Here’s what you get for the price of admission

1. Global Pricing Trends in a New Era
   • Brianna Boudreau

2. Towards an Interconnection Index: Ranking the World’s Greatest Hubs
   • Tim Stronge

3. The Data Center Market Blazes a New Trail
   • Jon Hjembo

https://www2.telegeography.com/ptc-2024
Global Pricing Trends in a New Era

Brianna Boudreau

PTC
January 21, 2024
The Set List

• Transport Pricing
  • Are we out of the woods yet? Has price erosion returned to “normal?”
  • How do trends compare across regions?

• 400 Gbps
  • How have 400 Gbps pricing models rolled out?
  • Lessons learned from 100 Gbps

• IP Transit Pricing
  • Impact of transport on transit pricing
  • Impact of network investments on existing hubs & secondary markets

• Our Next Era
  • Where are we headed in 2024?
  • Potential changes in customer purchasing patterns
Transport Pricing

Are we *out of the woods* yet?
Wavelength prices declining is *Nothing New*

Weighted Median 100 Gbps Wavelength Prices, 2020-2023

-13% Average CAGR price decline globally since 2020
Long Story Short, declines slower than earlier eras

Weighted Median 100 Gbps Wavelength CAGR Price Decline, 2017-2020 vs. 2020-2023

- Marseille-Singapore: 2020-2023 CAGR: 30%, 2017-2020 CAGR: 30%
- Hong Kong-Singapore: 2020-2023 CAGR: 13%, 2017-2020 CAGR: 30%
- Los Angeles-Sydney: 2020-2023 CAGR: 13%, 2017-2020 CAGR: 30%
On routes to Asia, erosion has yet to **Begin Again**

**Weighted Median 100 Gbps Wavelength Prices & CAGR Price Decline**

- **100 Gbps MRC**
- **2020-2023 CAGR**

<table>
<thead>
<tr>
<th>Route</th>
<th>Weighted Median Monthly Lease Price (USD)</th>
<th>2020-2023 CAGR Price Decline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong-Singapore</td>
<td>$12,500</td>
<td>0%</td>
</tr>
<tr>
<td>Singapore-Tokyo</td>
<td>$17,500</td>
<td>5%</td>
</tr>
<tr>
<td>Los Angeles-Singapore</td>
<td>$22,500</td>
<td>10%</td>
</tr>
<tr>
<td>Marseille-Singapore</td>
<td>$27,500</td>
<td>15%</td>
</tr>
<tr>
<td>Hong Kong-Los Angeles</td>
<td>$32,500</td>
<td>20%</td>
</tr>
<tr>
<td>Los Angeles-Singapore</td>
<td>$37,500</td>
<td>25%</td>
</tr>
</tbody>
</table>
That’s When modest price erosion maintains global price differences

Weighted Median 100 Gbps Monthly Lease Prices Relative to London-New York

- Marseille-Singapore: 4.3x price of Lon-NY
- LA-Tokyo: 2.7x price of Lon-NY
- Miami-São Paulo: 2.8x price of Lon-NY
But it’s been a *Cruel Summer* on other routes

**Weighted Median 100 Gbps Wavelength Prices, 2020-2023**

- **Marseille-Mombasa**
- **Johannesburg-London**

- **RFS of PEACE**
- **RFS of Equiano**

-26% Average CAGR price decline since 2020
But it’s been a *Cruel Summer* on other routes

**Weighted Median 100 Gbps Wavelength Prices, 2020-2023**

- Buenos Aires-Miami
- Miami-São Paulo
- Fortaleza-Miami

-34% Average CAGR price decline since 2020
New cable construction isn’t going out of Style

Total Cable Construction Costs by Region

- Asia
- Europe-Asia
- Latin America
- Oceania
- Other
- Trans-Atlantic
- Trans-Pacific

Contruction Cost (USD billions):

$0.0  $0.5  $1.0  $1.5  $2.0  $2.5

2020-2022  2023-2025
New cable construction isn’t going out of Style

https://www.submarinecablemap.com/status/planned
So, are we *Out of the Woods* yet?

