

Technical Report:

Multi-Platform Cloud Deployment & Comparative Analysis

Optimizing Static Web Hosting for Scalability and Cost-Efficiency

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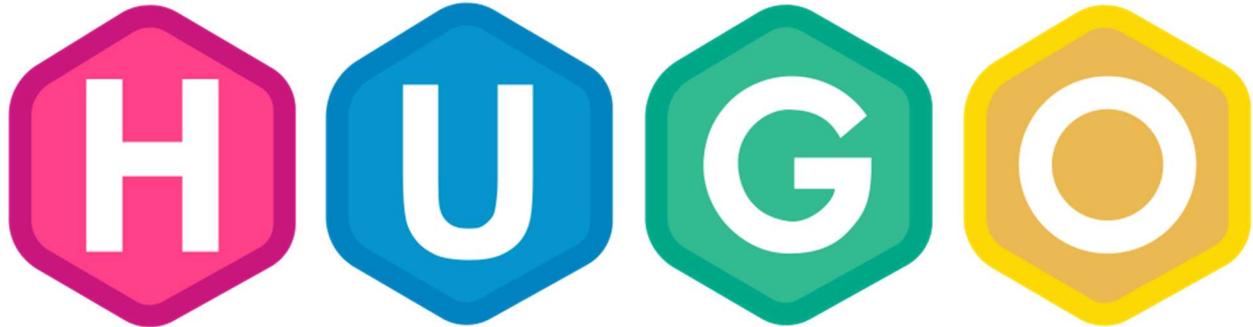


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Summary

This report evaluates the deployment of a static Hugo-based web application across three distinct Microsoft Azure service models: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Object Storage. The objective is to determine the optimal hosting environment based on cost-optimization, service availability (SLAs), and operational overhead.

Implementation Overview

The deployment was executed across three environments to test the versatility of the Hugo static site engine:

A. Infrastructure as a Service (VM Deployment)

- Environment: Linux Virtual Machine (Ubuntu).**
- Web Server: Configured Nginx for high-performance static file serving.**
- Workflow: Leveraged Git-based deployment for seamless file transfer from local environment to the production VM.**

B. Platform as a Service (Azure App Service)

- Environment: Managed PaaS (App Service).**
- Deployment Method: Utilized SCM & FTP integration for optimized artifact deployment.**
- Key Insight: Optimized the deployment speed by implementing a Zip-based artifact transfer via Kudu File Manager, significantly reducing deployment latency compared to individual file uploads.**

C. Cloud Object Storage (Azure Blob Storage)

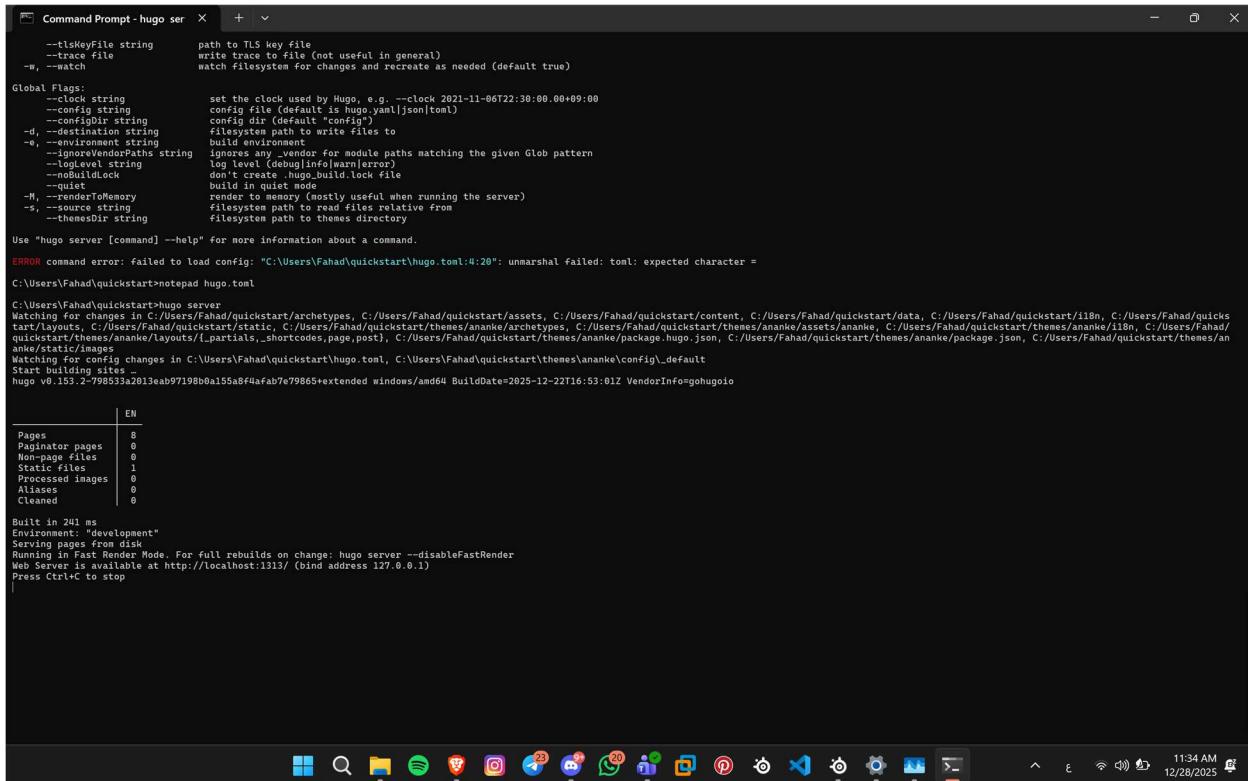
- Environment: Serverless Static Website Hosting via Azure Blob Storage.**
- Configuration: Enabled anonymous public access and configured specific index/error document endpoints.**
- Storage: Direct deployment to the \$web container, bypassing server management entirely.**

All resources overview

The screenshot shows the Microsoft Azure Resource Manager interface. The left sidebar includes links for Home, Resource Manager, All resources, Favorite resources, Recent resources, Resource groups, Tags, Organization, Tools, Deployments, and Help. The main content area displays a table of resources with columns for Name, Type, Resource Group, Location, and Subscription. The table lists 11 resources, all located in Switzerland North and Azure for Students, including App Service plans, Storage accounts, Virtual machines, App Services, Public IP addresses, Network security groups, Virtual networks, Network interfaces, Disks, and Network Watchers.

