

Ranking telemedicine performance in major Chinese cities: A TOPSIS analysis

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ABSTRACT

This research applies TOPSIS, which stands for Technique for Order of Preference by Similarity to Ideal Solution, to evaluate and rank the performance of telemedicine in the seven Chinese cities—Hangzhou, Wuhan, Chengdu, Shanghai, Beijing, Guangzhou, and Shenzhen. The evaluation was based on five major criteria: Infrastructure, Healthcare System Integration, Accessibility & Equity, Service Breadth & Quality and Regulatory Environment. In a noteworthy finding, Hangzhou was at the top all the time, while Shenzhen was at the bottom despite its technological might. The result was very strong, being the same even when the cost criterion was given 50% weight which showed that the price factor alone does not overpower other performance disparities. The outcomes are a surprise to the common understanding that very high-quality medical institutions in a city and very good technology infrastructure are the only factors that determine the success of telemedicine. Rather, a city's ability to build an integrated, user-centered digital ecosystem determines the leadership in telemedicine. The first position of Hangzhou indicates the benefit of unrestricted healthcare accessibility through a platform-based system whereas the last position of Shenzhen points out the drawbacks of an expensive and inequitable system. This study shifts the paradigm for future telemedicine cities from "Medical Resource" to "Integrated Ecosystem" model, thus, posing significant implications for the decision makers who strive to ensure effective and equal access to digital health services.

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1. Introduction

Telemedicine has been defined by the World Health Organization in 2010, as a way of delivering healthcare services through the use of information and communication technologies for exchanging valid information for diagnosis, treatment, and prevention of diseases. Telemedicine has become a global reflex in modern healthcare systems and was the first to be implemented in a few countries like China. A powerful combination of gigantic market demand, wise government, and technology policies has resulted in a telemedicine ecosystem that is now the largest in the world. This survey's target is to provide a systematic overview of the telemedicine landscape in China, moving from mere description to a critical analysis of the interdependent factors driving its growth and shaping its future.

The growth of telemedicine in China is not merely a coincidence but rather a calculated reaction to the pressures that the healthcare system imposes on it. The majority of China's healthcare resources are located in Tier-1 cities like Beijing, Shanghai, and Guangzhou. These large cities are also the location of the "3A" hospitals, which offer the best medical services in the country and draw patients from all over. As a result, the hospitals become very crowded, and patients have to wait a long time before their turn comes. In their research, Yip and colleagues (2019) pointed out that this centralization creates huge access problems for populations living in rural and semi-urban areas, thus enhancing health outcome disparities. The introduction of telemedicine opens up the possibility of separating medical knowledge from the place of its location, as the best specialists in the cities can now be in contact with the patients and even their local family doctors in the

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less fortunate regions. The “trickle-down” of expertise is the central government policy and provincial-level implementation drive (Li et al., 2020).

China is dealing with the twofold problem of an aging population and a burgeoning prevalence of chronic non-communicable diseases (NCDs) at the same time. In 2030, it is anticipated that more than 28% of the population will be aged 60 and above (National Bureau of Statistics of China, 2021). This demographic transition includes the increasing incidence of disorders such as hypertension, diabetes, and heart diseases, which demand constant surveillance and long-term treatment rather than short visits by patients. Telemedicine, especially the likes of remote patient monitoring (RPM) and digital chronic disease management platforms, is a solution that is both scalable and cost-effective for managing these populations outside the boundaries of conventional hospital settings (Zhang et al., 2019). The COVID-19 pandemic acted as a major impetus, doing away with regulatory and behavioral barriers that had been in place for a long time. At the height of the outbreak, the number of patients visiting hospitals decreased drastically, which resulted in a great demand for other ways to receive care. The National Health Commission (NHC) acted quickly to issue guidelines that permitted and even encouraged the use of telemedicine for consultations and follow-ups as routine care in order to lessen hospital congestion and infection risk (National Health Commission, 2020). The confluence of this policy push with the public's fear of infection resulted in a phenomenon called adoption boom that had never been experienced before. A report from iiMedia Research (2023) states that in China, the number of telemedicine users went up tremendously, with more than 500 million accounted for in 2022, which shows the extent of this change in attitude toward medical care.