- Delays in capacity upgrades and new cable activation
  - Global supply chain disruptions and card shortages have largely resolved themselves, but geopolitical issues (such as those in the South China Sea & the Red Sea) continue to delay new network projects.
  - Fewer cables with inventory at one time = less competitive price pressure.
  - On routes with recent upgrades, new supply, and pre-sales on new systems, price erosion returning to higher levels.

- *Look what you made me do*
  - Uncertainty on the timeline of future supply on some routes has changed customer purchasing patterns.
  - Supply is snatched up before it becomes available or bought in bulk. Customers taking capacity at the price that is offered helps maintain price points.
400 Gbps Pricing

...Ready for it?
I Can See You: 400 Gbps pricing models taking shape

Global 400 Gbps Prices & Price Multiples

- 400 Gbps MRC
- Price Multiple

100:400 GBPS AVERAGE GLOBAL PRICE MULTIPLE

| Terrestrial | 3.5x |
| Subsea      | 3.9x |

- Terrestrial
- Subsea

www.telegeography.com
The Last Time: Evolution of 10:100 Gbps price multiples

Global 10:100 Gbps Price Multiples

<table>
<thead>
<tr>
<th>City</th>
<th>2016 Multiple</th>
<th>2023 Multiple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miami-São Paulo</td>
<td>6.5x</td>
<td>4.0x</td>
</tr>
<tr>
<td>Hong Kong-Singapore</td>
<td>6.5x</td>
<td>4.0x</td>
</tr>
<tr>
<td>Los Angeles-Tokyo</td>
<td>6.5x</td>
<td>4.0x</td>
</tr>
<tr>
<td>London-New York</td>
<td>6.5x</td>
<td>4.0x</td>
</tr>
<tr>
<td>Frankfurt-London</td>
<td>6.5x</td>
<td>4.0x</td>
</tr>
</tbody>
</table>
400 Gbps Pricing ...Ready for it?

• 400 Gbps uptake reportedly slower than initially anticipated.
  • Sales limited to shorter terrestrial routes within Europe and the U.S, & trans-Atlantic.
  • Asia and Oceania reporting limited demand so far.

• As a result, only a slight discount between 100 & 400 Gbps.
  • Low multiples of 2.5-3x on terrestrial routes have been reported.
  • As demand picks up, multiples will erode.

• Additional savings on install, cross-connect charges, and power consumption compelling for higher capacity buyers.
IP Transit Pricing
A trend we know *all too well*
Transit prices starting to *Shake It Off*

Weighted Median 10 GigE IP Transit Prices in Major Global Cities

- Sydney
- Johannesburg
- Tokyo
- Hong Kong
- Singapore
- São Paulo
- Los Angeles

-17% Average CAGR price decline globally since 2020
Returning to that trend we know *All Too Well*

Weighted Median 10 GigE CAGR Price Decline, 2017-2020 vs. 2020-2023

- **2017-2020 CAGR**
  - Singapore: 10%
  - Mumbai: 8%
  - Hong Kong: 14%
  - Los Angeles: 11%
  - London: 12%
  - Sydney: 13%
  - Tokyo: 15%
  - Johannesburg: 25%
  - São Paulo: 25%

- **2020-2023 CAGR**
  - 10 GigE AVERAGE CAGR PRICE DECLINE MAJOR ROUTES
    - 2017-2020: -22%
    - 2020-2023: -17%
Timeless: Prices falling in APAC

Weighted Median 10 GigE IP Transit Prices & CAGR Price Decline

-20%
Average CAGR price decline since 2020
So It Goes: Reducing premium in secondary markets