Name	Type	Resource Group	Location	Subscription
ASP-cpt490-92bf	App Service plan	cpt490	Switzerland North	Azure for Students
blidstrongfaelafad	Storage account	cpt490	Switzerland North	Azure for Students
hugo	Virtual machine	cpt490	Switzerland North	Azure for Students
hugo-fahad	App Service	cpt490	Switzerland North	Azure for Students
hugo-fahad2	App Service	cpt490	Switzerland North	Azure for Students
hugo_ip	Public IP address	cpt490	Switzerland North	Azure for Students
hugo-nsg	Network security group	cpt490	Switzerland North	Azure for Students
hugo-vnet	Virtual network	cpt490	Switzerland North	Azure for Students
hugo_z9_1	Network Interface	cpt490	Switzerland North	Azure for Students
hugo_OsDisk_1.4ac50856936454e95297d1bcf56c179	Disk	CPI490	Switzerland North	Azure for Students
NetworkWatcher switzerlandnorth	Network Watcher	NetworkWatcherRG	Switzerland North	Azure for Students

Prerequisites: downloading hugo and testing it



```
Command Prompt - hugo server + v
--tlscKeyfile string      path to TLS Key files
--trace file              write trace to file (not useful in general)
--watch                   watch filesystem for changes and recreate as needed (default true)

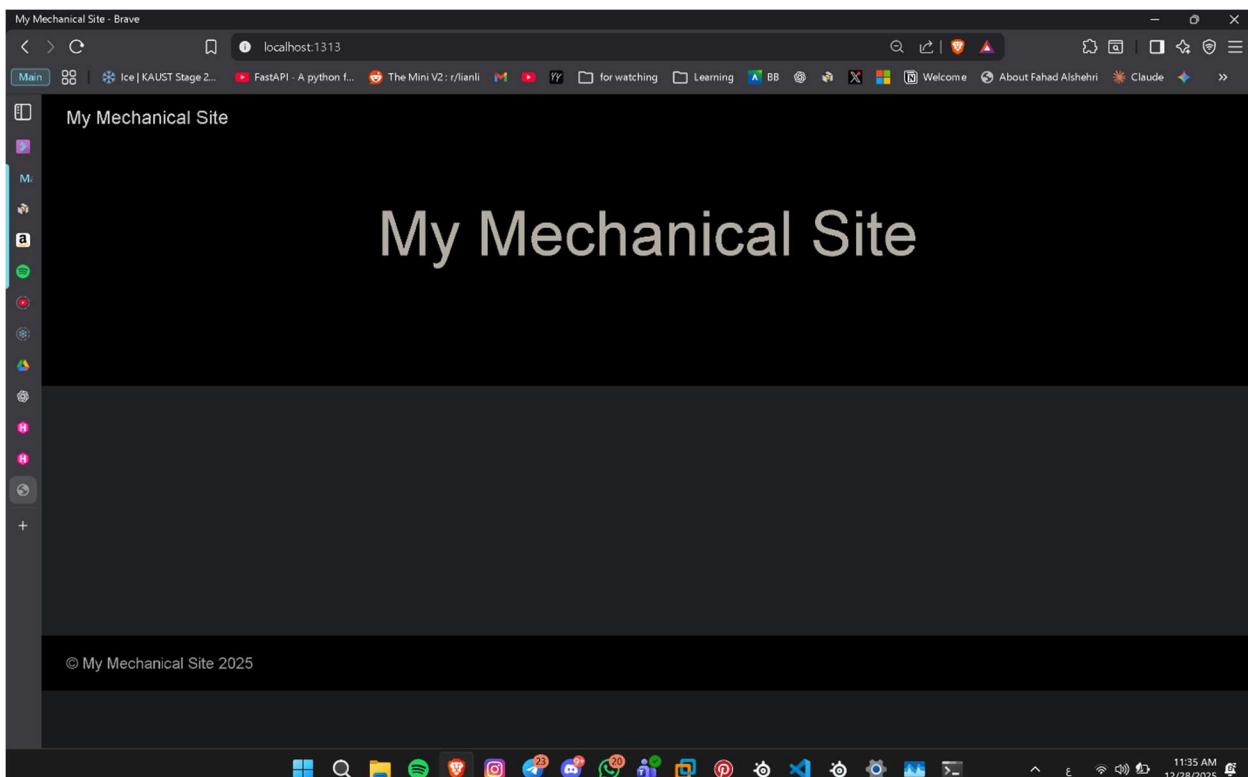
Global Flags:
--clock string            set the clock used by Hugo, e.g. --clock 2021-11-06T22:30:00.00+09:00
--config string            config file (default is Hugo.yaml|json|toml)
--configDir string         config dir (default "config")
-d, --destination string  filesystem path to write files to
-e, --environment string  build environment
--ignoreVendorPaths string ignores any vendor for module paths matching the given Glob pattern
--logLevel string          log level (debug/info/warn/error)
--noBuildLock              don't create .hugo_build.lock file
--quiet                   build in quiet mode
-M, --memoryToMemory      run hugo in memory (mostly useful when running the server)
-s, --source string         filesystem path to read files relative from
--themesDir string          filesystem path to themes directory

Use "hugo server [command] --help" for more information about a command.

ERROR command error: failed to load config: "C:\Users\Fahad\quickstart\hugo.toml:4:20": unmarshal failed: toml: expected character = C:\Users\Fahad\quickstart>notepad hugo.toml

C:\Users\Fahad\quickstart>hugo server
Watching for changes in C:/Users/Fahad/quickstart/archetypes, C:/Users/Fahad/quickstart/assets, C:/Users/Fahad/quickstart/content, C:/Users/Fahad/quickstart/data, C:/Users/Fahad/quickstart/i18n, C:/Users/Fahad/quickstart/layouts, C:/Users/Fahad/quickstart/static, C:/Users/Fahad/quickstart/themes/ananke/archetypes, C:/Users/Fahad/quickstart/themes/ananke/assets/ananke, C:/Users/Fahad/quickstart/themes/ananke/i18n, C:/Users/Fahad/quickstart/themes/ananke/layouts/, C:/Users/Fahad/quickstart/themes/ananke/partials/, C:/Users/Fahad/quickstart/themes/ananke/shortcodes/, C:/Users/Fahad/quickstart/themes/ananke/page.json, C:/Users/Fahad/quickstart/themes/ananke/package.hugo.json, C:/Users/Fahad/quickstart/themes/ananke/package.json, C:/Users/Fahad/quickstart/themes/ananke/images/
Watching for config changes in C:/Users/Fahad/quickstart/hugo.toml, C:/Users/Fahad/quickstart/themes/ananke/config_.default
Start building sites - Start building sites - 
hugo v0.153.2-798533a2013eab97198b0a155a8f4afab7e79865+extended windows/amd64 Build Date=2025-12-22T16:53:01Z VendorInfo=gohugoio
| EN
| Pages          8
| Paginator pages 0
| Non-page files 0
| Static files   1
| Processed images 0
| Aliases        0
| Cleaned        0
Built in 241 ms
Environment: "development"
Serving pages from disk
Running in Fast Render Mode. For full rebuilds on change: hugo server --disableFastRender
Web Server is available at http://localhost:1313/ (bind address 127.0.0.1)
Press Ctrl+C to stop
|
```

