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About the Data Gravity Index™

As the largest global provider of multi-tenant datacenter capacity, we have a unique vantage point on how technology infrastructure is built, deployed and operated. Our customers continue to solve the most complex infrastructure, connectivity and workload use cases on our platform globally. This includes use cases across network peering, hyperscale, low-latency, high-performance computing, big data and artificial intelligence.

Recently, we have witnessed the emergence of a new megatrend occurring on our platform: specifically, the explosion of enterprise data growth globally. This drove us to understand more. We conducted research between August 2019 and August 2020 and drew upon more than a dozen third-party data sources, ranging from the World Economic Forum and United Nations to global consulting and market research firms. We also developed a patent-pending formula to measure, quantify and determine the implications of the explosion of enterprise growth. The methodology is based on the analysis of thousands of attributes of Global 2000 Enterprise companies' presences in each metro, along with variables for each metro, including GDP, population, number of employees, technographics, IT spend, average bandwidth and latency, as well as flows of data.

We are publishing our findings as an annual report to facilitate industry dialogue and to assist both our Enterprise and Service Provider customers as they shift their infrastructure strategy to address this emerging megatrend. Introducing the Data Gravity Index DGx^{TM} - a global forecast that measures the intensity and gravitational force of enterprise data growth for 21 metros across the world.

About Digital Realty

Digital Realty supports the world's leading enterprises and service providers by delivering the full spectrum of data center, colocation and interconnection solutions. PlatformDIGITAL®, the company's global data center platform, provides customers a trusted foundation and proven Pervasive Datacenter Architecture PDx™ solution methodology for scaling digital business and efficiently managing data gravity challenges. Digital Realty's global data center footprint gives customers access to the connected communities that matter to them with 280 facilities in 47 metros across 22 countries on six continents.

To learn more about Digital Realty, please visit **digitalrealty.com** or follow us on **LinkedIn** and **Twitter**.







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1. 451 Research, Market Forecast, Leased Datacenter Global Providers, 2020.

Capacity measured in terms of both the number of datacenters and operational square footage.

Foreword

It's the first time Data Gravity has been measured and quantified for the Global 2000¹ Enterprises.

The Digital Economy

The digital economy is remaking both private and public enterprises across all industries, transforming how they create and deliver value.

Requires a New Business Architecture

To succeed, enterprises need to operate ubiquitously and on-demand, augmented by real-time intelligence to best serve customers, partners and employees across channels, business functions, and multiple points of business presence.

Data Gravity is the Obstacle

Data Gravity inhibits enterprise workflow performance, raises security concerns, and increases costs, all complicated by regulatory requirements and other artificial constraints. With Data Gravity, the laws of physics and IT intersect to provide a proxy for a new age of business architectures that Enterprises will be driven to adopt and Service Providers will be pressed to support.

Forces a Shift to Data-Centric Architecture

Data Gravity forces a new architecture, one that inverts traffic flow and brings users, networks and clouds to privately hosted enterprise data. With this new architecture. Data Gravity barriers are removed and new capabilities are unlocked.

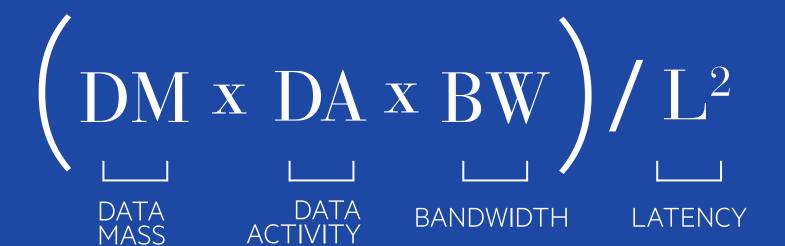
Elevates the Role of a Multi-Tenant Datacenter

To implement this data-centric architecture. Enterprises and Service Providers need a secure, neutral meeting place to host their infrastructure in proximity to yet separate from each other. A multi-tenant datacenter platform enables such a deployment paradigm.

1. Defined by Forbes' annual ranking of the world's 2000 largest public companies

Data Gravity¹ Index Formula²

A methodology to measure the creation, aggregation, and private exchange of enterprise data globally.



Bandwidth is a multiplier to Data Gravity. Higher Bandwidth represents more potential. Latency is an inhibitor to Data Gravity.

Higher Latency represents less potential.

