



CLOUD COMPUTING

Economics

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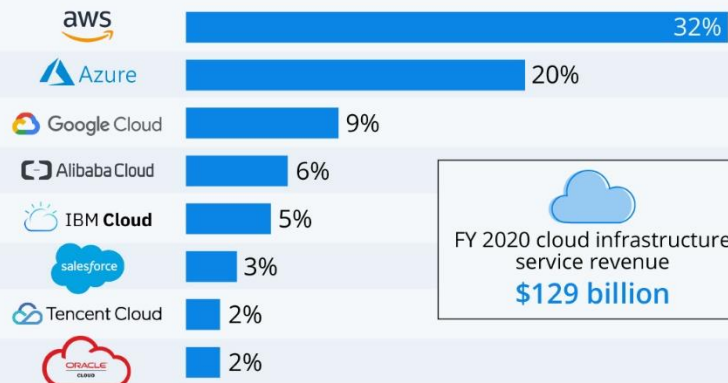


Cloud Providers: Global market trends

MARKET CONSOLIDATION

Amazon Leads \$130-Billion Cloud Market

Worldwide market share of leading cloud infrastructure service providers in Q4 2020*

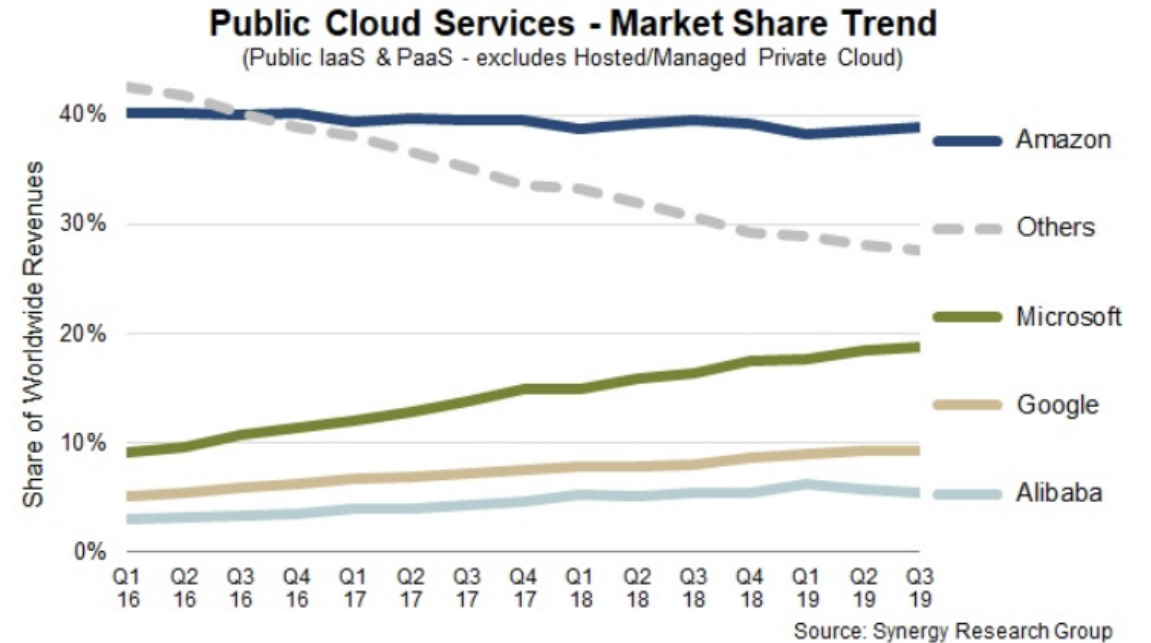


* includes platform as a service (PaaS) and infrastructure as a service (IaaS) as well as hosted private cloud services