Weighted Median 10 GigE IP transit prices relative to Singapore

- **Bangkok**: 4.4x price of Singapore
- **Manila**: 4.7x price of Singapore
- **Taipei**: 1.5x price of Singapore
Change to 100 GigE in global hubs

Weighted Median 100 GigE IP Transit Port Prices

Global by carrier average 10:100 GigE port multiple
It’s Time to Go: Assessing the case for 100 GigE

Nx10 GigE & 100 GigE with Cross Connect Prices in New York

Cheaper to purchase 100 GigE port

Cheaper to purchase 10 GigE port
IP Transit Prices

• Return to a trend we know *all too well*
  • Global IP transit prices continue to fall at a steady pace.
  • In established hubs declines enabled by escalating volumes & lower unit costs.
  • In secondary markets declines drive by reductions in the underlying cost of transport and increasing local traffic exchange.

• 100 GigE ports now represent majority of sales in key hubs
  • Price multiples remain high, but savings on install, cross connects & ease of management are compelling factors.
Our Next Era

• Will price erosion return to normal? Or is there a “new normal?”
  • While supply chain constraints are largely resolved, geopolitical issues still delaying new submarine cable systems on some routes.

• Change in the competitive landscape
  • Approaching an era of cable retirements, which could change the number of bandwidth suppliers on some routes.

• Change in customer purchasing patterns
  • When does it make sense to purchase a fiber pair/spectrums vs leasing wavelengths?
  • Fiber pair pricing is very cable specific and not subject to the same pricing trends we are used to.

• More local market growth for IP transit
Towards an Interconnection Index: Ranking the World’s Greatest Hubs

Tim Stronge

PTC
January 21, 2024
The interconnection index: what we’re doing

• Questions we’re often asked
  • What is the next emerging hub in region x?
  • How do various hubs compare to each other?
  • Where should I expand in country X besides the largest city?
• We will solve with data and maps
  • 😎
Let’s think about the data sets for each city

• Data Centers
  • Data center infrastructure
  • Internet exchange infrastructure

• Network Connectivity
  • Cloud infrastructure
  • Long-distance internet
  • Long-distance transport
  • Pricing

• Market Potential
  • Geography and demographics
  • Local access
  • Power
  • Regulations and governance
Example city: Osaka

<table>
<thead>
<tr>
<th>Data Group</th>
<th>Category</th>
<th>Value</th>
<th>Normalized Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geography and Demographics</td>
<td>GDP per Capita</td>
<td>$39,734</td>
<td>17.7</td>
</tr>
<tr>
<td>Geography and Demographics</td>
<td>Population</td>
<td>12,815,240</td>
<td>39.8</td>
</tr>
<tr>
<td>Geography and Demographics</td>
<td>Population in Nearby Cities</td>
<td>20,298,215</td>
<td>25.2</td>
</tr>
<tr>
<td>Geography and Demographics</td>
<td>Group Average</td>
<td>27.6</td>
<td></td>
</tr>
</tbody>
</table>

Smallest city = 500 pop.
Largest city = 32,224,328 pop.
Osaka is 39.8% between the MIN and MAX cities
## Example city: Osaka

<table>
<thead>
<tr>
<th>Data Group</th>
<th>Category</th>
<th>Value</th>
<th>Normalized Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geography and Demographics</td>
<td>Group Average</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td>Cloud Infrastructure</td>
<td>Group Average</td>
<td>28.3</td>
<td></td>
</tr>
<tr>
<td>Data Centers</td>
<td>Group Average</td>
<td>31.8</td>
<td></td>
</tr>
<tr>
<td>Internet Exchanges</td>
<td>Group Average</td>
<td>18.0</td>
<td></td>
</tr>
<tr>
<td>Local Access</td>
<td>Group Average</td>
<td>36.3</td>
<td></td>
</tr>
<tr>
<td>Long-Distance Transport</td>
<td>Group Average</td>
<td>13.7</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>Group Average</td>
<td>30.8</td>
<td></td>
</tr>
<tr>
<td>Pricing</td>
<td>Group Average</td>
<td>85.3</td>
<td></td>
</tr>
<tr>
<td>Regulations and Governance</td>
<td>Group Average</td>
<td>84.4</td>
<td></td>
</tr>
<tr>
<td><strong>Overall Score</strong></td>
<td></td>
<td><strong>39.6</strong></td>
<td></td>
</tr>
</tbody>
</table>
Screenshot of full list: 600k data points
What are the highest-scoring hubs?