Accessing hugo site before doing deployments



VM Deployment: VM creation

The screenshot shows the Microsoft Azure portal interface. On the left, a sidebar navigation pane includes 'Compute infrastructure' and 'Virtual machines'. The main content area displays the 'Overview' tab for a virtual machine named 'hugo'. Key details shown include:

- Resource group: [cpit490](#)
- Status: Running
- Location: Switzerland North (Zone 1)
- Subscription: [Azure for Students](#)
- Subscription ID: 8e0719ae-9ae3-43f5-8a5f-9ab94ee06ac5
- Availability zone: 1
- Operating system: Linux (ubuntu 24.04)
- Size: Standard B1ms (1 vcpu, 2 GiB memory)
- Primary NIC public IP: 74.161.40.53 (1 associated public IP)
- Virtual network/subnet: [hugo-vnet/default](#)
- DNS name: Not configured
- Health state: -
- Time created: 12/28/2025, 11:23 AM UTC

The 'Networking' section shows:

- Public IP address: 74.161.40.53 (Network interface hugo739_z1)
- Public IP address (IPv6): -
- Private IP address: 10.0.0.4
- Private IP address (IPv6): -
- Virtual network/subnet: [hugo-vnet/default](#)
- DNS name: Configure

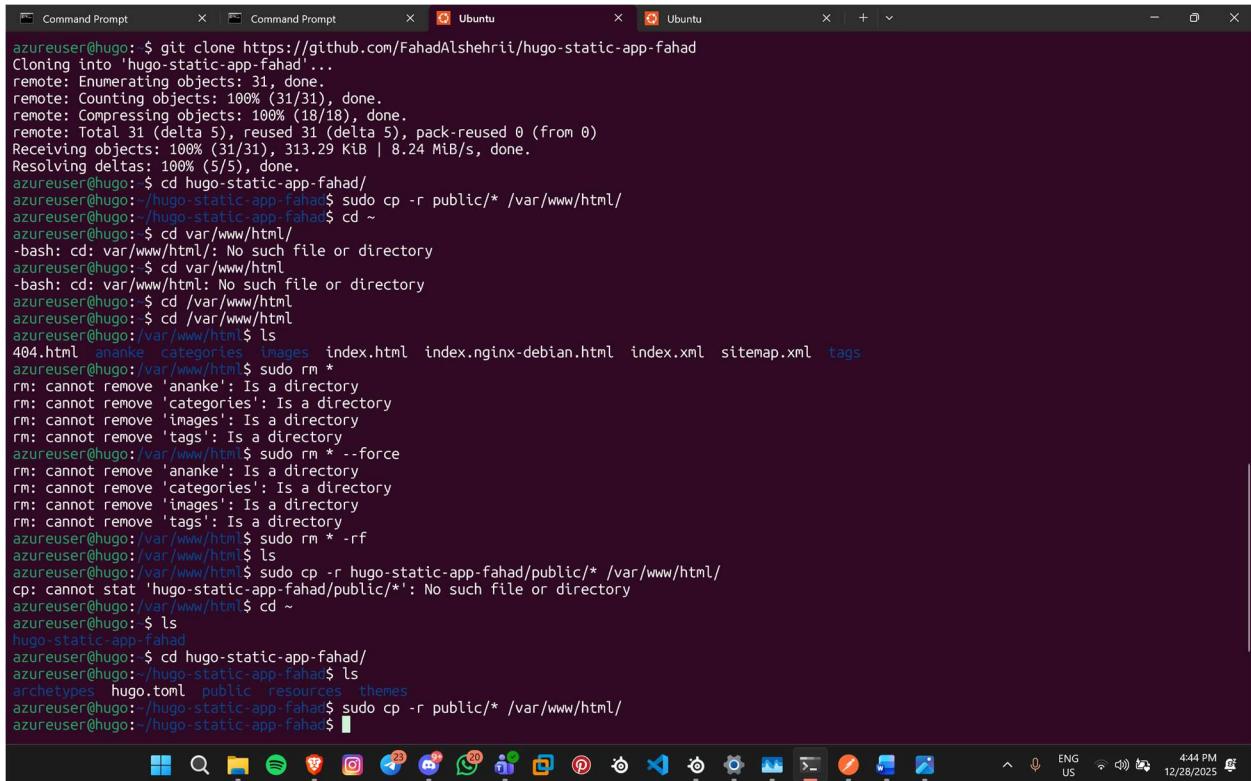
At the bottom of the main content area, there are tabs for 'Properties', 'Monitoring', 'Capabilities (7)', 'Recommendations (3)', and 'Tutorials'. The URL in the browser bar is https://portal.azure.com/?Microsoft_Azure_Education_correlationId=7fe25a4f-ced8-48cc-9459-e3767134f619&Microsoft_Azure_Education_newA4E=true&Microsoft_Azure_Education_aeoSubGuid=8e0719ae-9ae3-43f5-8a5f-9ab94ee06ac5#.