Calculating Data Gravity

Data Mass

Data that is accumulated (Stored or Held)

Data Activity

Data that is in motion (Creation, Interactions)

Bandwidth

The Total Aggregate Bandwidth available to this location

Latency

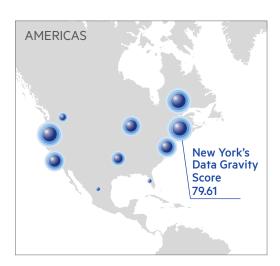
The Average Latency between this location and ALL other locations

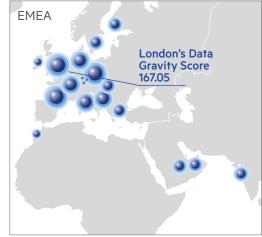
Dave McCrory, Data Gravity in the Clouds, Dec. 2010
 Digital Realty Market Intelligence & Analytics, Sept. 202

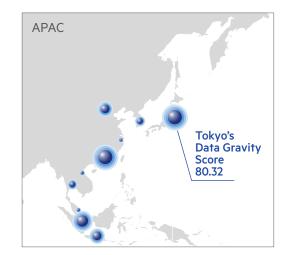
Data Gravity Index Score Reflects Intensity

The Data Gravity Index Score measures the intensity and gravitational force of enterprise data growth across 21 metros globally. The score, as measured in gigabytes per second, provides a relative proxy for measuring data creation, aggregation and processing.

Data Gravity scores, as measured in gigabytes per second, illustrative of actual results







The Data Gravity Score considers 1,000+ attributes from 13 authoritative sources on G2000 Enterprises including:

Firmographic Data

- Industry segment(s)
- Employee data
- Revenue data
- Location data
- Corporate entity

Technographic Data

- IT spend
- Preferred vendors
- Network traffic distribution
- Network PoPs
- DC PoPs
- Cloud PoPs

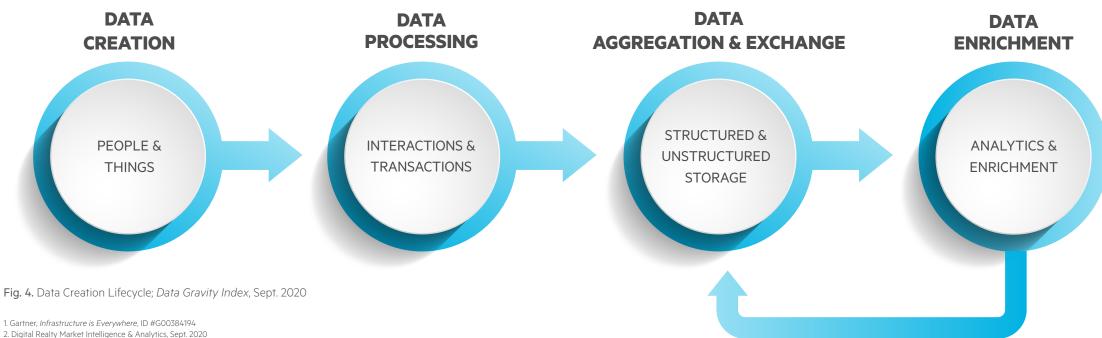
Industry Benchmarks

- Data creation/ transfer rates
- Latency by access method, user type, location, application type
- Growth rates
- Cloud usage
- Networking services
- Distributed services
- Data technologies
- End points, user devices
- Application use cases

/

Figs. 1, 2 and 3. Data Gravity Index, Sept. 2020

Continuous Data Creation Lifecycle Underpins Data Gravity



- 3. Digital Realty Market Intelligence & Analytics, Sept. 2020
- 4. Gartner, 100 Data and Analytics Predictions Through 2024, ID #G00721868

Enterprises serve an increasing number of users and endpoints that are creating and exchanging data

By 2022, more than 50% of enterprise data will be created outside the data center or cloud 1

Files and messages invoke concurrent interactions and transactions between users and machines

By 2024, G2000 Enterprises in these 21 metros will be required to add an additional 8,960 petaFLOPs to process new digital workflows²

Enterprise Data has to be gathered and formatted for presentation, exchange and compliant storage

By 2024, across the 21 metros, G2000 Enterprises will be adding storage at a combined rate of 496 terabytes per second for aggregation & exchange³ Analytics, machine learning and AI enable enterprises to embed workflow intelligence

By 2022, 65% of CIOs will incorporate Al into their ERP strategies to gain competitive advantage⁴

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Macro Trends Amplifying Data Gravity

Enterprise Data Stewardship

The enterprise is **fast** becoming the world's data steward

Mergers & Acquisitions

Globalization is driving corporate M&A to achieve scale



Digital-Enabled Interactions Increasing digitization of

enterprise workflows



Data Localization

Expanding legal and regulatory policies requiring local data storage



Cyber—Physical Integration of physical and

digital security systems to improve enterprise cybersecurity

WHY

WHAT

By 2025, **80% of data** worldwide will reside in enterprises¹

M&A Volumes are expected to return to pre-Covid levels in 2021²

Digitally-enabled interactions rank **2x greater** importance vs. physical interactions ³