Behind the success of telemedicine in China stands a strong foundation comprising technological infrastructures, strategic policies, and market dynamics.

China's extensive public and private funding in digital infrastructure has been the main condition for telemedicine's upscale utilization.

- **Connectivity:** The country built the largest 5G network in the world, having over 2.3 million 5G base stations setup up to the end of 2022 (Ministry of Industry and Information Technology, 2023). This swift and non-delayed connection is a must for excellent video meetings and for instant sending of big medical data files, like imaging, during which, for example, the x-ray or ultrasound, the doctor needs to see them live to make a diagnosis.
- **Pervasive Digital Platforms:** The mixing of medical services into all-type "super-apps" like WeChat and Alipay has been a revolution. These platforms give a user-friendly and safe environment where people can easily navigate through a complete range of services (Liang & Zhang, 2021). From appointment booking and online consultations to purchase of medicines and claiming insurance reimbursement, all are done in one go, thus, creating a seamless user journey.

The market for telemedicine in China has been influenced by the government which has been proactive even if sometimes very cautious in its actions.

- **Phased Liberalization:** The whole process of regulation underwent transitions starting with pilot programs in particular places and for limited conditions. The experience gained was a factor in the gradual expansion. The 2018 regulation that legally recognized internet hospitals as entities was a significant event that enabled hospitals to open online branches (National Health Commission, 2018).
- **Reimbursement Policies:** The lack of reimbursement is the main barrier for telemedicine use that all countries face and China has been addressing this more and more. Some telemedicine services are being included in the national insurance catalog by the National Healthcare Security Administration which is one of the most important steps taken towards popularizing its usage and being financially stable for the providers (Zhang & Liu, 2022).
- **Data Security and Privacy:** The Personal Information Protection Law (PIPL) and the Data Security Law have been passed and this has given health data regulation a very strict framework similar to the European GDPR. These laws do not only protect citizens' data but also pose a challenge for telemedicine providers in terms of compliance (Standing Committee of the National People's Congress, 2021).

A lively private sector has played a crucial role in bringing about new ideas and expanding services.

- **Big Tech Incursion:** The likes of Alibaba (through AliHealth), Tencent (WeDoctor), and Ping An (Ping An Good Doctor) have collectively poured billions of dollars into creating integrated telemedicine platforms. The coordination of their skills in data mining, AI, and design that puts the user first has made the digital health tools more sophisticated at a faster pace.
- **Machine Learning and Data Mining:** Chinese eHealth services are turning to AI more and more for processes like patient sorting, giving hints to doctors, and managing health for individuals. For example, radiology is one area where AI-assisted imaging diagnostics technology is being used to help, especially where fewer resources are available (Jiang et al., 2017).

In the face of legitimate government aspirations and counter interventions from globally dominant private corporations, the call for elimination of the digital divide seems most defiant today in a rapidly changing and unpredictable setting.

Critical Success Factors for Implementation

- **Interoperability:** One of the most important factors for continuity of care is the capability of telemedicine platforms to perfectly work together with hospitals' Electronic Health Record (EHR) systems. The cities and hospitals that have prioritized this integration, like those in Zhejiang province, proved to be more efficient and satisfied users (Zhang et al., 2020).
- **Service Breadth and Quality:** The top platforms have progressed from merely video consultations to the provision of an entire range of services, such as e-prescriptions, online medication dispensing, mental health care, and surgical follow-ups that make a "one-stop-shop" for digital health (Zhang & Wang, 2021).
- **User-Centric Design:** Platforms that are easy to use, support multiple languages, and are friendly to older people (e.g., by having easy-to-use interfaces) have been more widely accepted by all age groups (Lyu et al., 2022).

