Goals of sustainable infrastructure, industry, and innovation: a review and future agenda for research

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Abstract

Sustainable Development Goal 9 targets (SDG 9 targets) are mainly tracked through the indicators of penetration of internet and mobile broadband subscription, logistic performance index, quality and ranking of the universities, investment in research and development initiatives, industrial reforms and emission control, and connectivity to rural areas. The attainment of many of these targets and tracking of indicators is confronted by challenges of poor awareness, funding issues, distorted policies, and implementation failures. This systematic review on achievements, challenges, and future scope in attaining SDG 9 consolidates the literature from the Web of Science, related to SDG 9 and indicators, since 2017; develops bibliometric patterns; conducts thematic analysis by focusing the leading indicators of SDG 9; and develops agenda for future research. The major limitations of this study include focusing on selected indicators and limited literature availability. This review recommends policymakers, researchers, and administrators to focus on promising themes such as tackling the digital divide and ensuring digital justice and digital equality; clean fuel and technology adoption; enhancing internet and mobile broadband subscription with reduced negative impacts, logistic sector reforms; industrial policy reforms and technology integration; improving the quality and sustainability of universities; and increasing funding and support for research and development initiatives and improving the rural connectivity.

Introduction

Infrastructure, sustainable industrialization, and innovation is the key to achieving Sustainable Development Goal 9 (SDG 9). The SDG 9 can be tracked with eight targets and twelve indicators developed by the United Nations (United Nations 2021): road access to rural population, passenger and freight volume by mode of transport, increasing the share of manufacturing in GDP and employment, increasing share small scale industries, medium and hi-tech industries in total industry value-added, carbon dioxide emissions for economic value-added, expenditure on research and

development as a percentage of GDP, the share of researchers among inhabitants, international support to infrastructure, and the population covered by the mobile networks and internet access (SDG Tracker 2021; United Nations 2021). The UN updates of these targets show that 57.7% of the rural dwellers lack good access to the road in twenty-five countries, and COVID-19 impact is severe on the targets of SDG 9, with poor numbers from manufacturing and employment manufacturing and weak air travel demand. Imposing restrictions on the exploitation of resources; monitoring, and controlling emissions, enhancing urban public infrastructure and public services, rationally planned industrial development; and reducing dependence on fossil fuels are essential for attaining sustainability goals (Zhao et al. 2021). The impact of carbon emissions is causing severe challenges in the attainment of the SDG 9 targets by 2030, and policy actions, green energy consumption, and successful migration to clean technologies are inevitable to attain these targets (Akhtar et al. 2022). Similarly, supporting tourism and innovation in industries and infrastructure development are

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also essential for attaining the targets of SDG 9 (Anser et al. 2021). However, there is increased spending in research and development and progress in the number of researchers among inhabitants (United Nations 2021). Moreover, the sustainable development goals of industry, innovation, and infrastructure (SDG 9) are highly connected with other SDGs (Mantlana and Maoela 2020) (Coenen et al. 2021) and climate actions (Coenen et al. 2021).

In Asia, six countries have internet penetration below 25%, and thirteen countries are in the 25–50% level of internet penetration. Eight Asian countries are with internet penetration between 50 and 75% and fourteen countries with internet penetration above 75%. The mobile broadband penetration of twelve Asian countries is below 50%, and the remaining countries have achieved mobile broadband penetration above 50%. According to the logistic performance index (measured on a scale of 1–5), twenty-seven Asian countries are with logistic performance index below 3, and fourteen countries are with logistic performance index above 3. Fourteen Asian countries have a "Times Higher Education Universities Ranking" (average score of top three universities) zero, twenty-four Asian countries have an average score below fifty, and four countries have an average score above fifty. Only seven Asian countries are spending more than 1% of their GDP on research and development (Sachs et al. 2021).

Thirty-two African countries have internet penetration below 25%, and eleven countries are in the 25–50% bracket and 50–75% each. Eighteen African countries are with mobile broadband penetration above 50%, and thirty-six countries are with mobile broadband penetration below 50%. Only two African countries are with logistic performance index above three. Only one African country is with an average score of the top three universities above fifty, and none of the African countries are spending at least 1% of their GDP for research and development initiatives (Sachs et al. 2021).

All countries in Europe are having internet penetration above 50%, and twenty-eight countries are with internet penetration above 75%. Similarly, two European countries are with mobile broadband penetration below 50%. Only thirteen European countries are with a Logistic performance index below three. Thirteen European countries with an average score of top three universities above fifty, and fourteen European countries are spending less than 1% of their GDP for research and development (Sachs et al. 2021). Sustainable infrastructure and sustainable industries are very essential for the achievement of SDG 9. The research development, sustainable transport, and innovations are the focus areas for the SDG 9 targets in the European context (Bere-Semeredi and Mocan 2019).

In the Oceanic region, two countries are with internet penetration above 75%, and two countries have internet penetration levels between 50 and 75%. Three countries have poor penetration of the internet, below 25%, and seven countries are in the 25–50% bracket. Nine countries from the Oceanic region are with mobile broadband penetration below 50%. There are two countries with the logistic performance index above three. Two Oceanic countries with an average score of the top three universities above fifty and only two Oceanic countries are spending more than 1% of their GDP for research and development (Sachs et al. 2021).

In North America, all three countries have internet penetration above 70% and mobile broadband penetration above 75%. The logistic performance index of all countries except one is above three. Similarly, except for one country, the average score of the top three universities is above fifty, and the spending on research and development is above 1% of the GDP figures (Sachs et al. 2021). In South America, one country has internet penetration below 25%, three countries are in the 25–50% bracket, and seven countries are in the 50–75% level of achievement. Two countries are with mobile broadband penetration below 50%. Only one South American country is with logistic performance index above three. None of the South American countries is with an average score of the top three universities above fifty. Similarly, the only country in the region is spending at least 1% of its GDP on research and development initiatives (Sachs et al. 2021).