Top 5 Cities by Overall Score

Overall Scores
Overall quantity isn’t all that matters

The “shape” of a city’s interconnection assets matters too!
Top 3 hubs in each region

Legend

- Data Centers
- Internet Exchanges
- Cloud Infrastructure
- Power
- Long-Distance Transport
- Geography & Demographics
- Regulations & Governance
- Pricing

Johannesburg  Tokyo  London  São Paulo  Dubai  Sydney  Washington

Cape Town  Singapore  Frankfurt  Santiago  Istanbul  Melbourne  New York

Cairo  Seoul  Amsterdam  Bogotá  Tel Aviv  Auckland  San Francisco
Biggest gainers in near term

Top 20 Cities with Fastest Expected Gains in Next Two Years

- Beijing
- Kuala Lumpur
- Madrid
- Riyadh
- Fortaleza
- Santiago
- Beijing
- Kuala Lumpur
- Madrid
- Riyadh
- Fortaleza
- Santiago
**Governance Scores for Selected Asian Hubs**

<table>
<thead>
<tr>
<th>City</th>
<th>Control of Corruption</th>
<th>Government Effectiveness</th>
<th>Regulatory Quality</th>
<th>Rule of Law</th>
<th>Voice and Accountability</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokyo</td>
<td>80</td>
<td>88</td>
<td>83</td>
<td>91</td>
<td>80</td>
<td>84</td>
</tr>
<tr>
<td>Singapore</td>
<td>93</td>
<td>100</td>
<td>100</td>
<td>96</td>
<td>52</td>
<td>88</td>
</tr>
<tr>
<td>Seoul</td>
<td>61</td>
<td>82</td>
<td>77</td>
<td>81</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>Beijing</td>
<td>44</td>
<td>64</td>
<td>43</td>
<td>53</td>
<td>11</td>
<td>43</td>
</tr>
<tr>
<td>Jakarta</td>
<td>33</td>
<td>62</td>
<td>56</td>
<td>49</td>
<td>57</td>
<td>52</td>
</tr>
<tr>
<td>Kuala Lumpur</td>
<td>49</td>
<td>75</td>
<td>66</td>
<td>67</td>
<td>53</td>
<td>62</td>
</tr>
<tr>
<td>Bangkok</td>
<td>33</td>
<td>56</td>
<td>56</td>
<td>55</td>
<td>37</td>
<td>47</td>
</tr>
<tr>
<td>Manila</td>
<td>31</td>
<td>54</td>
<td>53</td>
<td>42</td>
<td>52</td>
<td>46</td>
</tr>
<tr>
<td>Darwin</td>
<td>85</td>
<td>86</td>
<td>93</td>
<td>89</td>
<td>88</td>
<td>88</td>
</tr>
</tbody>
</table>

Underlying data source: Daniel Kaufmann and Aart Kraay (2023). Worldwide Governance Indicators, 2023 Update (www.govindicators.org)
Let’s talk electricity

Planned Electricity Generation Sites – All Sources

Underlying data source: Global Energy Monitor (https://globalenergymonitor.org/)
Can you guess the source of power?

Planned Electricity Generation Sites – Coal

Underlying data source: Global Energy Monitor (https://globalenergymonitor.org/)
Can you guess the source of power?

Planned Electricity Generation Sites – Gas

Underlying data source: Global Energy Monitor (https://globalenergymonitor.org/)
Can you guess the source of power?