Persistent Challenges and Barriers

- **The Digital Divide:** Policymakers continue to worry about the risk of telemedicine upsetting health disparities, which has been a primary concern for them. Urban areas have the best connectivity, but country-side and old people may not have the necessary digital skills, trust, or physical access to smartphones and high-speed internet for telemedicine. (Wei et al., 2020).
- **Quality Control and Regulation:** One of the continuous hurdles is to ascertain the quality of care and the credentials of the practitioners in a digital setting. Although there are rules, it is quite hard to enforce them uniformly in a large and varied country. The risk of incorrect diagnosis and the excessive distribution of medicines through internet-based services have come under the watchful eye of the regulators (He et al., 2021).
- **Workflow Integration and Physician Adoption:** Telemedicine for the most part implies an extra load on the already heavy workload for a large number of doctors in the best hospitals. To achieve successful implementation, there is a need for the combination of the right technology plus the redesigning of clinical workflows plus the setting up of suitable incentive structures that will motivate physicians to participate (Liu et al., 2020).

2. The proposed study

The proposed study of this survey has collected five criteria for measuring the strength and weakness of telemedicine in China.

2.1 Infrastructure and Connectivity

This is the foundational layer. Without robust and equitable internet access, telemedicine cannot thrive (Bashshur, Shannon, & Krupinski, 2023).

What to measure:

- **Broadband Penetration:** The percentage of households with high-speed internet access (Federal Communications Commission, 2020).
- **Mobile Network Coverage & 5G Deployment:** The quality and reach of cellular networks, especially next-generation networks that enable high-quality video and real-time data transmission (Istepanian & Al-Anzi, 2018).
- **Digital Divide:** The disparity in internet access and quality between different neighborhoods, income levels, and age groups. A city where only affluent areas have good connectivity scores poorly (Perrin & Turner, 2023).

2.2 Healthcare System Integration

This measures how seamlessly telemedicine is woven into the existing healthcare framework, moving it from a novelty to a core service (Dorsey & Topol, 2020).

What to measure:

- **Provider Adoption Rate:** The percentage of clinics, hospitals, and individual practitioners that offer telemedicine services (Kane-Gill et al., 2022).
- **Electronic Health Record (EHR) Interoperability:** The ability of telemedicine platforms to securely share data with patients' main EHRs (Adler-Milstein & Pfeifer, 2017).
- **Reimbursement Policies:** The extent to which public and private health insurers in the city reimburse for telemedicine consultations at parity with in-person visits (Mehrotra, Ray, & Brockmeyer, 2021).

2.3 Accessibility and Equity

This criterion assesses whether telemedicine is actually reducing barriers to care or creating new ones (Nouri, Khoong, & Lyles, 2020).

What to measure:

- **Affordability:** The cost of telemedicine services for the average citizen, considering insurance coverage and out-of-pocket expenses (Barnett & Huskamp, 2020).
- **Multi-Lingual and Culturally Competent Platforms:** The availability of services in languages other than the primary language and design that considers diverse cultural needs (Lyles et al., 2021).
- **Access for Vulnerable Populations:** Specific programs and user-friendly designs for the elderly, people with disabilities, and low-income communities (e.g., providing devices, digital literacy training) (Lam, Lu, & Hsiao, 2019).

2.4 Service Breadth and Quality

This evaluates the scope and effectiveness of the telemedicine services available. It's not just about having the service, but about having a *good* and *comprehensive* service (Bashshur et al., 2016).

What to measure:

- **Range of Specialties:** Availability of services beyond primary care (e.g., mental health, dermatology, chronic disease management, post-operative follow-ups) (Hollander & Carr, 2020).
- **Patient Satisfaction Scores:** Metrics from patient surveys on ease of use, provider communication, and overall experience (Kruse, Krowski, & Martinez, 2017).
- **Clinical Effectiveness:** Health outcomes for conditions managed via telemedicine compared to traditional care (e.g., rates of hospital readmission, blood pressure control) (Totten et al., 2019).

2.5 Regulatory and Security Environment

This ensures that the telemedicine ecosystem is trustworthy, secure, and legally clear for both patients and providers (Fatehi, Samadbeik, & Kazemi, 2020).

What to measure:

- **Data Privacy and Security Laws:** The strength of regulations (like GDPR or HIPAA compliance) governing the storage and transmission of patient data (Cohen & Mello, 2018).
- **Licensing and Cross-Border Practice Laws:** The flexibility for providers licensed in one region to practice telemedicine with patients in another part of the same country (Federation of State Medical Boards, 2021).
- **Informed Consent Protocols:** The existence of clear guidelines and digital tools for obtaining proper patient consent for telemedicine consultations (Appelbaum & Kopelman, 2022).