In the Caribbean region, one country is with internet penetration below 25%, and five countries are in the 25–50% bracket. Eight Caribbean countries are in the 50–75% bracket in respect of internet penetration, and three countries are with internet penetration above 75%. Eight countries from the Caribbean region are with mobile broadband penetration below 50%. None of the Caribbean countries are with logistic performance index above three. Similarly, no country in the Caribbean region is with an average score of the top three universities above fifty. None of the Caribbean countries are spending more than 1% of their GDP on research and development (Sachs et al. 2021).

High mobile broadband penetration and internet penetration of the country show the progress of the country in digital infrastructure and the level of the digital-savvy population. The higher ranking of universities shows the quality of infrastructure in education. In short, higher numbers are preferred in all these three indicators of SDG 9. Figures 1 and 2 are based on the Sustainable Development Report 2021, by Cambridge University Press, and visualized in this review using Excel tools. Figure 1 visualizes the internet penetration, mobile broad brand subscription, and the performance of leading universities among leading economies of the world. The internet penetration among the leading countries is at above 80% level in leading economies other than China. China has a huge population and its no one country in the world and that can be the reason for a comparatively lower level of internet penetration. All the

Fig. 1 Selected SDG 9 indicators of leading economies. Data source: Sustainable Development Report 2021, by Cambridge University Press
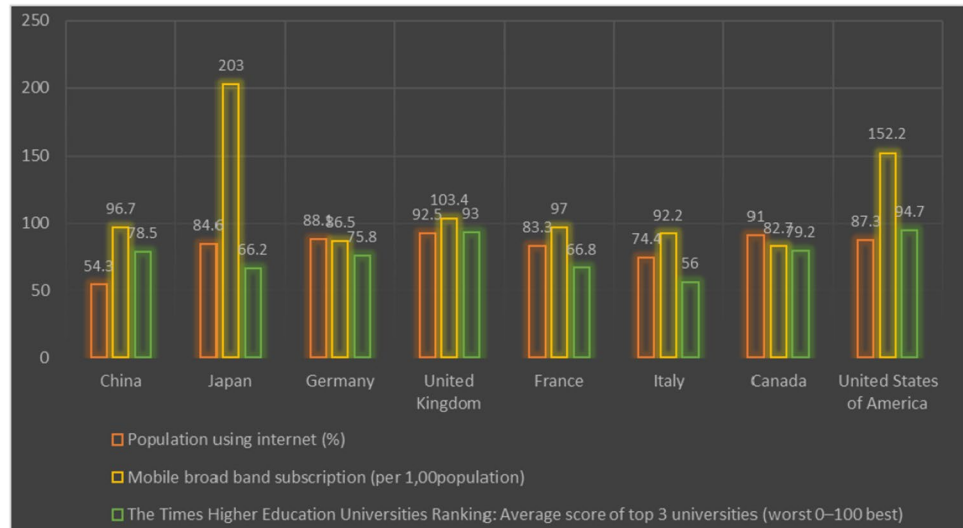
Fig. 2 Selected SDG 9 indicators of leading economies. Data source: Sustainable Development Report 2021, by Cambridge University Press
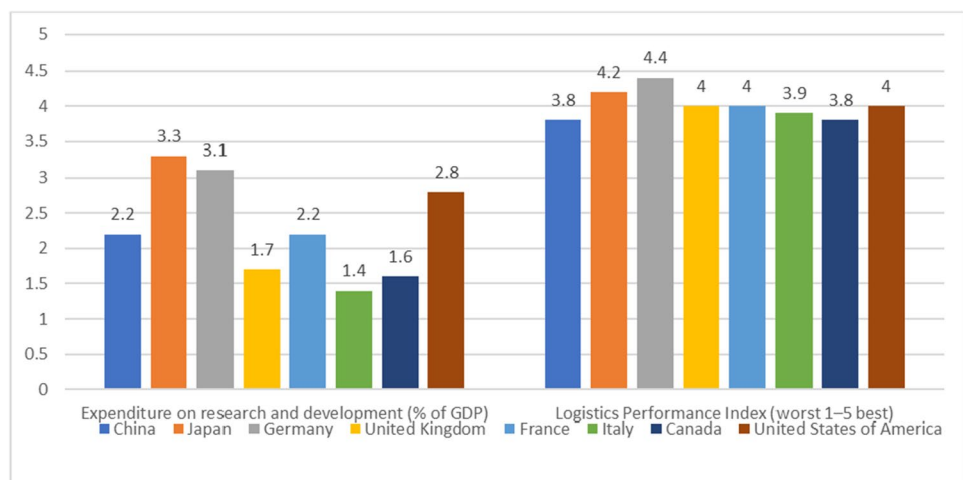
leading economies have high-level penetration of mobile broad brands; Japan and the USA are much ahead of other leading economies. Based on the average score of the top three universities, the USA and the UK are the regions with top universities, and Italy is comparatively lagging in performance in this indicator of SDG 9.

A higher level of spending for research and development as a percentage of the GDP and, similarly, a higher number in the logistic performance index on a scale from 1–5 are desirable. Figure 2 is the continuation of Fig. 1 and tracks the performance of the leading economies in the world in respect of their expenditure on research and development as a percentage of the Gross Domestic Product and the logistic performance index on a scale of 1–5. Japan is the country with the highest spending for research and development, as a percentage of GDP. Japan spends about 3.3% of its GDP followed by Germany and the USA. Italy, comparatively spending less in this respect, spends only 1.4% of the GDP for research and development initiatives. The logistic

performance index of Germany is the best in the group, followed by Japan. The logistic performance of all the countries in the group is more than satisfactory level.