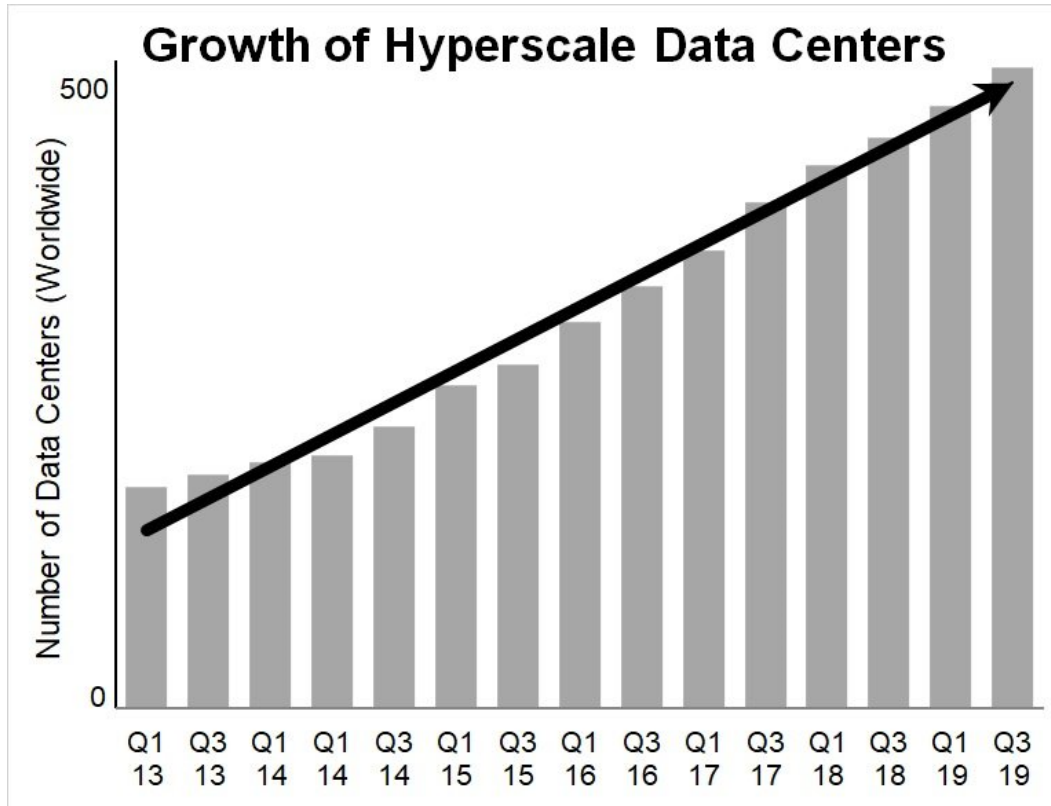
Source: Synergy Research Group



statista

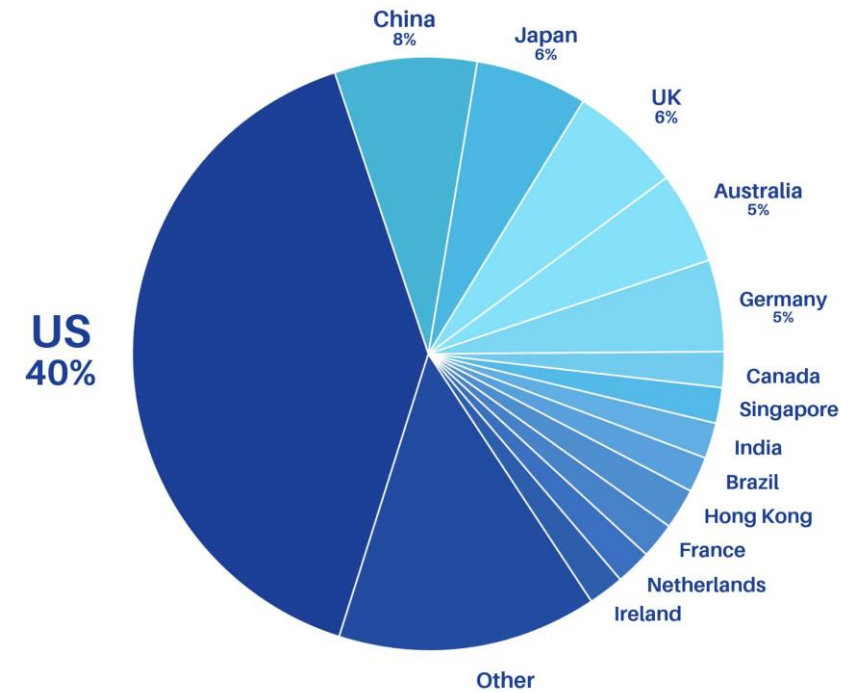


HYPERSCALE



Hyperscale Data Center Operators

Data Center Locations By Country- December 2018



TRENDS

Strong growth in the Cloud market

Consolidation: small number of companies have a rising market share

Decline in European Cloud provider market

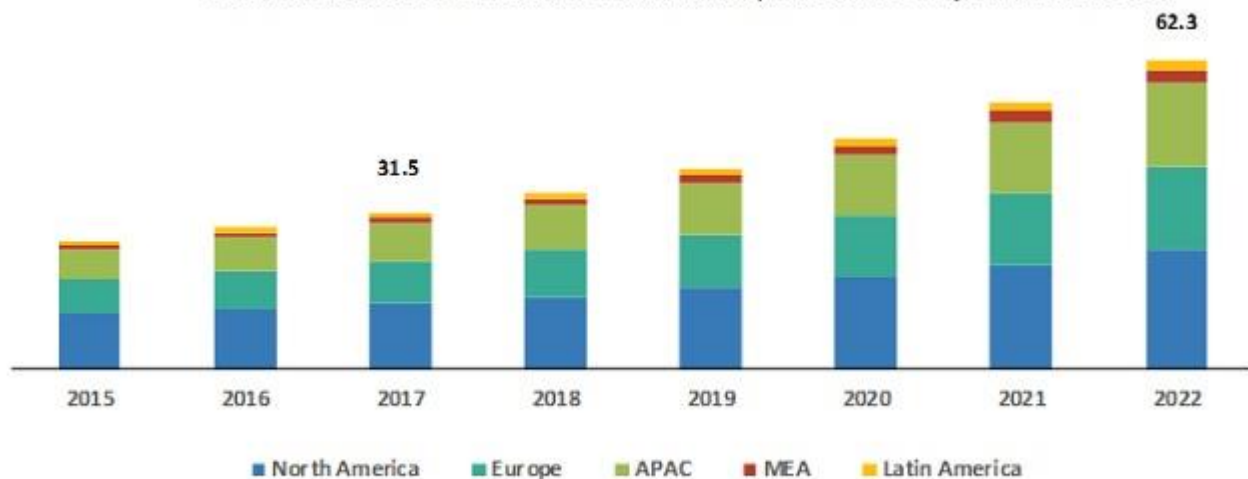
Market is dominated by the US

Rise of the hyperscale data center

Why do you think these trends are occurring?

DON'T FORGET THE CO-LO MARKET