By 2022, 87% of IT Leaders will maintain local copies of customer and transaction data for compliance⁴ By 2023, **70%** of security products will integrate IT-OT-IOT systems⁵

HOW

Increases the volume of

data that needs to be aggregated and stored

Source: 1DC #US44413318, Data Age 2025, The Digitization of the World From Edge to Core, November 2018

Increases # of data sources

participating in data exchange

Source: 2Goldman Sachs, BRIEFINGS Newsletter June 16, 2020

Increases enterprise data exchange volumes globally

Source: ³McKinsey, B2B Decision Maker Pulse Survey, April 2020

Increases # of enterprise **locations** of data aggregation

Source: 4451 Research, Infrastructure Imperative - IT Leader Survey, November 2019

Increases types and volumes

of data creation & exchange

Source: 5Gartner, Emerging Technology Analysis- Cyber-Physical Security. ID: G00726994

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About

INTRODUCTION

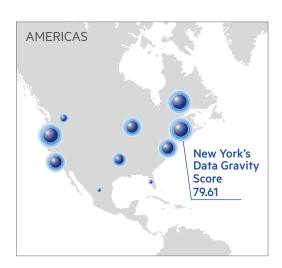
Forecasts

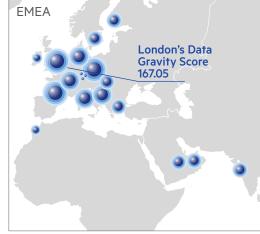
Implication

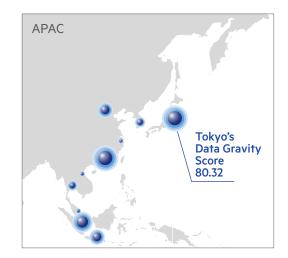
Methodology

Why Data Gravity Impedes G2000 Enterprises

As a cohort, Global 2000 Enterprises have the greatest propensity to need to address Data Gravity. This segment spends \$2.6T annually on IT Infrastructure & Networking,¹ operating the most complex systems and serving millions of users and endpoints, with coverage across many points of presence globally.







G2000 ENTERPRISE IT COMPOSITE

PROFILE 1,2,3,4,5,6,7,8

- 13+ Countries w/Business Presence
- 19k Business Units in Top 21 Metros
- 36+ Points of Presence (PoPs)
- 7k+ Datacenter PoPs
- 100m+ Employees
- 11m+ Applications
- 57k+ SAAS Applications
- \$2.6T+ Annual IT & Network Spend
- \$18B+ Annual IAAS Spend
- \$8B+ Annual PAAS Spend
- \$40B+ Annual SAAS Spend
- \$7B+ Annual Colocation Spend

Figs. 5, 6 and 7. Data Gravity Index, Sept. 2020

Highlights

Data Gravity Index DGx[™] measures, quantifies and predicts the intensity of Data Gravity across Global 2000 Enterprises.

- **Accelerating growth across all regions and metros.** Data Gravity Intensity, as measured in gigabytes per second, is expected to grow by a compound annual growth rate of 139% globally by 2024 as data stewardship drives global enterprises to increase their digital infrastructure capacity to aggregate, store and manage the majority of the world's data.
- **Pairs of metros share unique attraction rate.** Specific metro pairs were identified as having flows between each other, directly increasing their Data Gravity Intensity both within their metro and their high attraction between metros. This shift in importance towards digitally-enabled interactions across global enterprises will increase data exchange volumes exponentially.
- **Approaching quantum computing levels of data creation, processing & storage.** By 2024, it is estimated G2000 Enterprises will create data at a rate of 1.1 million gigabytes per second and will require 15,635 exabytes of additional data storage annually. Data location matters to global enterprises as they look to meet compliance requirements by maintaining local copies of critical data.
- 4 Requires data-centric enterprise architecture & connected community approach to address. Current backhaul architecture cannot address enterprise Data Gravity needs, including data exchange across multiple internal/external platforms, local data copies and ability to run performant analytics across each global point of presence. Data Gravity requires a connected community approach between enterprises, connectivity, cloud and content providers integrating core, cloud and edge at centers of data exchange, implementing a secure, hybrid IT and data-centric architecture globally at points of business presence.

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Forecasts

Data Gravity Index forecasts through 2024 by region, metro, metro-to-metro exchange, enterprise data creation, processing and storage

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Global Forecast

Accelerating growth across all regions. Data Gravity Intensity, as measured in gigabytes per second, is expected to grow by a compound annual growth rate of 139% globally by 2024 as data stewardship drives global enterprises to increase their digital infrastructure capacity to aggregate, store and manage the majority of the world's data.