Industry, innovation, and infrastructure are the three basic pillars for achieving SDG 9, and the industry-related targets of SDG 9 can be better monitored by an index on SDG 9 indicators on industry-based indicators. In the study on the industry-based index related to SDG 9, the industrially developed countries (Ireland, Germany, the Republic of Korea, Switzerland, and Japan) are much ahead of the remaining countries (Kynclova et al. 2020), and similarly, the index for monitoring the SDG 9 targets is an index based on five indicators related to three industry-related targets (Saieed et al. 2021). Better policy implementation and policy reforms can be possible through the analysis comprehensive evaluation index for SDG 9-related targets.

This paper is with six chapters: an introduction section of SDG 9 with a global focus is the first chapter, followed by a review methodology of the paper. Bibliometrics is in

the third and fourth sections which are thematic discussions. The recommendations and agenda for future research are the fifth section, and the concluding section is the last chapter. This paper on the industry, infrastructure, and innovation in the global scenario discusses the role of internet penetration, mobile internet, ranking of the top universities, logistic performance, and the government spending in research for achieving targets of SDG 9, i.e., for the goals of sustainable industries and sustainable infrastructure.

Research objectives

1. To summarize the SDG 9 initiatives and achievements at a global level
2. To consolidate the literature on SDG 9
3. To find out future research niches on SDG 9

Research questions

1. What challenges are faced in the achievement of SDG 9 targets?
2. What can be done for achieving the targets of SDG 9?
3. What are the achievements of SDG 9?
4. Which are the promising areas for future research?

Review methodology

Web of Science is a professional database for academic records comprising highly impactful journals and conference proceedings. It covers more than two hundred and fifty disciplines and has a huge collection on the topics of sustainability, sustainable development goals, sustainable industry, infrastructure, and innovation. There are high-quality academic papers based on the single-source model (Lage Junior and Godinho Filho 2010; Jabbour 2013; Talan and Sharma 2019). This paper adopted the single-source model (only Web of Science resources). This paper has used the goal-specific keywords "Sustainable Development Goal 9" and "SDG 9" and indicator-specific keywords "internet penetration," "logistic performance index," "mobile broadband subscription," "Times University Ranks," "Scientific and technical journal articles (per 1000 population)," and "Expenditure on research and development" (% of GDP) which were used on 19/12/2021 and drew 204 papers which were obtained for the review on topic-based research. However, thematic analysis is conducted only on four indicators, as no suitable publication is obtained on the last two indicators. This paper followed paper selection based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (refer to Fig. 3). PRISMA guidelines is used for introducing better transparency in the systematic review. It includes the minimum set of disclosures/reporting items in systematic reviews and meta-analyses. PRISMA guidelines facilitate a better quality analysis of the systematic review/meta-analysis and also help in replicating the study. PRISMA guidelines provide a detailed checklist for preparing a systematic review/meta-analysis (including 27 checklist items). The checklist covers guidelines for the preparation of the title, abstract, introduction, method, result discussion, and funding.

In the first step of paper selection, the 204 documents are checked for anonymous records and duplicates. In this step, all papers are passed to the next stage for screening, as there are no duplicates and anonymous records. The 204 documents are checked for eligibility to include in this paper. A total of 164 documents are removed after reading the title and abstract due to irrelevance to the topic in discussion or without an abstract. In the final step, forty papers are selected for thematic discussion. This paper was motivated by the structure and model adopted in the works (Bansal et al. 2019; Jain et al. 2019; Srivastava et al. 2020).

This paper has used two filters or exclusion criteria for article selection. All publications before 2016 have been

Fig. 3 Paper identification and screening process. Data source: Web of Science database
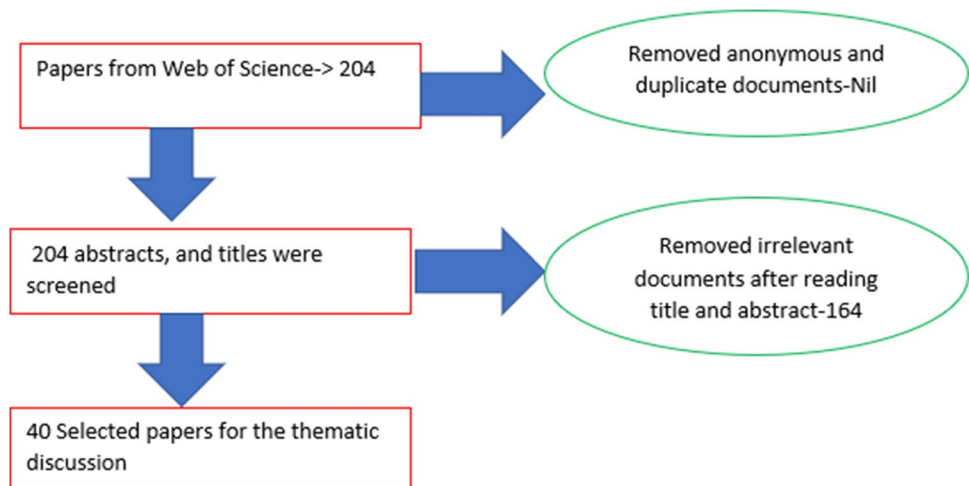
avoided from thematic analysis. Similarly, non-English publications are also avoided.

Bibliometric results

Bibliometric analysis is performed on the search result from the Web of Science. The major research parameters like the H index, M index, and G index are used for measuring the impact of document sources and authors. H index value one shows that one publication has received one citation. M index, a derivative of the H index, analyzes the H index on yearly basis from the first publication. The G index number represents the top g articles received together with at least g^2 citations. The figures used in the bibliometric analysis (Figs. 4, 5, 6, 7, and 8) are based on the bibliometric details of articles downloaded from the Web of Science database, and results are visualized using the "Biblioshiny."