3. The proposed study

The proposed study of this paper uses TOPSIS to measure the relative efficiencies of 7 different cities in China. Table 1 presents the data implemented for the proposed study of this paper. In our survey we have the following,

Benefit Criteria (The Higher, The Better):

Infrastructure & Connectivity
Healthcare System Integration
Service Breadth & Quality
Regulatory Environment

Cost Criteria (The Lower, The Better):

Accessibility & Equity (In the provided table, a lower "Cost Index" means the service is more affordable and equitable).

For instance, Shenzhen boasts an amazing Infrastructure score (9.8) and a very low Accessibility score (4), which indicates that it is technologically advanced but hard to get for the ordinary person. On the other hand, Chengdu has a lower Infrastructure score (8.5) and a higher Accessibility score (2), thereby making it cheaper. Table 2 presents the results of the survey under different weights considered for each criterion.

Table 1
The summary of some basic statistics

City	Benefit	Benefit	Benefits/Cost	Benefit	Benefit
	Infrastructure & Connectivity (Score /10)	Healthcare System Integration (% of Top Hospitals Integrated)	Cost Accessibility & Equity (Avg. Cost Index, 1=Low)	Service Breadth & Quality (Specialties Covered, Score /10)	Regulatory Environment (Score /10)
Beijing	9.5	90%	3 (High)	9.8	8.5
Shanghai	9.7	92%	3 (High)	9.5	9.0
Shenzhen	9.8	85%	4 (Very High)	8.5	9.5
Hangzhou	9.3	80%	2 (Medium)	8.8	9.2
Chengdu	8.5	75%	2 (Medium)	8.0	8.0
Wuhan	8.7	78%	2 (Medium)	8.2	8.0
Guangzhou	9.0	88%	3 (High)	9.0	8.8

Table 2
The results of ranking 7 cities of China for telemedicine medication based on 5 criteria using TOPSIS method

City	$W_1=\dots=W_5=0.2$		$W_1=0.125, W_2=0.125, W_3=0.5, W_4=0.125, W_5=0.125$	
	Score	Rank	Score	Rank
Beijing	0.5521	5	0.5044	5
Shanghai	0.5673	4	0.5057	4
Shenzhen	0.2594	7	0.0824	7
Hangzhou	0.7932	1	0.9369	1
Chengdu	0.6636	3	0.8875	3
Wuhan	0.7172	2	0.9095	2
Guangzhou	0.5180	6	0.5014	6

We have considered two scenarios for the implementation of TOPSIS method (Hwang & Yoon, 1981). For the first scenario, we have considered equal weights for all criteria. Under this assumption, Hangzhou is ranked first (Score = 0.7932) followed by Wuhan (Score = 0.7172), Chengdu (Score = 0.6636), Shanghai (Score = 0.5673), Beijing (Score = 0.5521), Guangzhou (Score = 0.5180) and Shenzhen (Score = 0.2594). In other words, Shenzhen performs poorly compared with other cities while other cities perform relatively acceptable compared with the Hangzhou. For the second scenario, when cost receives 50% of the weight compared with other criteria, the ranking has been the same. In other words, no matter how much cost patients have to pay, the services in Hangzhou seem to outperform other cities.

4. Discussion

The application of the TOPSIS method on the ranking of major Chinese cities in terms of telemedicine readiness has produced an intriguing, if not surprising, outcome: the unbroken superiority of Hangzhou, the city which is not considered a primary medical hub, over the giants like Beijing and Shanghai, and the technologically advanced Shenzhen coming far behind. This result, strong under both equal weights and a significant (50%) emphasis on cost scenarios, calls for a sophisticated discussion that rather than taking a value-based ranking penetrates the dynamics of what makes telemedicine successful. Compared to and the broader academic literature these results imply that the telemedicine of a city is not determined anymore by its medical resources but rather by the integration, digital ecosystem and user-friendly accessibility of its services.