Planned Electricity Generation Sites – Wind

Underlying data source: Global Energy Monitor (https://globalenergymonitor.org/)
Can you guess the source of power?

Planned Electricity Generation Sites – Hydro

Underlying data source: Global Energy Monitor (https://globalenergymonitor.org/)
Can you guess the source of power?

Planned Electricity Generation Sites – Solar

Underlying data source: Global Energy Monitor (https://globalenergymonitor.org/)
The importance of weighting

Selected City Scores – Default Weights

- Frankfurt
- Tokyo
- Singapore
- Amsterdam
- Beijing
- Stockholm
- Madrid
- Guangzhou
- Oslo

Overall Scores:

30 35 40 45 50 55 60
The importance of weighting

Selected City Scores – Heavier Weight on Power/Electricity

<table>
<thead>
<tr>
<th>City</th>
<th>Overall Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frankfurt</td>
<td></td>
</tr>
<tr>
<td>Tokyo</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td></td>
</tr>
<tr>
<td>Amsterdam</td>
<td></td>
</tr>
<tr>
<td>Beijing</td>
<td></td>
</tr>
<tr>
<td>Stockholm</td>
<td></td>
</tr>
<tr>
<td>Madrid</td>
<td></td>
</tr>
<tr>
<td>Guangzhou</td>
<td></td>
</tr>
<tr>
<td>Oslo</td>
<td></td>
</tr>
</tbody>
</table>

Overall Scores range from 30 to 60.
Final thoughts

- All the stuff you’ve just seen is subject to change
- We need your help!
  - What data sets are important to you?
  - What weights should we assign?
Sources

- Telecom and demographic:
  - https://www2.telegeography.com/data-center-research-service
  - TeleGeography proprietary datasets

- Power:
  - https://globalenergymonitor.org
  - Global Energy Monitor

- Governance:
  - https://www.govindicators.org
  - Daniel Kaufmann and Aart Kraay (2023). Worldwide Governance Indicators.
The Data Center Market Blazes a New Trail

Jon Hjembo

PTC
21 January 2024
Themes we’ll investigate

Exploring the APAC frontier

Is power the new gold?

Coping with high costs
Exploring the APAC frontier

Source: National Geographic. “Admiral Zheng He, surrounded by the “treasure ships”” by Hong Nian Zhang
The market has already ventured forth

- Singapore: few sites have opened since moratorium began
- Mumbai: among the 20 largest global markets, Mumbai’s growing the fastest
- Kuala Lumpur and Jakarta already experiencing rapid growth that will only gain momentum
And continues to develop new markets

**Singapore**: Pipeline limited to license winners + SingTel

**India**: 3rd only to U.S. and China globally for number of new projects

Chinese and U.S.-based operators converging in **Malaysia**

International providers snapping up land in **Malaysia** and **Indonesia**

Lots of global operators building into **Japan** and **Korea**
Chinese development pushes inland

- Very slow growth for Hong Kong
- Strong growth in Yangtze River Delta and capital region
- Focus has moved to the mainland and will continue to do so

Capacity and Growth, Select Data Center Markets, 2023

- Gross mn sqft
- Growth Rate

Growth (2019-23 CAGR)

- Beijing
- Hong Kong
- Shanghai
- Nantong
- Tianjin
Chinese development pushes inland

Chinese policy: “Eastern Data, Western Compute”
- Eastern Data: low-latency applications for large population centers
- Western Compute: data storage in areas with more abundant power

Significant pipeline development:
- North – Beijing
- Yangtze Delta – Shanghai
- Greater Bay Area – Shenzhen, Guangzhou
  - Hong Kong? Not so much

Number of Planned Sites by Metro in China, 2023
Is data power the new gold?
Commercial operators in these ten data center markets consume about 12 gigawatts (GW) of power.