Journal analysis

The most influential journals related to research on SDG 9 are " Sustainability" (14 citations), "Journal of Cleaner Production" (234 citations), "Applied Energy" (20 citations), " Environmental Science and Pollution Research"(4 citations), and "International Journal of Sustainable Development and World Ecology" (22 citations). The detailed analysis of document sources mentioned above is shown in Fig. 4. "Sustainability" leads in document production, with eight publications followed by "Journal of Cleaner Production" (seven publications) and "Applied Energy" (six publications). In all three research quality parameters, the H index, the M index, and the G index, the "Journal of Cleaner Production" has a leading role. "Sustainability" and "Applied Energy" have a similar impact on all these parameters and closely follow the "Journal of Cleaner Production."

"Sustainability" published articles on the topics related to Logistics 4.0 of Brazil's industry and its relation with
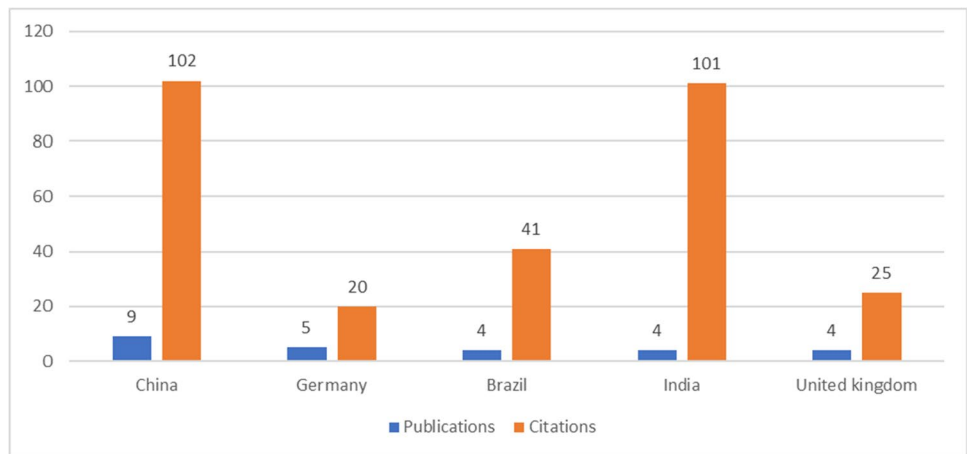

Fig. 4 Journal impact analysis. Data source: Web of Science database
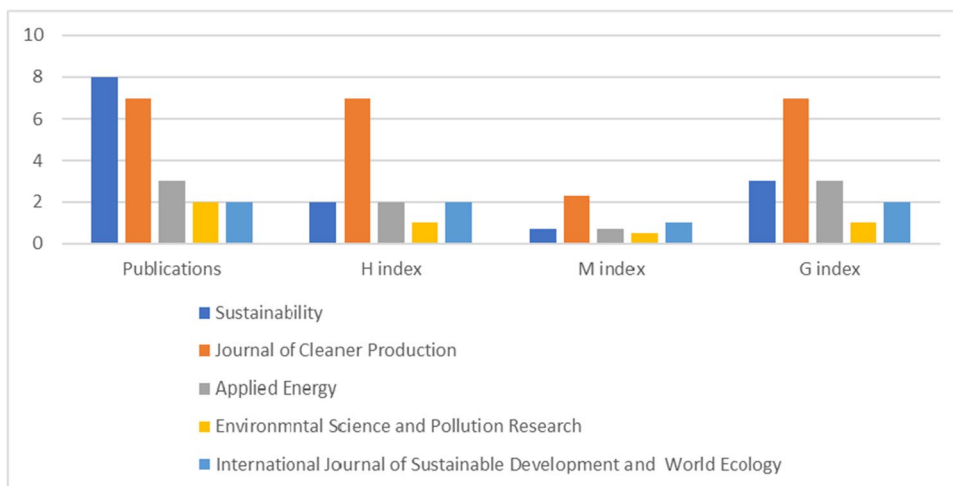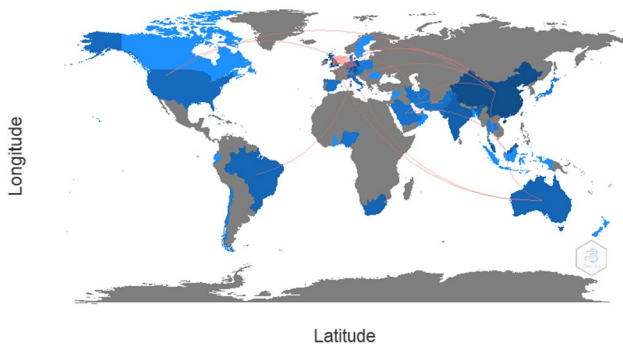

Fig. 5 Author analysis. Data source: Web of Science database
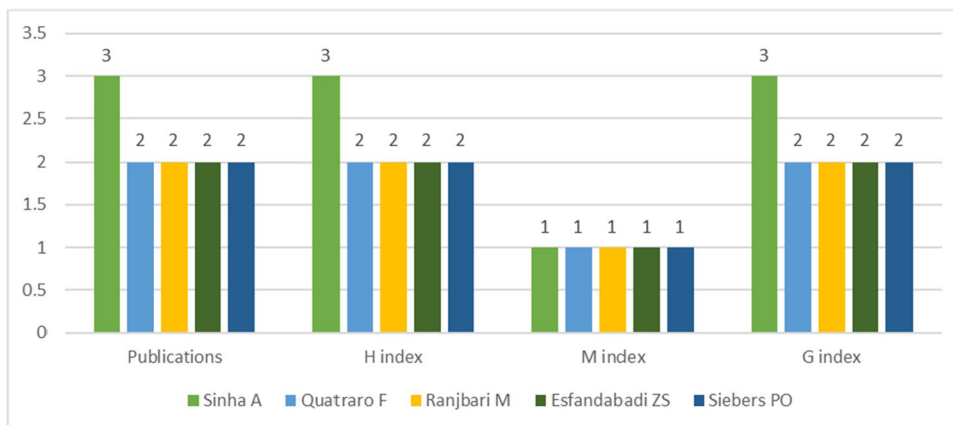
Fig. 6 Country analysis. Data source: Web of Science database