Downloading Nginx on VM

The terminal window shows the following output:

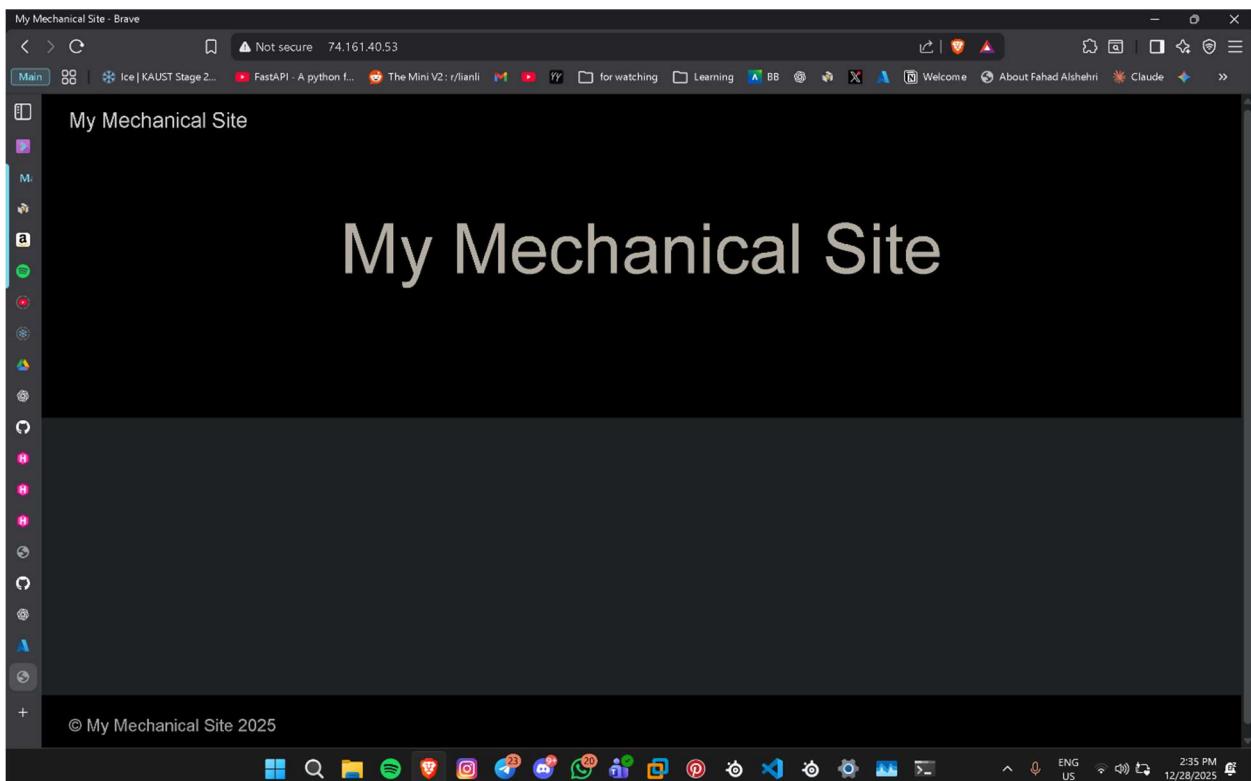
```
azureuser@hugo: $ sudo apt install nginx
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  nginx-common
Suggested packages:
  fcgiwrap nginx-doc ssl-cert
The following NEW packages will be installed:
  nginx nginx-common
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 564 kB of archives.
After this operation, 1596 kB of additional disk space will be used.
Do you want to continue? [Y/n] Y
Get:1 http://azure.archive.ubuntu.com/ubuntu noble-updates/main amd64 nginx-common all 1.24.0-2ubuntu7.5 [43.4 kB]
Get:2 http://azure.archive.ubuntu.com/ubuntu noble-updates/main amd64 nginx amd64 1.24.0-2ubuntu7.5 [520 kB]
Fetched 564 kB in 0s (7567 kB/s)
Preconfiguring packages ...
Selecting previously unselected package nginx-common.
(Reading database ... 68451 files and directories currently installed.)
Preparing to unpack .../nginx-common_1.24.0-2ubuntu7.5_all.deb ...
Unpacking nginx-common (1.24.0-2ubuntu7.5) ...
Selecting previously unselected package nginx.
Preparing to unpack .../nginx_1.24.0-2ubuntu7.5_amd64.deb ...
Unpacking nginx (1.24.0-2ubuntu7.5) ...
Setting up nginx-common (1.24.0-2ubuntu7.5) ...
Created symlink /etc/systemd/system/multi-user.target.wants/nginx.service → /usr/lib/systemd/system/nginx.service.
Setting up nginx (1.24.0-2ubuntu7.5) ...
 * Upgrading binary nginx
Progress: [ 78%] [#####.....]
```