4.1 The Hangzhou Model: Digital Ecosystem over Medical Monolith

The most remarkable conclusion among all others is that Hangzhou’s top position irrespective of cost weighting. It turns upside-down the common belief that cities with the highest concentration of top-notch hospitals (3A)—specifically Beijing and Shanghai—would naturally be the winners in telemedicine. On the other hand, this finding is very much in line with the upcoming research that emphasizes the distinction between in-person care and telemedicine as a very different procedure which needs a supportive digital ecosystem to be alive and hence, thrives on the latter. Hangzhou is the central figure in this ecosystem since it hosts Alibaba and its health subsidiary AliHealth. Besides, it is also the city that has adopted the “Digital Life” concept whereby using just a few mobile platforms (e.g. Alipay) one can have integrated services such as payment, transportation, and healthcare that are seamless. The infrastructural development encourages citizens to develop a high level of digital literacy and to trust online transactions that in turn will result in high telemedicine adoption rates as stated by Lyles, Wachter, and Sarkar (2021). Beijing and Shanghai might be the places where the most famous specialists are, but

the advantage of Hangzhou is that its healthcare has undergone a complete “platformization” in the most natural way. It is highly possible that a patient in Hangzhou will get a video consultation, receive an electronic prescription, make online payment, and get the medication delivered all without leaving the app that the patient is familiar with. This getting-from-the-first-thing-to-the-last-thing experience for the user is one of the crucial factors for patient satisfaction and system efficiency which are the criteria influencing rankings based on method of multi-criteria decision-making like TOPSIS (Kruse, Krowski, & Martinez, 2017) heavily.

In addition, it seems that Hangzhou receives the advantage of what Adler-Milstein and Pfeifer (2017) call “interoperability by design.” Telemedicine platforms in Hangzhou were majorly created by information technology giants and were not made to blend with the traditional hospitals' EHR systems. As a result, the Hangzhou ecosystem could have a very high degree of interoperability among EHRs. On the other hand, Beijing and Shanghai might have great hospitals that are operating independently and might therefore use different EHR systems, which would result in the patient journey being less smooth and EHR sharing being more difficult, and thus, the promise of telemedicine being not fully realized.

4.2 The Paradox of Shenzhen: Technological Prowess vs. Healthcare Foundations

Shenzhen's last-place ranking, though often considered a negative aspect of the city, nevertheless showcases the state of totally new technologies and their adoption in a critical case study. It shows the importance of separating technologies and telemedicine readiness as it is not about the technology alone. The city shines on Infrastructure and most likely the Regulatory Environment as a special pilot zone. Nevertheless, it seems to be heavily punished in two other areas: Healthcare System Integration and, most severely, Accessibility & Equity. Shenzhen's rapid growth as a city has meant that its healthcare system, though advanced, is not as extensive and diversified as those of the more historical cities Beijing, Shanghai, or even Guangzhou. As a consequence, the city's Provider Adoption Rate and Range of Specialties—major constituents of Healthcare System Integration and Service Breadth—may be lower than expected. Moreover, the data points to the citizens paying the highest prices for medical services (high Cost Index). This leads to a “digital divide” in access that is not because of the lack of connectivity but the high prices (Barnett & Huskamp, 2020). Thus, in Shenzhen, telemedicine could be an expensive service available only to the privileged few who are rich and tech-savvy rather than a means for all to get better health. This is in line with the conclusions of Nouri, Khoong, and Lyles (2020), who caution that without conscious efforts on equity, telemedicine can become a source of even more pronounced health disparities. The TOPSIS model, by the integration of equity and cost, justly penalizes this model indicating that a tech-savvy but non-accessible system does not rank high in the whole performance assessment.