Country Collaboration Map

Fig. 7 Country collaboration. Data source: Web of Science database

SDG 9, digital infrastructure assessment tools in line with SDG 9, impacts of the production of woody pellets and SDG 9, usage and applications between artificial intelligence and SDGs including SDG 9, the role of the construction industry in the achievement of SDG 9 targets, research and development and sustainable economic performance, and sustainable e-tourism. "Journal of Cleaner Production" published on technological innovation and environmental quality, sustainability implications of the carbon emissions, circular supplier selection in the petroleum industry, innovations in sustainable supply chains, energy consumption and urbanization, and bio-economy-related SDGs. "Applied Energy" published articles on measuring the achievement of SDG 9 targets, tracking the progress on SDG 9, and inclusive and sustainable industrial development in China. The article published in "Environmental Science and Pollution Research" is related to pavement maintenance management of roads and the relation between international tourism and environmental degradation. "International Journal of Sustainable Development and World Ecology" published articles related to economic activities and SDGs and business models towards SDGs.

Fig. 8 Keyword analysis. Data source: Web of Science database
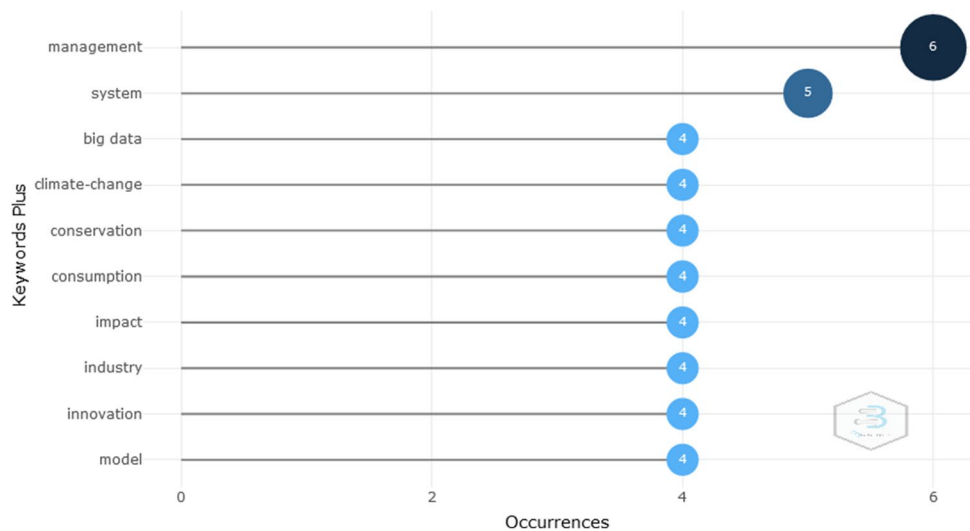
Analysis of authors

The leading authors related to SDG 9 are Sinha A, Quatraro F, Ranjbari M, Esfandabadi ZS, and Siebers PO. The detailed analysis of authors on leading parameters is compared in Fig. 5. Sinha A leads in the *H* index and *G* index value and is the influential author on this topic. Quatraro F, Ranjbari M, Esfandabadi ZS, and Siebers PO have similar impacts on this topic, especially in the case of the *H* index and *G* index. All the top five authors of this topic have similar *M* index (refer to Fig. 5).

Sinha A leads the domain with three publications and a total of 127 citations. The major works are related to technological innovations and sustainable development goals including SDG 9. The articles Chen et al. 2021) and (Sinha et al. 2020b) are published on "Technological Forecasting and Social Change"; (Sinha et al. 2020a) is published in "Journal of Cleaner Production." The collaboration among Quantraro F (University of Turin), Rajbari M (University of Turin), Esfandabadi ZS (Polytechnic University of Turin, Italy), and Siebers PO (University of Turin) has written two articles related to SDG 9, (Ranjbari et al. 2021a, b), published in "Environmental Development and Sustainability," and (Ranjbari et al. 2021b) published in "The total citations for these articles is thirty-nine. The articles dealt with sustainable development goals and COVID 19."

Analysis of countries

The region-wise analysis related to SDG 9 and the bibliometric details is given in Fig. 6. The collaborations based on countries are given in Fig. 7. The dark blue color indicates leadership in research, the red lines are used for showing collaborations, and the thickness of the red lines indicates the strength of research relation between countries. The leading countries of this research domain are China, Germany, Brazil, India, and the UK. China has strong research collaborations with the USA, the UK, Italy, Malaysia, Denmark, and Iran. Germany has strong research connections in this topic with the UK, Brazil, and the USA. The other countries with active collaborations include the UK and Italy.

China leads in document publications with nine publications and one hundred and two citations. China is followed by Germany in document publications (five publications) and India in citations (one hundred and one citations) (refer to Fig. 6).

Keyword analysis

The keyword analysis was shown in Fig. 8. Management, system, big data, climate change, conservation, consumption, and impact are the most occurred keywords in the documents selected for thematic analysis.

Thematic analysis

The sustainable development goals of industry, infrastructure, and innovation focus on six major indicators for the monitoring of performance and for reframing strategies and policies. However, the thematic framework of this paper is based on four of these indicators, and two indicators are avoided due to the unavailability of published documents directly related to this topic. The indicators to be monitored for the achievement of SDG 9 targets are the internet penetration levels, logistic performance index published by the World Bank, percentage of mobile broadband subscription, and the average score of the top three universities in the Times Higher Education University Ranking (Fig. 9).