Moving files to VM using git clone to deploy



```
azureuser@hugo: $ git clone https://github.com/FahadAlshehri/hugo-static-app-fahad
Cloning into 'hugo-static-app-fahad'...
remote: Enumerating objects: 31, done.
remote: Counting objects: 100% (31/31), done.
remote: Compressing objects: 100% (18/18), done.
remote: Total 31 (delta 5), reused 31 (delta 5), pack-reused 0 (from 0)
Receiving objects: 100% (31/31), 313.29 KiB | 8.24 MiB/s, done.
Resolving deltas: 100% (5/5), done.
azureuser@hugo: $ cd hugo-static-app-fahad/
azureuser@hugo:~/hugo-static-app-fahad$ sudo cp -r public/* /var/www/html/
azureuser@hugo:~/hugo-static-app-fahad$ cd ~
azureuser@hugo: $ cd var/www/html/
-bash: cd: var/www/html/: No such file or directory
azureuser@hugo: $ cd var/www/html
-bash: cd: var/www/html: No such file or directory
azureuser@hugo: $ cd /var/www/html
azureuser@hugo: $ cd /var/www/html
azureuser@hugo:~/var/www/html$ ls
404.html ananke categories Images index.html index.nginx-debian.html index.xml sitemap.xml tags
azureuser@hugo:~/var/www/html$ sudo rm *
rm: cannot remove 'ananke': Is a directory
rm: cannot remove 'categories': Is a directory
rm: cannot remove 'images': Is a directory
rm: cannot remove 'tags': Is a directory
azureuser@hugo:~/var/www/html$ sudo rm * --force
rm: cannot remove 'ananke': Is a directory
rm: cannot remove 'categories': Is a directory
rm: cannot remove 'images': Is a directory
rm: cannot remove 'tags': Is a directory
azureuser@hugo:~/var/www/html$ sudo rm * -rf
azureuser@hugo:~/var/www/html$ ls
azureuser@hugo:~/var/www/html$ sudo cp -r hugo-static-app-fahad/public/* /var/www/html/
cp: cannot stat 'hugo-static-app-fahad/public/*': No such file or directory
azureuser@hugo:~/var/www/html$ cd ~
azureuser@hugo: $ ls
hugo-static-app-fahad
azureuser@hugo: $ cd hugo-static-app-fahad/
azureuser@hugo:~/hugo-static-app-fahad$ ls
archetypes hugo.toml public resources themes
azureuser@hugo:~/hugo-static-app-fahad$ sudo cp -r public/* /var/www/html/
azureuser@hugo:~/hugo-static-app-fahad$
```

Site on VM using VM IP



PaaS Deployment: Creation

The screenshot shows the Microsoft Azure portal interface for creating a PaaS deployment. The left sidebar navigation bar includes Home, hugo-fahad (selected), Overview, Activity log, Access control (IAM), Tags, Diagnose and solve problems, Microsoft Defender for Cloud, Events (preview), Log stream, Resource visualizer, Deployment (selected), Deployment slots, Deployment Center, Settings, Environment variables (selected), Configuration (preview), Instances, Authentication, Identity, Backups, Custom domains, Certificates, Networking, Webhooks, and Add or remove favorites by pressing **Ctrl+Shift+F**. The main content area displays the 'Overview' page for the 'hugo-fahad' web app. It shows the following details:

Setting	Value
Resource group	cpnf490
Status	Running
Location	Switzerland North
Subscription	Azure for Students
Subscription ID	8e0719ae-9ae3-43f5-8a5f-9ab94ee06ac5
Default domain	hugo-fahad-c7phbuddfsbqc4bj.switzerlandnorth-01.azurewebsites.net
App Service Plan	ASP-cpnf490-92bf (B1: 1)
Operating System	Linux
Health Check	Not Configured
Git/Deployment username	
Git clone url	https://null@hugo-fahad-c7phbuddfsbqc4bj.scm.switzerlandnorth-01.azurewebsites.net/

Below the main table, there are tabs for Properties, Monitoring, Logs, Capabilities, Notifications (1), and Recommendations. The Properties tab is selected. To the right of the main table, there are sections for Deployment Center, Application Insights, and Networking. The Networking section shows the Virtual IP address as 20.208.5.35 and Outbound IP addresses as 20.250.63.97, 20.250.63.163, 20.250.63.236, 20.250.120.5, 20.250.120.78, 20.250.120.171, 20.250.108.88, 20.250.109.146, 20.250.110.52, 20.250.111.11, 20.250.200.134, 20.250.202.57, 20.208.5.35, 20.250.63.97, 20.250.63.163, 20.250.63.236, 20.250.120.5, 20.250.130.78, 20.250.130.171, 20.250.108.88, 20.250.109.146.

Enabling SCM & FTP

The screenshot shows the Microsoft Azure portal interface for configuring General settings for the 'hugo-fahad' web app. The left sidebar navigation bar includes Home, hugo-fahad (selected), General settings (selected), Overview, Activity log, Access control (IAM), Tags, Diagnose and solve problems, Microsoft Defender for Cloud, Events (preview), Log stream, Resource visualizer, Deployment, Settings, Environment variables (selected), Configuration (preview), Instances, Authentication, Identity, Backups, Custom domains, Certificates, Networking, Webhooks, and Add or remove favorites by pressing **Ctrl+Shift+F**. The main content area displays the 'General settings' page for the 'hugo-fahad' web app. It shows the following configuration options:

Setting	Value
SCM Basic Auth Publishing Credentials	<input checked="" type="checkbox"/>
FTP Basic Auth Publishing Credentials	<input checked="" type="checkbox"/>
FTP state	FTPS only
Inbound IP mode	IPv4
HTTP version	1.1
HTTP 2.0 Proxy	Off
SSH	<input checked="" type="checkbox"/>
Always on	<input type="checkbox"/>
Session affinity	<input type="checkbox"/>
Session affinity proxy	<input type="checkbox"/>
HTTPS only	<input checked="" type="checkbox"/>
Minimum Inbound TLS Version	1.2
Minimum Inbound TLS Cipher Suite	TLS_RSA_WITH_AES_128_CBC_SHA (Default) Change

At the bottom of the page, there are 'Apply' and 'Discard' buttons, and a 'Give feedback' link. The status bar at the bottom indicates ENG US, 12:49 PM, and 12/28/2025.