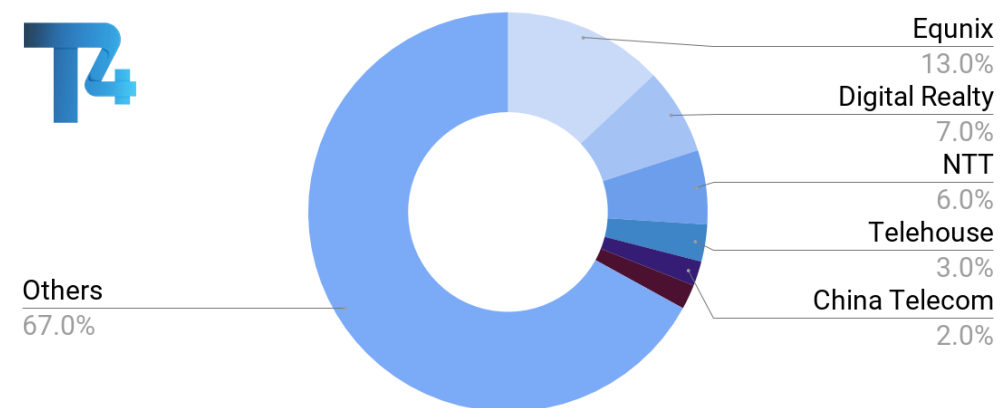
DATA CENTER COLOCATION MARKET, BY REGION (USD BILLION)



Source: Investor Presentation, Secondary Literature, Expert Interviews, and MarketsandMarkets Analysis

Data Center Colocation Market Share, 2018

www.T4.ai



Surveys

VENDOR LOCK-IN

Survey of 114 participants from UK industry (small to large enterprises)

J. Opara-Martins, R. Sahandi, F. Tian, "Critical analysis of vendor lock-in and its impact on cloud computing migration: a business perspective", Journal of Cloud Computing: Advances, Systems and Applications (2016)