Data Gravity Intensity Global Forecast^{1,2}

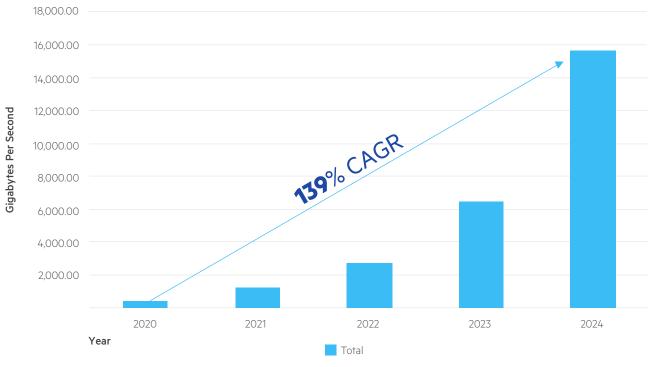


Fig. 8. Data Gravity Index, Sept. 2020

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^{1.} Data Gravity Intensity is calculated by the Data Gravity Index Formula: (DM x DA x BW) / L²

^{2.} Data Gravity Intensity is defined by the Data Gravity Index Score. See Methodology for scoring and data.

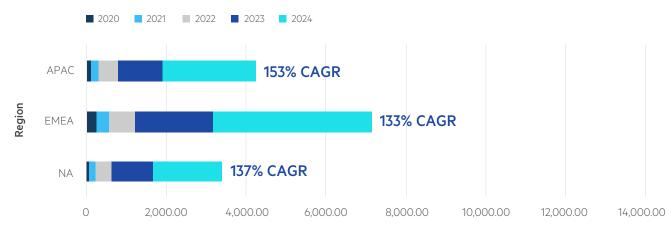
Regional Forecast

Accelerating growth across all regions. Data Gravity Intensity, as measured in gigabytes per second, is expected to grow by a compound annual growth rate of 133% or higher in each region by 2024.

Forecast Highlights

- By 2024, EMEA is expected to remain the home to the greatest intensity of Data Gravity across the 21 metros.
- Across the 21 metros, EMEA and APAC Data Gravity Intensity are increasing at faster rates than North America.
- Across the 21 metros, EMEA region Data Gravity Intensity will exit 2024 at almost double the rate of North America.

Data Gravity Intensity Regional Forecast^{1,2}



Gigabytes Per Second

Fig. 9. Data Gravity Index, Sept. 2020

Data Gravity Index **DGx**™ I digitalrealty.com

^{1.} Data Gravity Intensity is calculated across 21 metros using the Data Gravity Index Formula: (DM x DA x BW) / L²

^{2.} Data Gravity Intensity is defined by the Data Gravity Index Score. See Methodology for scoring and data.

Metro Forecast

From 2020 to 2024, the top 6 metros with the highest CAGR (in descending order) are:

Singapore | Hong Kong | Dallas | Sydney | Seattle | Tokyo

Singapore is a critical business and data hub for global enterprises with presence in the APAC region with its pro-business policies and diverse connectivity options.

Hong Kong is an international financial and trade hub and connectivity gateway between APAC and the rest of the world for global enterprises.

Dallas is a preeminent business hub for global or regional headquarters and provides a connectivity gateway for global enterprises.

Sydney has developed into a global business hub with a majority of global enterprises with operating presence, in addition to serving as a rich connectivity gateway.

Seattle is becoming the home to many global enterprises participating in the cloud ecosystem, in addition to being a connectivity conduit between North America and APAC regions.

Tokyo is one of the largest economies in the world, a business and financial hub for global enterprises and drives large amounts of data creation.

Data Gravity Intensity Metro Forecast^{1,2}

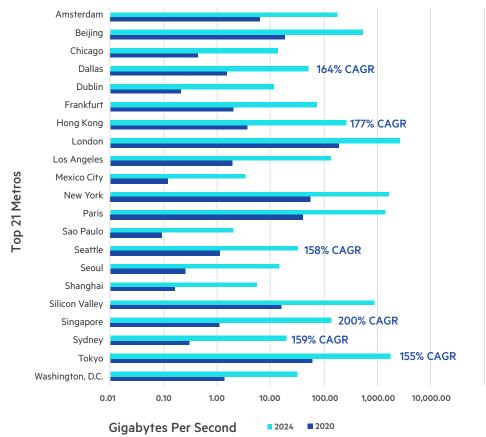


Fig. 10. Data Gravity Index, Sept. 2020

^{1.} Data Gravity Intensity is calculated by the Data Gravity Index Formula: (DM x DA x BW) / L^2

^{2.} Data Gravity Intensity is defined by the Data Gravity Index Score. See Methodology for scoring and data.