Using Kudo file manager to put zipped file “sitemap.zip” that compressed public directory files

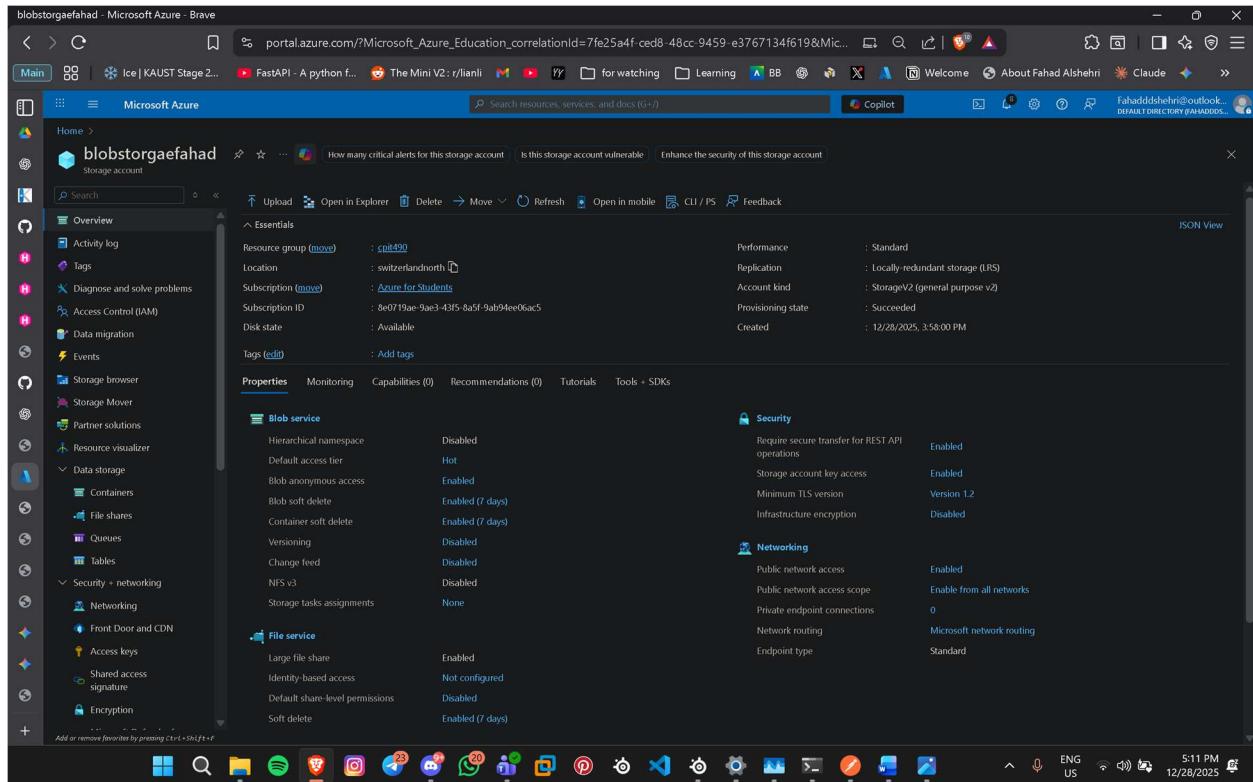
Note: tried multiple ways but zip file method is the best and fast

The screenshot shows the Azure App Service File Manager interface. The left sidebar includes options like Home, Environment, Logs, SSH, and File Manager. The main area displays a file list under the path `home/site/wwwroot/`. A modal window is open over the list, showing the contents of a `public` folder. This folder contains files: `index.html`, `index.xml`, `sitemap.xml`, and `sitemap.zip`. The `sitemap.zip` file is described as a Compressed (zipped) file of size 318. The status bar at the bottom indicates the deployment was completed at 5:00 PM on 12/28/2025.

App deployed on PaaS as seen url “hugo-fahad...”

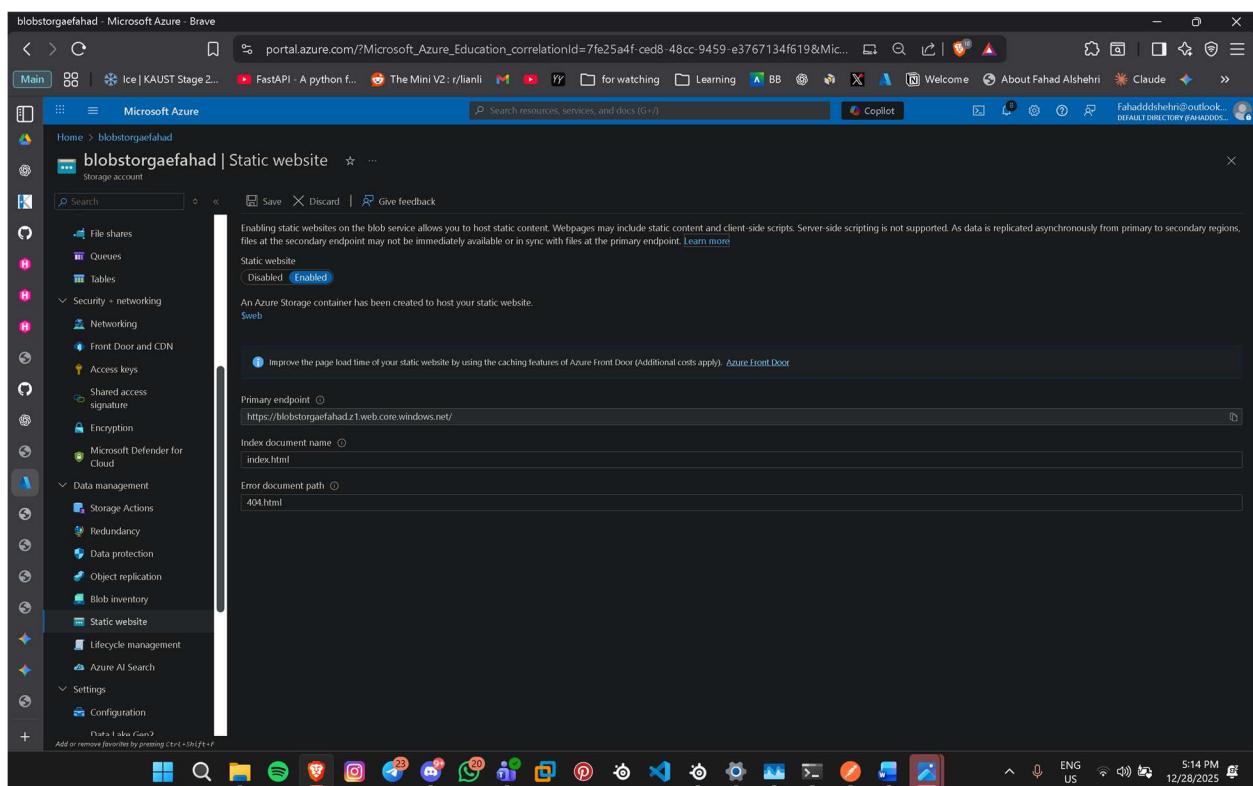
The screenshot shows a web browser window titled "My Mechanical Site". The page content displays the title "My Mechanical Site" in a large, bold font. At the bottom of the page, there is a footer with the text "© My Mechanical Site 2025". The browser's address bar shows the URL `hugo-fahad-c7hpbumfsbq4hj.switzerlandnorth-01.azurewebsites.net`. The status bar at the bottom indicates the page was loaded at 5:04 PM on 12/28/2025.