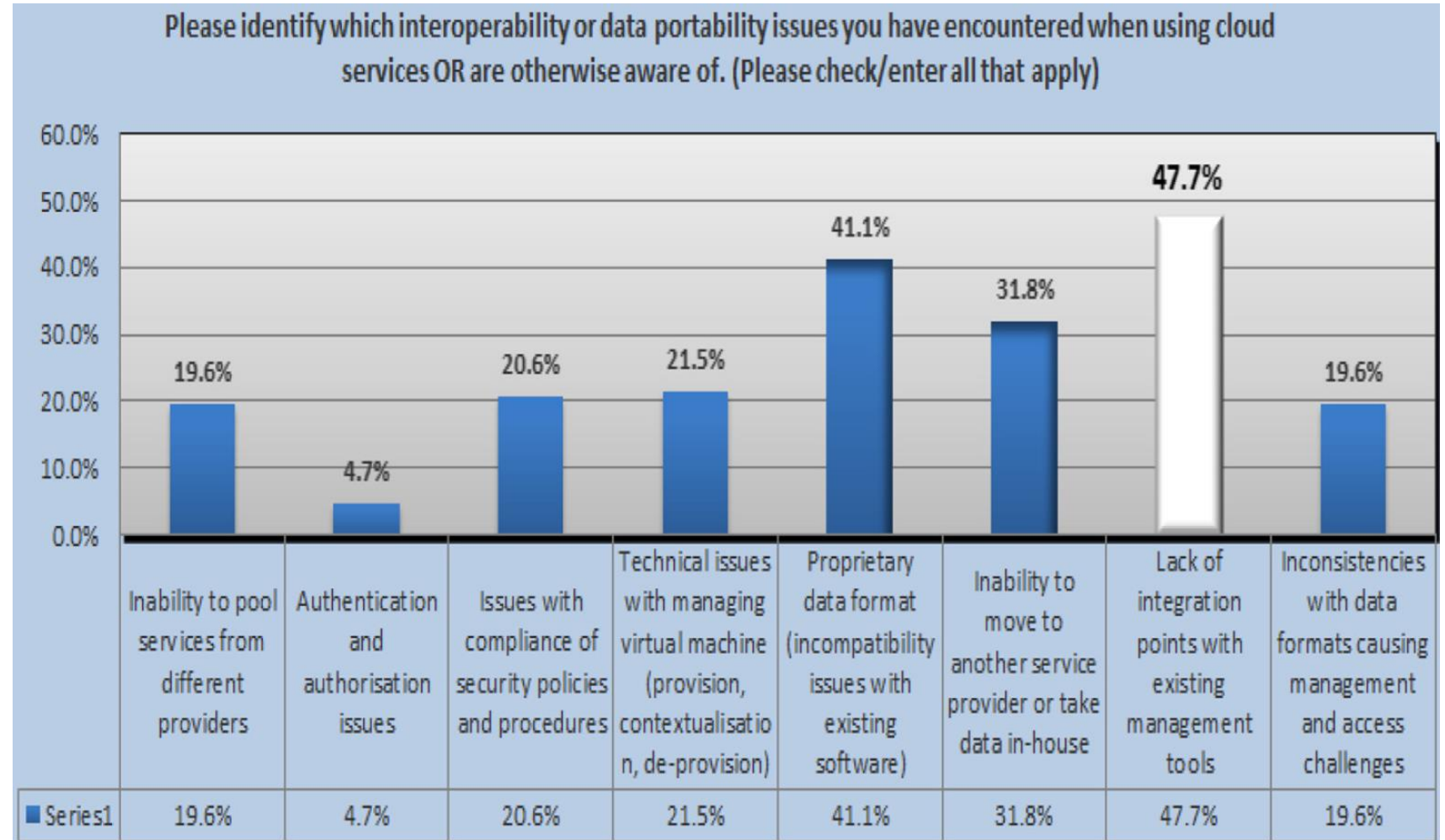
Lock-in is a deterrent to Cloud migration

Definitely yes	Possibly yes	Not sure	No
9%	71%	11%	9%

VENDOR LOCK-IN [2]