- That’s roughly the same amount of power used by 9 million homes...for about 1,000 data centers.
Scarcity is already an issue

- Singapore: limited pool of licenses
- Netherlands: zoning laws effectively ban hyperscale
- Germany: Federal Energy Efficiency Act adds restrictions
- Dublin: operators must provision own energy generation, but projects still may not be approved
- UK: Ofgem urgently cleaning up power connection queue
- Dominion in NoVA is out of transmission capacity
AI will only make this situation tougher

Amount of power needed is staggering

- Estimates that AI data centers will require 2-5x capacity of other cloud data centers
- Latest gen of individual Nvidia GPU chips can use as much or more power than entire cloud servers.
- H100 and H200 Tensor Core GPUs tout up to 700W max thermal design power
Most sites can’t handle the density needed

- Nvidia GPUs use about 6.5-11 kW per 6U box.
  - So about 45-80 kW per 42U rack
- Vast majority of sites can’t support even 20 kW/rack

Supportable Colocation Rack Density, Share of Sites Globally (kW/rack), 2023
- > 20 kw per rack 11%
- <= 20 kw per rack 89%
How far can we go in searching for power?

- Will data centers be constrained by location in their hunt for power?
  - Training - perhaps less constrained
    - Could open opportunities to deploy to less crowded, more cost-effective locations with more abundant power
  - Inference – more constrained due to latency requirements
    - Compounds demand for capacity in already congested locations

Source: Bulk Infrastructure
Adapting to the situation

Strong utility partnerships and creative power solutions will be key

- **Location:** Proximity to utility providers for access to generation
  - AWS in Louisa County, VA with Rappahannock Cooperative near nuclear plant
  - Digital Realty procuring hydropower from Süwag near Hattersheim campus (FRA)

- **Conversion:** Site-based mini generator solutions to convert gas power to electricity
  - Expensive but plausible

- **Making use of waste heat:** Heat transfer for resourceful use of power
  - Germany: will be increasingly mandated to transfer waste heat.
  - Telehouse to share in FRA via the Mainova district heating network
Coping with High Costs
Some tech workers fleeing San Francisco for Austin

The cost of living is too high!
Energy prices have dropped, but still sit higher than before

- Prices have generally fallen since 2020-2022 surge but sit historically higher than before 2020
- European rates down more than 60% Y-o-Y but still more than double what they had been
- Singapore sits 2x higher than Eur rates
- Rise and fall relatively moderate in U.S.

Source: IEA Real-Time Electricity Tracker
Do colocation prices rise with utility rates? It’s complicated

- Long-term contracts and lag effect
- Pass-through vs. rolling increases
- Hiding inflationary costs elsewhere—cross connects, base colocation rate, etc
- Government subsidization
Colocation prices are higher too

- European rates rose about 40% between 2H21 and 1H23 and have leveled off.
- Asian hub rates continue to climb north of $500/kW (driven by Singapore).
- U.S. has lagged at more competitive level due to localized competitive pressure.

Average Monthly Price per Kilowatt at 4-Kilowatt Density, H2 2021-H2 2023
Will rates continue to rise?

- Still inflationary expectation but outliers are much less extreme
- Average expectation for price inflation per kW slightly slower than H1
- Average expectation for higher cross-connect rates has risen. Think lag effect and hidden cost

Note: Columns represent high to low reported expectations of change, and light blue circles represent average.
The takeaways?

- As Singapore’s growth is curtailed, there’s a concerted push into other subregional markets:
  - South Asia – India
  - Southeast Asia – Malaysia
  - North Asia - Japan
- And as new infrastructure investment in Hong Kong diminishes, China’s focus moves further into the mainland
- Commercialized generative AI compounds difficulties in sourcing power
- Inflation is slowing, but rates in many markets are settling at higher levels
Slide download

https://www2.telegeography.com/ptc-2024
Thank You

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Jon Hjembo  jhjembo@telegeography.com