Internet penetration

Sustainable Development Goal 9 deals with industry, innovation, and infrastructure. The internet infrastructure and internet penetration of the country can play a big role in communication, education, entertainment, and other

Fig. 9 Key themes, sub-themes
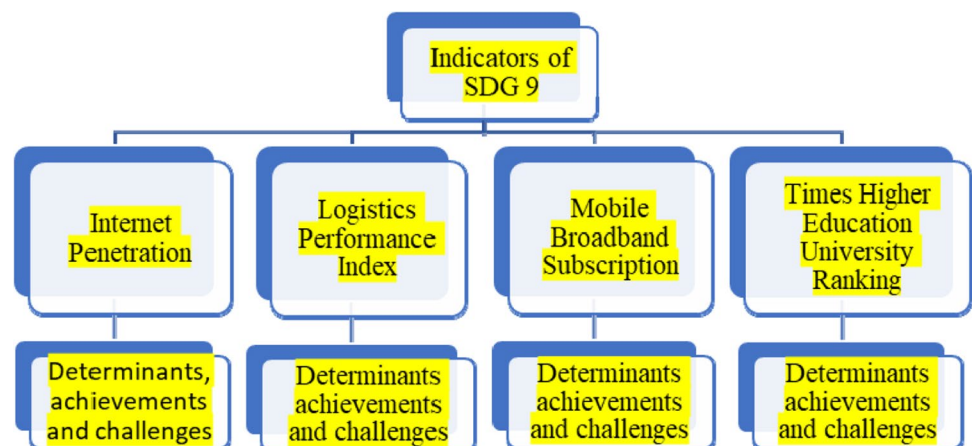
industries. Internet penetration has casual relations with economic growth, and thus, rapid internet penetration is key for economic growth (Pradhan et al. 2016)(Harb 2017)(Haini 2019); for promoting economic growth, especially farmers' income (Li 2020) and regional financial development (Jiang et al. 2020); and for stock market efficiency (Afshan et al. 2021). However, the contradictory results were obtained on the results on the role of internet penetration on income and environmental actions (Zhang and Meng 2019) and inclusive financial development and growth in per capita income (Song et al. 2017). The internet penetration itself is dependent upon income, education, demographics, telephone and broadband subscriptions, computer and mobile phone ownership, networks, political environment and media (Vincent 2016), tariff, and competition policy (Lange 2017). Even though internet access can bring business growth and employment, it can also enhance the digital divide (Latapu et al. 2018). The digital divide in Sub-Saharan Africa is due to the spillover effect, GDP, per capita income levels, politics, regulations, population, and electricity infrastructure of the country (Myovella et al. 2021).

However, the impact of internet penetration in income inequality in developing regions is severe in comparison with developed regions in Asia (Panichsombat 2016); there are also studies pointing out the reduction in inequality due to enhanced internet penetration (S A Asongu and Odhiambo 2019a, b). Industrial intensity and internet penetration are related and are substitutes. Industrial penetration can reduce the total expenditure on internet intensity (Chang et al. 2018). Internet penetration also promotes Internet Financial Reporting (Ariff et al. 2018). Internet penetration can also promote sustainable consumption (Wang and Hao 2018) and innovations (Xiong et al. 2021); international tourism (Vanesa Lorente-Bayona et al. 2021)(Lee et al. 2021), but subject to forex regulations (Vanesa Lorente-Bayona et al. 2021); higher education (Mousa and Elamir 2019) and school education (Asongu 2020)(Mate et al. 2020); for gender economic inclusion (Asongu and Odhiambo 2020); promote insurance penetration and governance (Asongu et al. 2020) and government's environmental protection expenditure (Zhang et al. 2022).

Mobile broadband subscription

Mobile broad brand subscription rates are increasing and improving energy efficiency, promoting environmental sustainability reducing carbon emissions (Zhao et al. 2021), and promoting international tourism (Kumar and Kumar 2020). The mobile broadband penetration can be in three phases take-off, fast-diffusion, and saturation (Teklemariam and Kwon 2020). Mobile broadband subscriptions are saturating in many developed countries (Bento 2016). They have diversified applications and huge potential for exploring the opportunities

for e-governance (Kyem 2016). Moreover, it is not only the mobile broadband subscriptions but, quality, i.e., the speed of networks is also equally important (Abeliansky and Hilbert 2017). Mobile broadband penetration can be a determinant for enhancing subscriptions to life and non-life insurance policies (Simplice A Asongu and Odhiambo 2019a, b).

Times Higher Education University Ranking

University ranking is an important factor in higher education. Times Higher Education University Ranking analysis is one of the authenticated rankings of international universities, pointing out that size and internationalization are important determinants of ranking (McAleer et al. 2019), and shows different ranking performance by technical universities. Technical universities outshine in industrial income and lags in research and teaching (Perez-Esparrells and Orduna-Malea 2018).

Logistics performance index

Logistics has a significant role in the economic growth of modern trade and commerce. In a globalized world, the logistic efficiency and performance of the country are to be monitored for the development of industry and infrastructure. The logistic performance index monitors the country's logistic ability (Zekic et al. 2017) and is based on six indicators. Among various factors affecting the logistics performance index, the GDP per capita, the percentage of commercial service imports, and the liner shipping connectivity index are very important and have a negative relation with commercial transport service imports (Alnipak et al. 2021), reliability of supply chains, and the predictability of service delivery for producers and exporters (Kampf et al. 2016).

There are several challenges associated with attaining the targets of SDG 9. Road access for the rural population is still a long away from targets, and heavy investments are required in providing road access in rural areas. The targets of increased passenger and freight volume and share of the small, medium, and hi-tech businesses are severely strangled by the COVID pandemic. Even in these recovery periods from the pandemic, the volumes need to pick up for achieving the SDG 9 targets. Similarly, the achievements related to the reduction of carbon emissions are still far away from sustainability goals. However, positive signs are visibly related to the SDG 9 targets associated with research and development and the penetration of mobile networks and internet access. In mapping, in the literature related to indicators associated with SDG 9 and papers directly related to SDG 9, very few papers have worked on challenges and solutions associated with achieving internet penetration and mobile network access, except a few documents on the need for improving speed and quality of the network. Similarly, very

little literature has directly dealt with connections between rural road access and the attainment of SDG 9 targets. Internationalization, size, generation of industrial income, innovation, research funding, teaching quality, and research orientation are the key points to be focused on for achieving targets related to research and SDG 9. Very few research works are available on the logistic performance index and SDG 9 targets, passenger traffic volume, and SDG 9. These are promising research gaps, and the following section deals with research niches for further research.