Inter-Metro Forecast

Global Metro to Metro Gravity

Pairs of metros share unique attraction rate. Specific metro pairs were identified as having flows between each other, directly increasing their Data Gravity Intensity both within their metro and with their high attraction between metros. This shift in importance towards digitally-enabled interactions across global enterprises will increase data exchange volumes exponentially.

- **1.** London to Amsterdam is at the top in both 2020 and 2024. London is a leading financial center for international enterprises, and Amsterdam is headquarters to some of the world's largest companies and a leading financial hub for Europe. Data is exchanged for finance and trade purposes, among other reasons, creating a very high level of attraction.
- **2.** Paris to London is the second-highest attraction in both 2020 and 2024. Paris and London are both financial centers with large populations and are capital cities of their respective countries. With diverse G2000 Enterprise presence, their combined data being shared and generated makes their attraction very high.
- **3.** Hong Kong to Tokyo is projected to be in the top 10 attraction between metros by 2024. Hong Kong is a large financial center with high volumes of trade and is considered a gateway to China. Tokyo is the gateway to Asia from the US and has lots of manufacturing and, in addition to being a financial center, drives large amounts of data creation. While the attraction is predicted to increase between 2020 and 2024, this attraction is expected to stay in the top 10 for a long time.

Top 10 Metro to Metro Connections 2020				
Attraction	Metro A	Metro B		
14,344.22	London	Amsterdam		
12,162.51	Paris	London		
7,604.18	Washington, D.C.	New York		
4,533.48	Silicon Valley	Los Angeles		
1,611.46	Frankfurt	Paris		
1,211.34	London	Frankfurt		
1,109.79	Shanghai	Beijing		
420.32	New York	Silicon Valley		
386.90	New York	London		
369.07	Dublin	London		

Top 10 Metro to Metro Connections 2024				
Attraction	Metro A	Metro B		
387,160.00	London	Amsterdam		
351,187.93	Paris	London		
220,339.51	Washington, D.C.	New York		
167,647.26	Silicon Valley	Los Angeles		
54,800.54	Frankfurt	Paris		
34,162.12	Beijing	Shanghai		
27,464.84	London	Frankfurt		
12,193.56	New York	Silicon Valley		
11,183.59	New York	London		
10,795.09	Hong Kong	Tokyo		

Figs. 11 and 12. Data Gravity Index, Sept. 2020

^{1.} Attraction between metros is calculated by adding Data Masses together and adding the Data Activity numbers together, then multiplying them with Bandwidth and finally dividing the result by the Latency squared between them. 2. See Methodology for scoring and data.

Data Gravity Intensity Quantified -Enterprise Data Creation

By 2024, it is estimated G2000 Enterprises across the 21 metros will create 1.1 million gigabytes of data per second.

Calculating Enterprise Data Creation (Gigabytes Per Second) 1,2



Fig. 13. Data Gravity Index, Sept. 2020

^{1.} Data creation was calculated by combining data created by both G2000 Enterprise employees and end points..

^{2.} See Methodology for scoring and data.

Data Gravity Intensity Quantified – Enterprise Data Processing

By 2024, G2000 Enterprises across 21 metros will require 8.96 additional exaFLOPs to process new digital workflows.

Enterprise Data Processing 2020-2024 by Metro (pFLOPS)^{1,2}

Metro	2020	2024
Amsterdam	154.51	185.67
Beijing	1,598.23	1,920.55
Chicago	211.90	254.63
Dallas	250.34	300.82
Dublin	127.22	152.87
Frankfurt	64.99	78.10
Hong Kong	237.51	285.40
London	693.31	833.13
Los Angeles	130.28	156.55
Mexico City	48.16	57.87
New York	796.67	957.34
Paris	420.82	505.69
Sao Paulo	48.14	57.85
Seattle	227.47	273.35
Seoul	193.99	233.11
Shanghai	172.79	207.64
Silicon Valley	587.94	706.51
Singapore	101.40	121.85
Sydney	148.92	178.95
Tokyo	1,054.97	1,267.73
Washington DC	187.53	225.34
	7,457.06	8,960.96

Fig. 14. Data Gravity Index, Sept. 2020

^{1.} Data Processing was calculated by analyzing G2000 Enterprise IT processing needs to handle new data-centric workloads such as Al & ML, analytics, costs per TFLOPs, and other factors.

^{2.} See Methodology for scoring and data.