Object Storage Deployment:



The screenshot shows the Microsoft Azure Storage account overview for 'blobstorgaeafahad'. The left sidebar lists various storage services like Data storage, Security + networking, and Data management. The main pane displays the 'Essentials' section with details such as Resource group (cpl490), Location (switzerlandnorth), Subscription (Azure for Students), and Disk state (Available). It also shows Blob service and File service configurations, including access tiers, encryption, and endpoint types. The status bar at the bottom indicates the date and time as 12/28/2025, 5:11 PM.

Endpoint url & index,error docs to use to show site



The screenshot shows the 'blobstorgaeafahad | Static website' configuration page. The left sidebar includes 'Static website' under 'Data management'. The main pane shows the static website is currently disabled. It provides fields for enabling Azure Front Door, setting the primary endpoint to 'https://blobstorgaeafahad1.web.core.windows.net/', specifying the index document name as 'index.html', and defining the error document path as '404.html'. The status bar at the bottom indicates the date and time as 12/28/2025, 5:14 PM.

Enabling anonymous blob access to allow public access to site resources

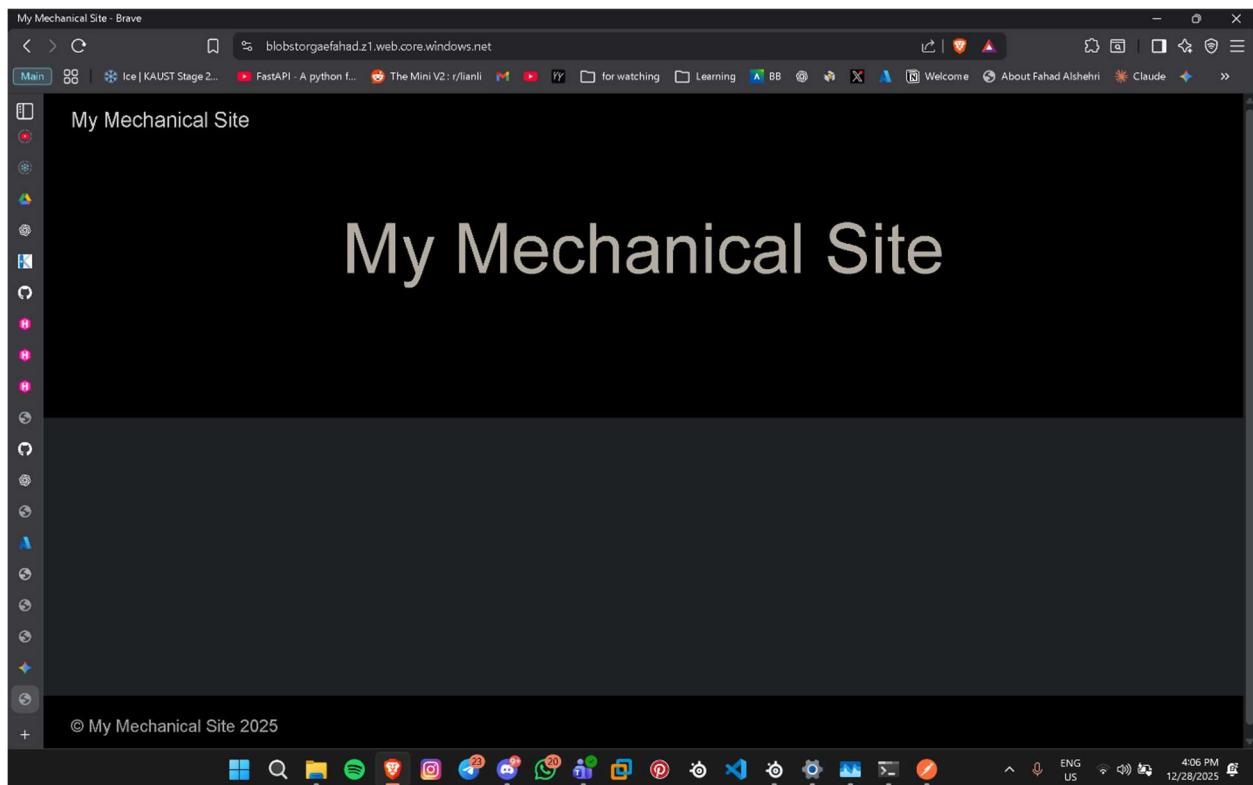
The screenshot shows the Azure Storage Account configuration page for 'blobstorgaeafahad'. The 'Configuration' tab is selected. Under 'Storage account', the 'Allow Blob anonymous access' setting is set to 'Enabled'. Other settings like 'Secure transfer required' and 'Allow storage account key access' are also visible.