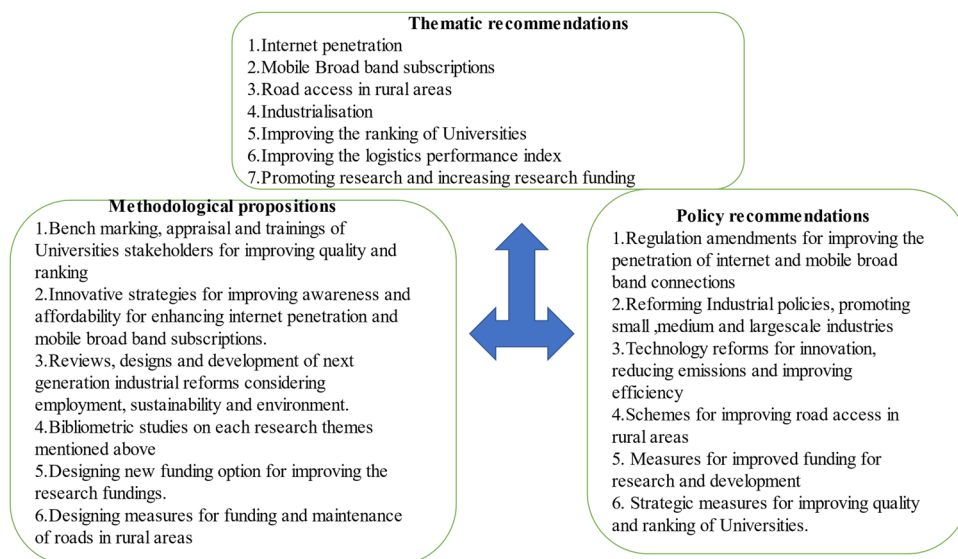## Future research agenda

Thematic recommendations

The major themes for future research related to SDG 9 can be on the various dimensions and impacts of internet penetration and mobile broadband subscriptions. The industrialization of various levels, impacts on employment and income, and the issues of technology integration and innovations are also promising themes for further research. The sustainability initiatives based on improving road access, measures for improving the rankings of universities, and strategies for improving the research and research fundings can also research themes for future research. The logistic performance index and related measures are also promising areas for future research (Fig. 10).

Methodological propositions

The literature review on SDG 9 has identified the conclusions that internet penetration cannot result in positive impacts in income, per capita income, inclusive financial development, and environmental actions. Empirical research can be conducted for further exploration of the relations and confirming the existing findings. If the negative impact is confirmed, the reasons and determinants for the negative impacts of internet penetration should be researched scientifically. Similarly, comparative studies based on multiple countries and demographies should also be tested to get a comprehensive picture of the socio-economic impacts of internet penetration. The digital divide is another area, that is, to be explored are solutions for the digital divide, and research can also be for ensuring digital justice and measures for improving digital literacy and digital access for all. Research can also be for documenting these issues in the countries with high internet penetration and the strategies for coping with these challenges. Such studies should explore the policy changes and reforms essential for improving internet penetration and removing the challenges. Initiatives can be taken up by the researchers for designing measures for innovative funding sources for the construction and maintenance of roads which can be a boost for connectivity and logistics. The appraisal of universities with global benchmarks and spotting out the quality issues and constraints can be a big step towards improving the quality of universities and helpful for improving university ranking at the global level. Research can also be for improving incomes and funding for universities. Awareness programs and training for removing the digital divide and improving the internet penetration and mobile broadband subscriptions are another area that can be taken up for further research. Reviews can be conducted on the constraints on various dimensions of industrial policies, which can spot out challenges and can be helpful for policy reforms. Bibliometric analysis can be considered on each research theme identified in "Thematic recommendations."

Fig. 10 Future research agenda

Thematic recommendations
1. Internet penetration
2. Mobile Broad band subscriptions
3. Road access in rural areas
4. Industrialisation
5. Improving the ranking of Universities
6. Improving the logistics performance index
7. Promoting research and increasing research funding

Methodological propositions
1. Bench marking, appraisal and trainings of Universities stakeholders for improving quality and ranking
2. Innovative strategies for improving awareness and affordability for enhancing internet penetration and mobile broad band subscriptions.
3. Reviews, designs and development of next generation industrial reforms considering employment, sustainability and environment.
4. Bibliometric studies on each research themes mentioned above
5. Designing new funding option for improving the research fundings.
6. Designing measures for funding and maintenance of roads in rural areas

Policy recommendations
1. Regulation amendments for improving the penetration of internet and mobile broad band connections
2. Reforming Industrial policies, promoting small, medium and largescale industries
3. Technology reforms for innovation, reducing emissions and improving efficiency
4. Schemes for improving road access in rural areas
5. Measures for improved funding for research and development
6. Strategic measures for improving quality and ranking of Universities.

Policy recommendations

Several positive impacts of the internet penetrations discussed in the literature have only regional confirmation, and further research on the global level can be more meaningful and provides more insights for policy and implementation levels. Better schemes at government and semi-government levels can be made for better connectivity to rural areas by all-weather roads and maintenance on an urgent basis. Fundings and multiple-level sanctioning should not be a constraint for such measures of infrastructural developments. Regulatory modifications can be planned for improving internet penetration and mobile broadband access, and measures can be taken to improve digital awareness, access, and affordability. Industry policy reforms with a focus on the environment, economy, and sustainability are inevitable. Reforms should be made without job losses, and for a smooth transition to more energy and climate, efficient technologies should be prioritized. More government funding and international funding including options of climate finance can be considered while developing policies and strategies for sustainable industrial reforms. This paper also recommends reforming the research and development sector, by providing automation and self-sufficiency for universities, quality improvement measures, better funding opportunities, and other measures for quality enhancement, research output, and ranking of the universities. Policy measures can also be initiated for improving the logistic performance index at country levels.