Data Gravity Intensity Quantified -Enterprise Data Storage

By 2024, it is estimated G2000 Enterprises across the 21 metros will require 15,635 exabytes of additional data storage annually.

Calculating Enterprise Data Storage Growth (Exabytes)^{1,2}

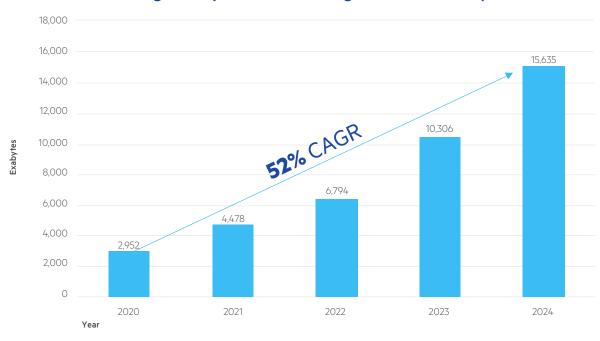
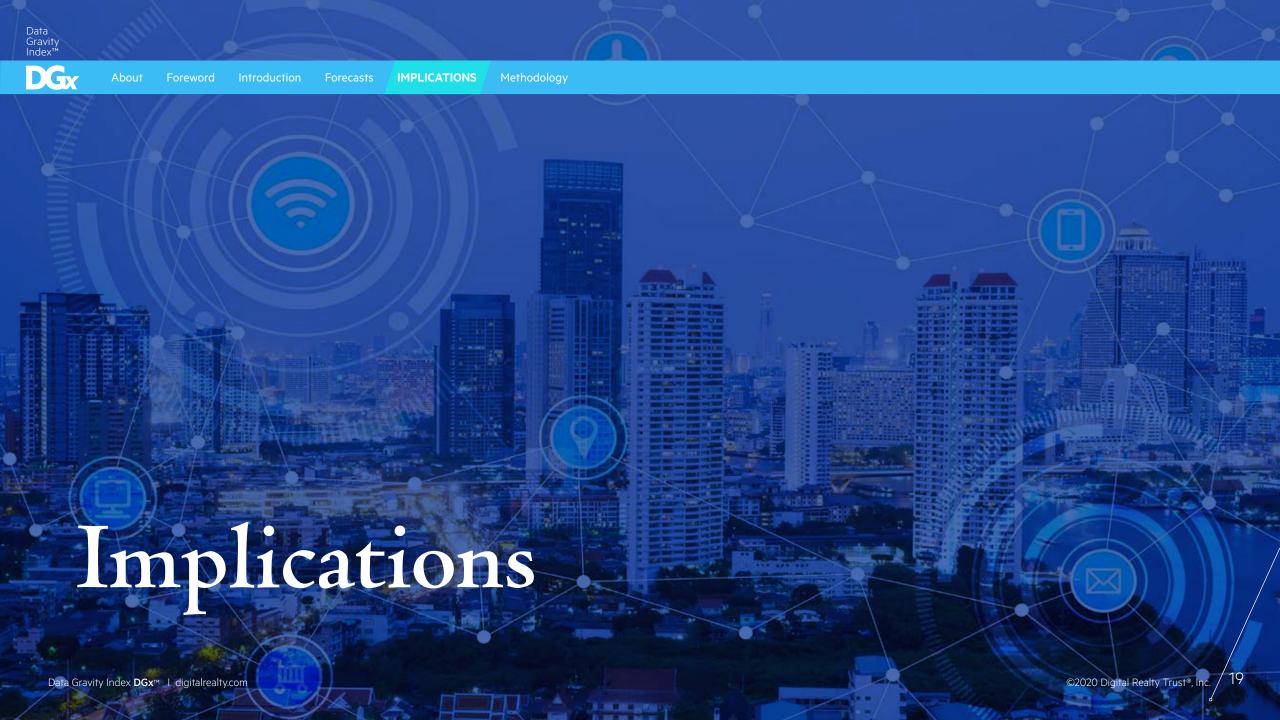


Fig. 15. Data Gravity Index, Sept. 2020

^{1.} Data Storage was calculated by taking the storage capacity, growth and annual rate of deployment of Enterprise storage (HDD, SSD, and Tape) and analyzing across 21 metros.

^{2.} See Methodology for scoring and data.





Forecasts

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Implication #I – A Data-Centric Architecture is Mandatory

Current backhaul architecture cannot address enterprise Data Gravity needs, including data exchange across multiple internal/external platforms, local data copies and the capabilities to run performant analytics across each global point of presence. Architecture needs to be inverted to a data-centric architecture deployed at points of presence in neutral, multi-tenant datacenters to integrate private and public data sources.