Upload of the Hugo site files HTML, XML etc.. in the \$web container in Azure Blob Storage

The screenshot shows the Azure Blob Container '\$web' for 'blobstorgaeafahad'. The 'Overview' tab is selected. The container contains several blobs: 'aranke', 'categories', 'images', 'tags', '404.html', 'index.html', 'index.xml', and 'sitemap.xml'. Each blob's properties like last modified, access tier, size, and lease state are listed.

Name	Last modified	Access tier	Blob type	Size	Lease state
aranke	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	2.14 KB	Available
categories	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	2.52 KB	Available
images	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	453 B	Available
tags	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	347 B	Available
404.html	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	2.14 KB	Available
index.html	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	2.52 KB	Available
index.xml	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	453 B	Available
sitemap.xml	12/28/2025, 4:04:48 PM	Hot (Inferred)	Block blob	347 B	Available

Accessing the live static website using the endpoint



Prices Of Each VM, PaaS, Object Storage

The screenshot shows the Microsoft Azure Pricing Calculator interface. At the top, it displays "Virtual Machines" with a total cost of \$19.27 monthly. Below this, there are dropdown menus for Region (Switzerland North), Operating system (Linux), Type (Ubuntu), and Tier (Standard). Further down, there are filters for Category (All) and Instance Series (All), with a detailed instance breakdown for "B1ms: 1 Cores, 2 GB RAM, 4 GB Temporary storage, \$0.026/hour". The quantity is set to 1 and the duration is 730 hours. A "Savings Options" section encourages exploring pricing models to optimize costs. The bottom right corner shows the date and time as 6:20 PM 12/28/2025.

VM Cost: \$19.27 monthly

Pricing Calculator | Microsoft Azure - Brave

azure.microsoft.com/en-us/pricing/calculator/

Main App Service Basic Tier; 1 B1 (1 Core(s), 1.75 GB RAM, 10 GB Storage) x 7... Upfront: \$0.00 Monthly: \$14.45

App Service

Region: Switzerland North Operating system: Linux Tier: Basic

Basic

INSTANCE: B1: 1 Cores(s), 1.75 GB RAM, 10 GB Storage, \$0.020

1 Instances 730 Hours = \$14.45

SSL Connections \$0.00

Custom Domain and Certificates \$0.00

Upfront cost \$0.00
Monthly cost \$14.45

Support SUPPORT: Basic (Included)

Chat with Sales

PaaS Cost: \$14.45 monthly

Pricing Calculator | Microsoft Azure - Brave

azure.microsoft.com/en-us/pricing/calculator/

Main Storage Accounts Block Blob Storage, General Purpose V2, Flat Namespace, L... Upfront: \$0.00 Monthly: \$1.15

Storage Accounts

Get \$200 credit plus free monthly amounts of popular services for 12 months—including Block Blob Storage, Standard tier. See free amounts

Region: Switzerland North Type: Block Blob Storage Performance: Standard Storage Account Type: General Purpose V2

File Structure: Flat Namespace Access tier: Hot Redundancy: LRS

Capacity 1 GB

Savings Options

Save up to 38% on pay-as-you-go prices with 1-year or 3-year Azure Storage Reserved Capacity. Learn more about Azure Storage Reserved Capacity pricing.

Pay as you go

Pay as you go

Chat with Sales

Blob price: \$1.15 monthly

Outbound Data Transfer



The first 5 GB/Month of Inter Region data transfer and the first 100 GB/Month of Internet Egress data transfer are free in each zone.

5

GB

Since the first 100GB of data transfer is free on Azure, setting the limit to 2GB will not add any cost to the monthly estimate

Pricing comparison:

Estimated for 10,000 monthly visitors / 2GB Bandwidth.

Component	VM	PaaS	Object storage
Compute/Storage	\$19.27 / month (Standard B1ms Instance)	\$14.45 / month (Basic B1 Tier)	\$1.15 / month (Standard, LRS)
Bandwidth (2GB)	(First 100GB/mo is free) \$0	(First 100GB/mo is free) \$0	(First 100GB/mo is free) \$0
Total Monthly Cost	\$19.27	\$14.45	\$1.15

Availability analysis:

Component	VM	PaaS	Object storage
SLAs	95% (Standard HDD)	99.95%	99.9%
Redundancy	Manually must configure backups	Automatic Azure manages hardware & runtime redundancy	Automatic Done by azure (LRS)
Failure Points	High, Risk of OS failure, single disk failure, and misconfiguration	Dependent on runtime stack and region uptime	Lower, no OS or server management risks

Recommendation:

I recommend option 3 (**Object storage**)

Cost: It is the cheapest option by far and it only costs about (\$1.15) per month. The other options cost between (\$14.45) and (\$19.27) per month and paying that much for a static website that doesn't need a server is just a waste of money.

Reliability: a static site doesn't need a complex server to run, This makes it safer because there is no OS to update and no risk of a server crash. It also has a better uptime guarantee (99.9%) compared to the VM (only 95%).

Scalability: Azure handles the traffic automatically. If the site suddenly gets a lot of visitors, Object storage will handle it without any issues and no need to manually add more servers or change settings.

Future Roadmap: DevOps Integration

As a next phase, the goal is to transition these manual deployments into a fully automated **CI/CD Pipeline** using:

- **Infrastructure as Code (IaC):** Leveraging **Terraform** to provision the Azure resources.
- **Continuous Deployment:** Using **GitHub Actions** to automate site builds and deployments upon every code push, ensuring a modern DevOps workflow.