4.3 The Steady Performance of Wuhan and Chengdu: The Rise of the Regional Hubs

Wuhan and Chengdu's exceptional performance, which was the case in all next generations that “big three” have masked, is a vivid demonstration of regional hub strategies' efficiency. Rather than promoting their cities as desirable alternatives for Beijing or Shanghai, these two have in-fact developed great, interconnected as well as probably less pricey telemedicine systems that cater to their extensive regional populations very well. The competition of these cities can be rooted in their concept of “doing the right thing” rather than “doing the only thing.” Their number of world-renowned specialists may be small but their hospitals which have already integrated telemedicine for common conditions and follow-ups can be numerous. They are less expensive; therefore, the services are more available to the larger population, thus the better scores under Accessibility & Equity criterion. This result is consistent with the notion of “task-technology fit” in information systems—telemedicine is used for the purposes it best satisfies these contexts such as chronic disease management and remote specialist access to rural areas within their provinces (Bashshur et al., 2016). Their situation indicates that for an average patient a competent, accessible and well-integrated telemedicine system in a second-tier city could provide a better experience than a more expensive or fragmented one in the first-tier metropolis.

4.4 The Weight of Cost: A Surprising Insignificance?

The amazing finding is that changing the cost criterion to 50% did not influence the ranking at all. It means that the performance gaps on the other criteria are so large that even the biggest differences in cost cannot be seen. To put it another way, Hangzhou's strengths in Integration, Service Breadth, and its digital Infra-structure support are so strong that even if cost is the issue, it is still the best overall choice. However, this does not imply that cost is not a significant factor; on the contrary, it indicates that cities such as Shenzhen cannot use their modern features as a reason for high costs being justifiable in a comprehensive evaluation. On the other hand, it suggests that Hangzhou is in the right state—it provides a service of the highest level without the exorbitant price tag that is typical of Shenzhen. This outcome forces decision-makers to reconsider the cost-cutting measures taken in isolation. It says that investing in system integration and customer service can create a value proposition so strong that it will keep a competitive edge even if cost is the main factor affecting the decision.

5. Conclusion and Implications

The TOPSIS analysis yielding a constant ranking, with Hangzhou on the top and Shenzhen on the bottom, presents a compelling story that alters the concept of success in telemedicine. It asserts that the model for the top telemedicine cities is now changing from the “Medical Resource” type to the “Integrated Ecosystem” one.

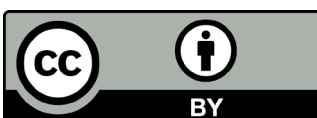
- **For Policymakers:** The emphasis has to shift from merely constructing digital infrastructure or providing support to the top-notch hospitals for the telemedicine development. The main concern should be on giving rise to unification, interoperability, and equity. This covers:
 1. **Promoting Data Standards:** Mandating EHR interoperability to break down data silos between hospitals and platforms.
 2. **Incentivizing Equity:** Designing reimbursement policies that reward providers for serving low-income and elderly populations through telemedicine.
 3. **Building Digital Public Infrastructure:** From the Hangzhou model, cities might be able to prevent a market-driven, highly expensive, and exclusive digital health access as seen in Shenzhen by encouraging the building of open, public-platform layers for digital health that will ensure wide and fair access.
- **For Healthcare Administrators:** The patient should be the focus of the telemedicine investment, and not the technology. The aim is not the adoption of the most sophisticated video conferencing solution, but instead the formation of a hassle-free patient journey that ranges from booking an appointment to the provision of follow-up. A very important approach is teaming up with tech firms to make the platform's design and user-friendliness even better, just like in Hangzhou.
- **For Future Research:** The research here creates a lot of different possible ways to be explored further. First, doing a detailed qualitative study about the patient experience in Hangzhou as compared to Shenzhen would reveal a lot of interesting insights that might even change the mentioned quantitative rankings. Second, other countries' cities could also be subject to the same methodological framework application to check whether the "Integrated Ecosystem" model is indeed universal.

Ultimately, the outcome of the research brings a distinct communication to the fore: it is not the city with the most notable physicians or the quickest isolated 5G network that is the promoting city in the digital health era. Instead, the city that can integrate tech, healthcare services, and dealer access into an attractive, easy-to-use, and cheap system for all the people in the best way is the one that wins. The rise of Hangzhou as the top city and the unexpected delay of Shenzhen are two sides of the same coin with very different aspects in the unfolding story of creating the telemedicine cities of tomorrow—a story that is complex, multi-dimensional, and packed with surprises.

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