Architecture is constrained IN THE CLOUDS Applications & Capacity **SENDS DATA TO RECEIVES DATA CLOUDS SLOWLY** AT THE EDGE Users & Things

Fig. 16. Data Gravity Index, Sept. 2020

CURRENT BACKHAUL ARCHITECTURE DOES NOT ADDRESS GLOBAL ENTERPRISES' DATA GRAVITY NEEDS TO:

- Exchange data across multiple internal/external platforms
- Maintain local data copies for data compliance
- Run concurrent multi-data set analytics in a performant manner at global points of presence

Needs to be inverted IN THE CLOUDS Applications & Capacity **BRINGS CLOUDS BRINGS USERS** Centers TO THE DATA TO THE DATA of Data **Exchange** AT THE EDGE Users & Things

A DATA-CENTRIC ARCHITECTURE IS REQUIRED TO ADDRESS **DATA GRAVITY BARRIERS, THIS INCLUDES:**

- Putting data at the center of the architecture
- Inverting traffic flow, leveraging interconnection and bringing clouds and users to the data
- Removes speed of light & Data Gravity performance constraints at global points of presence

Deployed at global points of presence



IMPLEMENTING A DATA-CENTRIC ARCHITECTURE IN **MULTI-TENANT DATACENTERS ADDRESSES DATA GRAVITY AT GLOBAL POINTS OF PRESENCE TO:**

- Reduce Risk with secure data exchange
- Lower Costs reduction in bandwidth and duplicated infrastructure
- **Grow Revenue** through unbounded data analytic performance

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Implication #2 – Requires a Connected Community Approach

Data Gravity requires a connected community approach between enterprises, connectivity, cloud and content providers. This approach integrates core, cloud and edge at centers of data exchange, implementing a secure, data-centric hybrid IT architecture at Global Enterprise points of business presence deployed in multi-tenant datacenters.

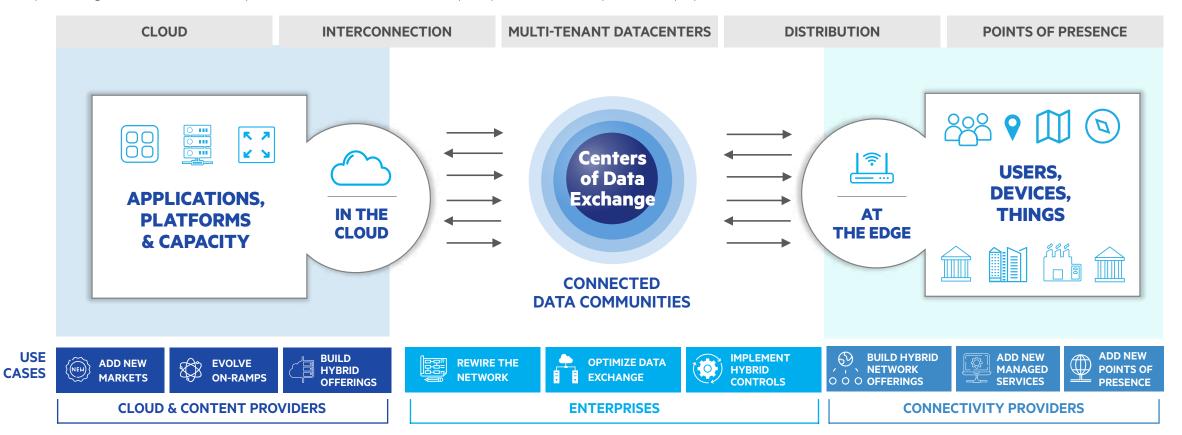
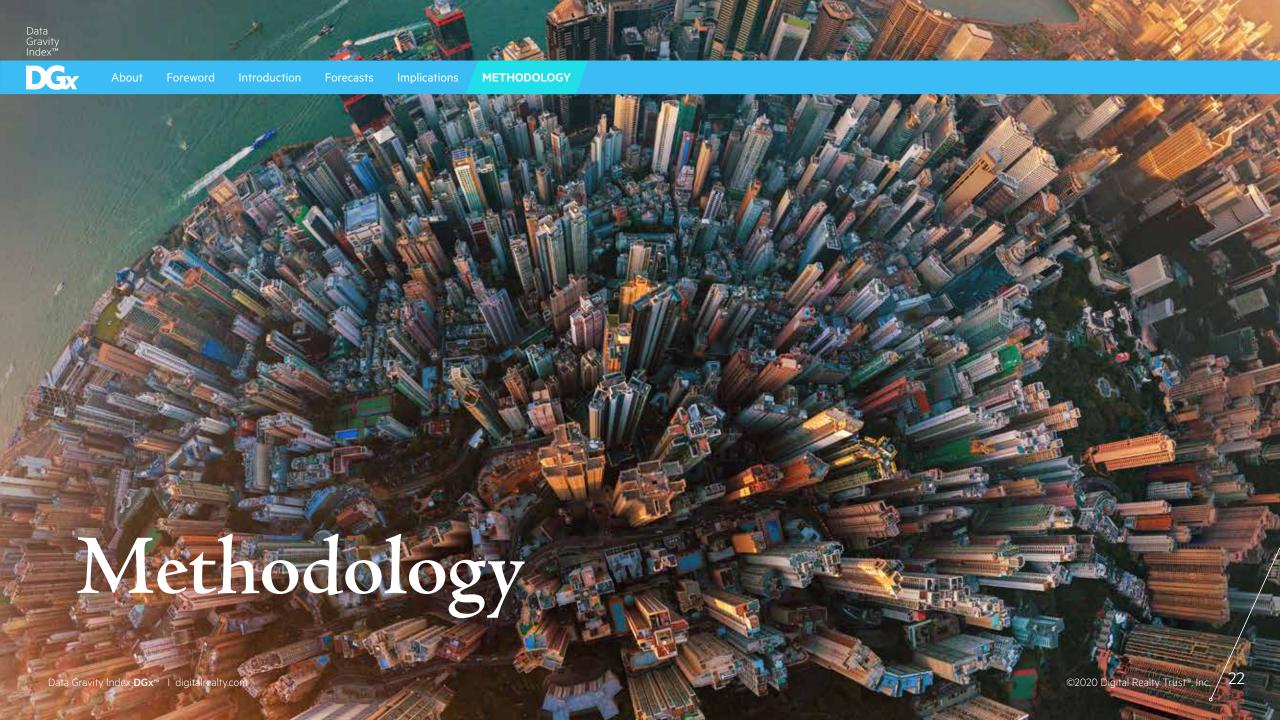