Discussion

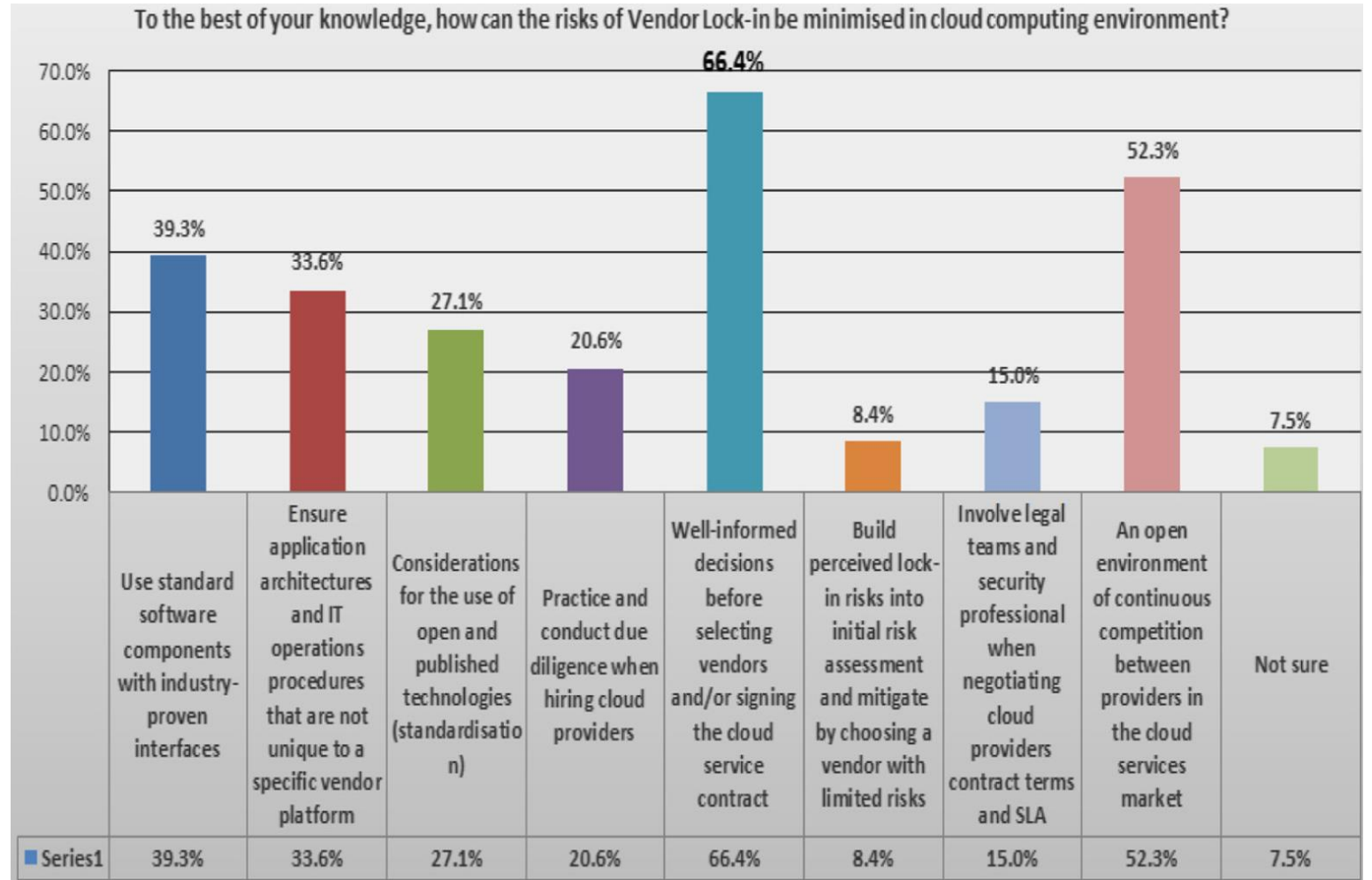
What sort of interoperability / data portability challenges might companies face?



VENDOR LOCK-IN [3]

Discussion

How can companies minimise the risk of vendor lock-in in a Cloud environment?



VENDOR LOCK-IN [4]

Provider perspective

Produces a steady income

Easier to predict how much hardware needed

Cheaper

User perspective

Less flexible

Can be cheap (discounts)

The longer used, the harder to leave

EGRESS FEES



EGRESS FEES

	AWS per GB	Azure per GB	Google
1 GB	0.09 \$	0.087 \$	0.12 \$
1 TB	0.09\$	0.085 \$	0.12 \$
10 TB	0.085 \$	0.083 \$	0.11 \$
150-500 TB	0.05 \$	0.05 \$	0.08 \$
500+ TB	Custom deal	Custom deal	0.08 \$

