII ranges between 0 and 1

This method is especially applicable to measure for the SDII, where the concept has to be strong and implementable in the Middle Eastern countries where the data is not available in all.

The higher the score the more developed the digital infrastructure, digital economy and readiness to support SDGs.

IV. EXPERIMENTAL RESULTS

4.1 Descriptive Statistics of the Core DSII

The final data contains 271 rows of data for the Middle East for the years 2010-2024. Table (3) shows the descriptive statistics for the sub-indicators and the composite indicator.

Table 3: The descriptive statistics for the sub-indicators and the composite indicator

Variable	Mean	SD	Min	Max
Digital Infrastructure Index (DI)	0.387	0.281	0.0003	1.000
Digital Economy Index (DE)	0.148	0.205	0.0023	1.000
Core DSII	0.401	0.270	0.0088	1.000

4.2 Country Ranking

The findings show that the overall average Core DSII score is 0.401, which is considered moderate level of integration relation between digital infrastructure and the digital economy in Middle Eastern countries. Moreover, the average DI (0.387) is significantly higher than the average DE (0.148) indicating that investment in digital infrastructure has been higher than in the digital economy.

Based on the Core DSII average, they are as follows:

Table 4: Top-ranked countries

Rank	Country	Mean Core DSII
1	ARE	0.787
2	BHR	0.675
3	SAU	0.674
4	KWT	0.623
5	QAT	0.602
6	OMN	0.515

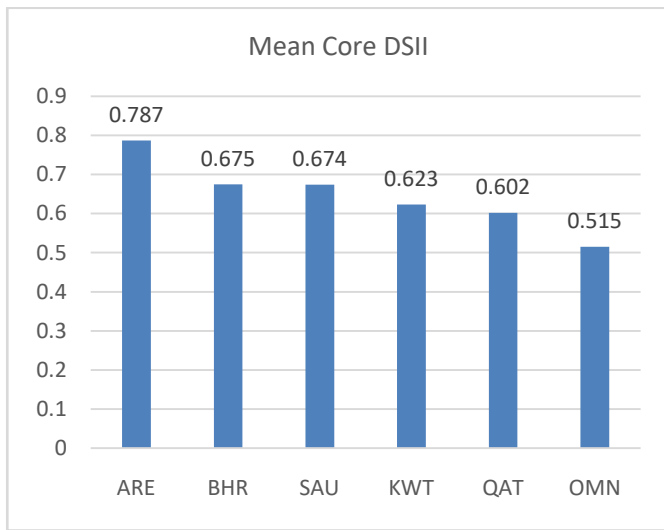


Figure 2: The results indicate for Top countries

The results indicate that overall, the GCC countries are scoring well, as investments have been made in digital infrastructure and digital transformation over the past decade.

4.3 Performance of Digital Dimensions

The results of the two sub-dimensions show that:

Digital Infrastructure (DI) was relatively high in most countries with internet penetration, mobile communications and 5G network coverage.

Digital Economy (DE) showed more variation, with high scores in fewer countries with technology sectors and digital exports that are developed.

This means, many countries have been successful in setting up the infrastructure needed for a digital transformation, but the process of transforming this infrastructure into economic value is not even.

4.4 Contribution of Indicators

The analysis showed that the contribution of the indicators varied between countries:

Table 5: Contribution of the indicators for top rank countries

Countries	Contribution of the indicators
UAE (ARE)	Higher values for Secure Internet Servers, 5G coverage, and Internet Users, along with better digital economy indicators were linked to high performance.

Bahrain (BHR)	Advanced e-government and digital infrastructure services were the main drivers of performance, supplemented by a good contribution from digital economy indicators.
Saudi Arabia (SAU)	Digital infrastructure was a major factor with a particular focus on internet penetration and digital security, with still potential for improvements in technology exports.
Kuwait (KWT)	The high usage of internet and mobile communications resulted in a higher DI value.
Qatar (QAT)	5G rollout and investment in telecom were correlated with performance.
Oman (OMN)	Performance was driven by some aspects of digital infrastructure and had only a limited contribution from the digital economy.

V. DISCUSSION

The study reveals that digital transformation varies significantly across countries in the Middle East, both in terms of the level of digital infrastructure and its capabilities to harness it. The Core DSII values were the highest for the GCC countries, highlighting the long-term policies and investments of governments in telecommunications networks, cloud computing, data centers and digital services.

In addition, the existence of missing data for some DE indicators points to the necessity of digital statistical systems in the region to be developed to provide more statistics that are comprehensive and make it easier to construct more robust composite indicators, which are vital for decision-making processes.

Future Roadmap toward Sustainable Development Goals Acceleration of Sustainable Development Goals (SDGs) in the Middle East needs: according to the Core DSII results.

1. To move from digital infrastructure towards a digital economy, with the support of start-ups, e-commerce and exports of information technology and services.
2. Focusing on strengthening research, development and innovation to boost technology's role in economic growth and contribute to SDG 16
3. Enhancing education and vocational training uses of digital skills for SDG 4 and SDG 8.3.
4. Improving cybersecurity and digital government services to support SDG 16.
5. Building a common regional approach to measuring digital transformation, through periodic updating of the Core DSII

indicator, ensuring it is aligned with SDG indicators and would provide a practical tool for monitoring progress and informing policy.

From the CoreDSII data, the overall results were as follows:

Table 6: The result for Core SDII

Statistical Analysis	Value
Number of Inputs	271
Mean	0.4010
Standard Deviation (SD)	0.2695
Lowest Value	0.0088
First Quartile (Q1)	0.1754
Median	0.3758
Third Quartile (Q3)	0.6200
Highest Value	1.0000

The results clearly show that countries with very mature digital ecosystems have systematically higher SDII scores. Rising investments in broadband infrastructure, secure digital services and policies that incentivize renewable energy and energy efficiency help advance the capabilities of advanced economies like UAE, BAHRAIN, Sudan Arabia and Qatar. The characteristics are further evidence of the close ties between digital transformation and sustainable development.

The trend observed from 2012 to 2022 is gradual increase in SDII, which was observed to be concurrent with the development of sustainable energy systems. This result aligns with the results from the broader literature, which suggests that digital technologies, when backed by sound policy frameworks, can lead to increased resource efficiency, better energy management, and better environmental performance.

The disparities between high and low-performing countries also highlight the fact that there is a digital sustainability gap that has not been bridged. Structural hindrances, such as weak infrastructure for information and communication technologies, low levels of investment, and sluggish development of renewable energy technologies, remain a problem in developing economies, including Iran. Therefore, digital transformation is not enough without sustainable energy and institutional capacity investments.

However, the downturn seen in 2023 shouldn't be seen as a sign of any shift in global digital sustainability. The observed trend may change due to the addition of new information to the underlying database, as the most recent year may have

incomplete statistical reporting. These results should be confirmed with new data as it becomes available in the future.

Overall, the core SDII is a robust set of tools that combines the development of ICTs with the energy sustainability indicators and can be used to evaluate digital sustainability. The index will enable policy makers to use it as a practical benchmark for national performance, to identify development gaps, and to track progress towards sustainable digital transformation.

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