Conclusions

The targets of SDG 9 focus on enhanced road connectivity in rural areas, industrial reforms, improved logistic infrastructure, higher level of internet penetration and subscription of mobile broadband connections, increased spending for research and development, and improving the quality and ranking of universities. This review looks into addressing the achievements, determinants, and challenges associated with these targets and indicators of SDG 9. Many of the targets and indicators associated with SDG 9 are under-researched and offer promising themes for academicians, researchers, and scholars for further research. The issues discussed in this review are important for policymakers and administrators for developing and reforming policies to better address challenges associated with the attainment of SDG 9 targets.

Internet penetration in society is influenced by income, education, demographics, telephone and broadband subscriptions, computer and mobile phone ownership, networks, political environment, media, forex regulations, tariffs, and competition policy. Internet penetration has several proven advantages including its positive role in economic growth,

regional financial development, stock market efficiency, and international tourism. The major concerns of internet penetration include its role in income and environmental actions, inclusive financial development, and the digital divide. Eighty-seven countries of the world are with internet penetration below 50%, where fourteen of them are from Asia, and forty-three are from Africa. These are the regions that need urgent action for digital awareness, training, and education. Huge investments are required for building digital infrastructure and connectivity. Policymakers and administrators should also focus on the next thirty-six countries with internet access in the range of 50–75%. The majority of the countries in this bracket are from Africa, Asia, and South America.

Along with internet penetration, the mobile broadband subscription trend is another leading target and indicator of SDG 9. Higher rates of mobile broad brand subscriptions have positive impacts on energy efficiency, environmental sustainability, and international tourism and have a big role in reducing carbon emissions. Fresh policy initiatives and reforms for enhancing mobile broadband subscriptions in under-penetrated areas need urgent priority. Funding and technology challenges need to be addressed to tackle this issue, and the below 50% subscription of mobile broadbands is concentrated on twelve Asian, nine Oceanic, two European, thirty-six African, and two South American countries.

Performance in the logistic performance index is crucial for the attainment of targets of SDG 9. The Asian and African regions need fresh projects, funds, and technology for improving their logistic infrastructure. Researchers should also focus on the development of industry and infrastructure, the GDP per capita level, the percentage of commercial service imports, the liner shipping connectivity index, the commercial transport service imports, and the reliability and predictability of logistic stakeholders for improving logistic performance. Fresh research is essential for removing various constraints in these regions for addressing funding challenges, repayment issues, etc.

The fourth pillar for better achievement of SDG 9 is related to spending on research and development and ranking of universities. Very few non-European countries spend more than 1% of their GDP on research and development. This paper recommends increased funding for research and development, promotion of collaborated research, and academic tie-ups in this regard. Educational reforms are the key to the rapid attainment of such goals. Equally important is the quality improvement of higher education institutions. The Times Higher Education Universities Ranking is the popular indicator in this regard, and size, internationalization, funding, income generation, and quality are the major factors affecting the university's ranking and performance. This paper recommends developing diversified income streams for universities, along with strong policy measures

for ranking improvement, quality education, and research outputs.

This paper recommends research themes for further research. These themes can encourage fresh research and also helps in obtaining sponsorship for better achievement of targets related to SDG 9. The promising themes can be the negative impacts of internet penetration and mobile broadband subscription, challenges and solutions, and policies, technology, and funding solutions for a higher level of internet penetration and mobile broadband subscription. The impact of internet penetration and mobile broadband subscription in education, the economy, society, and the environment can also bring positive outcomes for achieving the targets related to SDG 9. Future researchers can also focus on the digital divide, digital access, and affordability of digital technologies as also the security challenges and misuses. This paper strongly recommends digital justice and equality including gender equality and fairness in digital space. Improved connectivity and logistical infrastructure are other propositions for further research. The topics for improving educational ranking and quality improvement include research automation, income, funding of universities, benchmarking, accreditations, research, publications, affiliations, collaborations, industrial tie-ups, and scientific appraisal systems. This paper also recommends reviews on the constraints of various dimensions of industrial policies, for identifying challenges and policy reforms. The researchers can focus on two indicators untouched in the existing literature including rural road access, spending on research and development from GDP, and measures for increased research outputs.

This paper is subjected to limitations with very little extensive research in the literature related to individual indicators and due to limitation in literature and data availability, all indicators of SDG 9 is not analyzed, and the research is limited to the four important indicators. The constraints of secondary data are another limitation. Research funding is another challenge in this topic. Among the literature on this topic, only 56% of the publications are funded. Future researchers can focus on the leading sponsors for funding their projects. "National Council for Scientific and Technological Development" of Brazil and "Coordenação de Aperfeiçoamento de Pessoal de Nível Superior" or "CAPES Foundation" of Brazil are the leading sponsors in the research related to SDG 9, with three funded projects each. The sponsored research by the National Council for Scientific and Technological Development and CAPES Foundation has got forty-one citations, and the topics were related to business models towards SDGs and barriers and combined usage of circular economy and industry 4.0 for achieving SDGs including SDG 9. National Council for Scientific and Technological Development also funded the research on Logistics 4.0 in Brazil and the achievement of SDG 9 targets. CAPES Foundation has been funded individually for the research on smart practices in the Higher Education Institutions at Brazilian Universities. The other leading fund sponsors of SDG 9 are the Chinese Academy of Sciences, the European Commission, and the National Natural Science Foundation of China.

Declarations

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