COST OF EGRESS EXAMPLE

	AWS	Azure	Google
1 GB	0.09 \$	0.087 \$	0.12 \$
1 TB	90 \$	85 \$	120 \$
10 TB	850 \$	830 \$	1100 \$
500 TB	25000 \$	25000 \$	40000 \$

As an example, NASA is migrating 247 PB to AWS
Egress of this data will cost approximately \$12 M

CO-LOCATION

Up to seven times cheaper in some scenarios

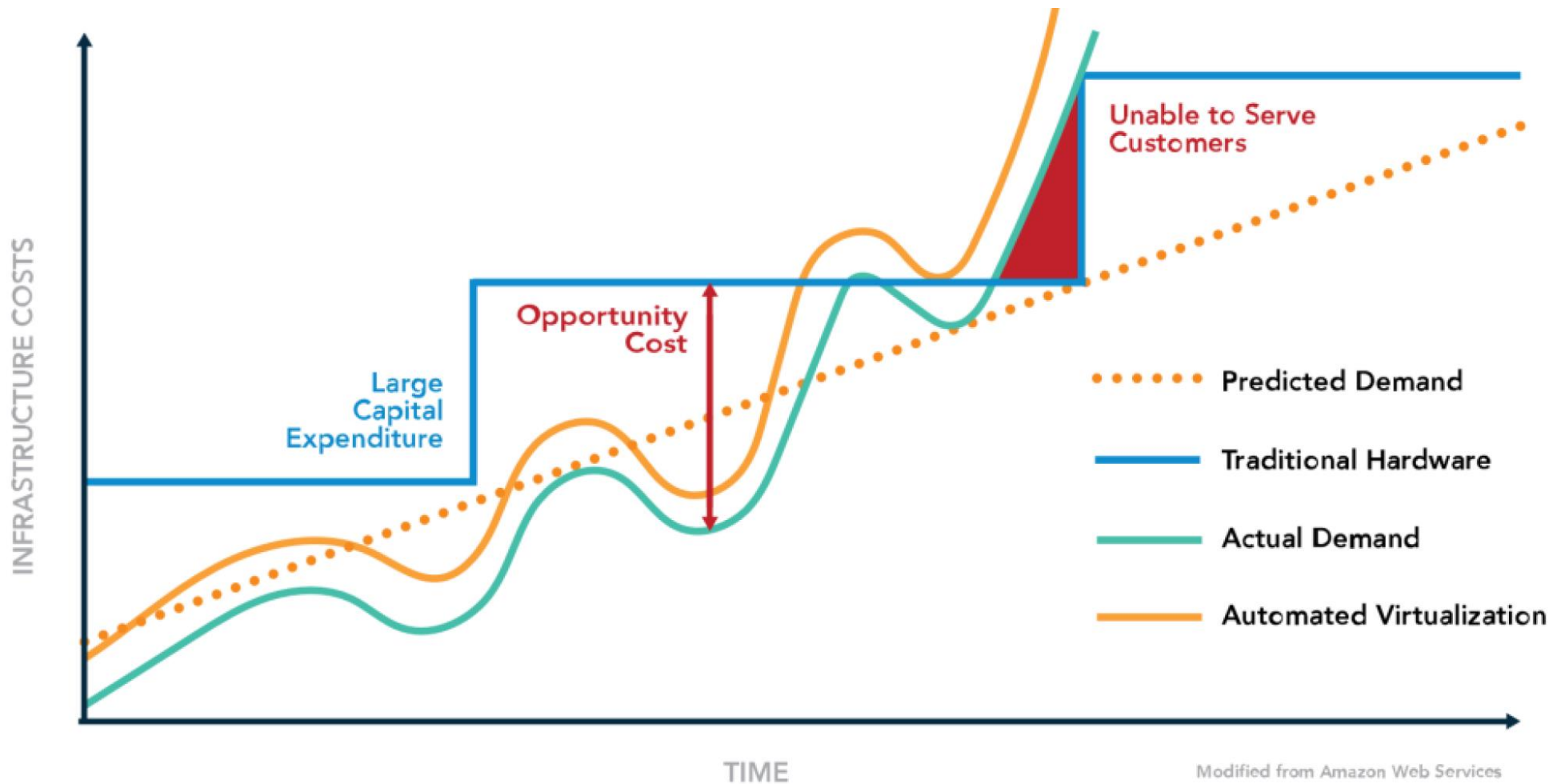
Can take a few years to pay off

You choose the hardware, systems, and tools

Bigger risk for smaller companies

Difficult to scale

CAPITAL VS OPERATIONAL COST



Cost comparison of providers

COMPARING PROVIDERS

Comparing providers is not trivial

Providers purposefully do not want to allow simple price comparisons

Each provider wants to emphasise their advantages

Many factors impact the final cost

Each provider has their own discount model (often high)