Fig. 17. Data Gravity Index, Sept. 2020



Methodology

The system for measuring Data Gravity for the Global 2000 Enterprises

Data Gravity Index DGx[™] implements a patent-pending formula which quantifies and predicts the continuous creation of data across 21 metros globally.

Analyzing Thousands of Attributes

The Data Gravity Index methodology is based on the analysis of thousands of attributes of Global 2000 Enterprise companies' presences in each metro, along with variables for each metro, including GDP, population, number of employees, technographics, IT spend, average bandwidth and latency, as well as flows of data.

Solving for Data Mass and Data Activity

The size and attraction of data for each metro was created by solving for a Data Mass number and a Data Activity number. The result was then multiplied by the average Bandwidth and divided by the average Latency squared.



Calculating Data Gravity Between Metros

The Data Gravity between metros was calculated by adding Data Masses together and adding the Data Activity numbers together, then multiplying their product by Bandwidth and dividing the result by the Latency squared between metros.

Calculating the Enterprise Data Creation Lifecycle

Data Creation was calculated by combining data created by both G2000 Enterprise employees and end points.

Data Processing was calculated by analyzing G2000 Enterprise IT processing needs to handle new data-centric workloads, such as AI & ML, analytics, costs per TFLOPs and other factors.

Data Storage was calculated by taking the storage capacity, growth and annual rate of deployment of Enterprise storage (HDD, SSD, and Tape) and analyzing across 21 metros.



Data Mass

The estimated volume of data stored in a metro over a period of time.



Data Activity

The estimated amount of data movement and interactions in a metro over a period of time.



Bandwidth

The average amount of bandwidth available in a metro or between two metros.



Latency

The average latency between all metros and a single metro or between two specific metros.

Development of Data Gravity Index referenced and/or considered various data sources, including HG Insights, Intricately, Synergy Research Group, Telegeography, PeeringDB, WonderNetworks, Dotcom-Monitor, Organization for Economic Co-Operation and Development, Wikipedia, Google Maps, Worldometer, US. Census, DataUS.io, IDC, 451 Research, Gartner, McKinsey, PWC, Accenture, World Economic Forum and United Nations.



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Learn More

Unlock New Capabilities to Manage the Effects of Data Gravity

Explore this new megatrend, and see how the explosion of data growth globally forces a shift to a new data-centric hybrid IT architecture. If you have any questions or want to learn more about this industry-first report, email datagravity@us.digitalrealty.com

Data Gravity Insights Hub Insights Videos

- Virtual Events
- Visualization Tools
- New Releases

DigitalRealty.com/Data-Gravity-Index

Pervasive Datacenter Architecture (PDx™) Library

- PDx Methodology
- Blueprints
- Design Guides
- Solution Briefs

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