Two very similar configurations can have different pricing

Discounts and prices change periodically

COMPARING PROVIDERS

Tools exist to compare prices

<https://azure.microsoft.com/en-us/pricing/calculator/>

<https://calculator.aws/>

<https://cloud.google.com/products/calculator/>

All are quite complex interfaces, with many tuneable parameters

COMPARING PROVIDERS (2)

Reserved instances are one reason why providers are difficult to compare

Typically 1-3 year contract,
paid monthly

Pay for estimated usage

Costs the same no matter
what utilisation

Can often be cancelled or
upgraded for a fee

Can reduce costs by a lot –
72% for AWS and Azure, etc.

Highest discount is achieved
when paid upfront

PROVIDER COMPARISON: FAAS (SERVERLESS)

512MB RAM

1 second execution

Bandwidth usage not included in Azure or AWS

Both Azure and AWS include 1M requests and 400,000 GB-s for free

What is a GB-s?

Observed resource consumption is calculated by multiplying average memory size in gigabytes by the time in milliseconds it takes to execute the function

# Requests	Azure	AWS	Google CF
10^6	\$1.61	\$1.63	\$6.8 (10KB)
10^9	\$8193	\$8494	\$21089

PROVIDER COMPARISON: STORAGE

No reserved instances, basic license

500 million inserts, 500 million fetches

Services are not entirely equivalent

Storage	Azure	AWS	Google CF
1 TB	\$1771	\$3000	\$2720
10 TB	\$2324	\$3239	\$2905

PROVIDER COMPARISON: DATABASE

PostgreSQL, storage with backup

Bound to instances, not exactly the same for all providers

Cheapest instance used

Storage	Azure	AWS	Google CF
500 GB	\$111	\$90	\$100
1 TB	\$162	\$163	\$186

PROVIDER COMPARISON: SUMMARY

Service	Azure	AWS	Google
FaaS	<u>1.61</u>	1.63	6.8
FaaS	<u>8193</u>	8494	21089
DB	111	<u>90</u>	100
DB	<u>162</u>	163	186
Storage	<u>1771</u>	3000	2720
Storage	<u>2324</u>	3239	2905

A BRIEF SUMMARY

Cloud is still experiencing
huge market growth

Hyperscale DCs are eating
smaller rivals.. But don't
forget the co-lo market

Is vendor lock-in a problem
or just perceived to be?

Are egress fees still a
problem?

It's hard to compare costs
between providers

What is the future of
Cloud?

Course Summary

COURSE SUMMARY

Give you a flavour of
Cloud and its
technologies

Show you that the
ERDC exists and you
can use it for your PhD

Basic Cloud
terminology

Data centers and how
they work

HDFS distributed
storage

Hadoop MapReduce

Spark distributed in-
memory processing

Storm stream
processing

Edge, fog

Serverless

Containers and
Kubernetes

Economics

COURSE SUMMARY

I will upload all slides to Canvas later today

Your ER DC accounts will not stay active for long – but as WASP PhDs, you can ask for a new account and then use ER DC to set up your own clusters and run experiments for your PhD

More details about the assignment will be uploaded to Canvas. HOWEVER, I can now reveal....

COURSE ASSIGNMENT!

WASP courses shouldn't give you work just for the sake of it – your real job is your PhD

Let's do something that won't take too long, but can benefit us all

Write a 2.5 - 3 page essay:

1st paragraph: introduce your research/area (200 words)

Remainder of essay: how Cloud technology can be useful to your research. Talk about at least four of the concepts mentioned on the previous slide.

Deadline is 25th March 2022.

Write three pages (that are original and show you've thought about this) and you pass, otherwise you fail.

FINAL WORDS

I hope you got something out of this course!

We have covered a lot of ground, and the practical was complicated.

If you can apply one thing that you've learnt to your PhD then it's a success.

You can always email me: paul.townend@umu.se if you want my opinion on anything Cloud in future.

You can connect on LinkedIn if you like (but I am slow to use that!)