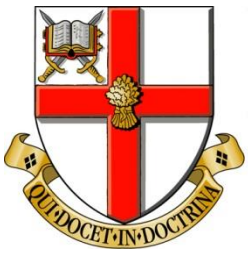

University of Chester

Unveiling the Operations of Datacentres: The backbone of Cloud Computing

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Research Dissertation

Department of Computer Science, Electronics and Electrical Engineering

1 Disclaimer

This work is original and has not been previously submitted in support of any other course or qualification.

Igor Jakub Karchut
Sign:

Date:16/04/2023

2 Abstract

Hypothesising that there was a gap in knowledge for the general public surrounding datacentres, the dissertation aimed to uncover the operations of datacentres. Alongside transforming the uncovered information into a digestible format of a responsive, interactive, and accessible webpage by having used an agile methodology to design and code the webpage in atom, visual code, and GitHub. Whose effectiveness then was tested using a questionnaire form which indicated through the results that the gap in knowledge existed and the webpage was able to pass on the knowledge effectively. The results however indicated similar testers possibly skewing the results. Furthermore, there were improvements that could be made to the artifact and research resulting in the future steps involving further topic research and information gathering alongside re-coding the artifact to better comply with results from code checkers as well as re-designing the form to test for accessibility, re-designing the questions to provide more accurate results and testing on a larger scale with a variety of attributes that could affect the results such as age, profession, education, etc..

3 Acknowledgements

I acknowledge and thank,

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4 Contents Page

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5 List of Figures/Photographs

6 Background and Motivation

6.1 Background Topic Research

There are plentiful amounts of information on cloud infrastructure and datacentres however they all fall under the same problems. The information was found in large bodies of text as seen in (Daigle, 2021) which are difficult to get through especially for users with learning difficulties such as dyslexia. Or the information was found in a video/audio format which weren't easy to navigate through as they required scrubbing or watching the video to find information needing as it may include unrelated information. Non education / governmental publishers but who were still trusted such as google (*See what's new and browse our innovations* 2022) tried to improve on this however their website still outsources information finding to large documents filled with text or audio formats. Users who lack patience or have trouble with retaining attention such as users with learning difficulties may give up on watching the video or reading the information short of finding the information they were after which is therefore the need to bridge the gap in this content depravity by creating a webpage that has less initial text and adds image associated to make it easier for people with learning difficulties such as dyslexia whilst adding interactivity to allow users with learning difficulties such as autism to be able to interact and retain their attention to create an informative webpage.

6.2 Aims & Objectives

6.2.1 Aims

- To accumulate accurate diverse knowledge on datacentres operations.
- To identify if people lack knowledge around datacentres.
- Transform the knowledge into a responsive, interactive, and accessible webpage.

6.2.2 Objectives

- Document research on datacentres
- Create a webpage.
- Add research to webpage.
- Make webpage accessible.
- Make webpage responsive.
- Make webpage research interactive.
- Create a form for testing the webpage.
- Test general public's knowledge on datacentres
- Test how well the webpage educates the general public.
- Collate the data and create graphics representing the results.

6.3 Hypothesis

Developing an accessible, interactive, and responsive informative webpage about datacentre will significantly reduce the knowledge gap among the general population regarding datacentres and their fundamental aspects.

6.4 Project Management

The project was complete on time by having used several time management tools such as a Gantt chart and kanban board.

Gantt chart was used as it allowed for keeping track of long-term goals such a draft milestone submission. This was performed by graphically representing the time left until the milestone through a bar chart.

Kanban was used for keeping track of tasks necessary to transform the original sprint designs into a html-based webpage. Colour was used to highlight the personal perceived difficulty of the tasks which correlate with how long it took to implement the feature.

GitHub was used for version control of the code space. This provided periodic backups, error handling through merge requests that dealt with conflicting code and allowed for the user of GitHub-pages to publicly host the webpage.

6.4.1 Time breakdown

The time scheme for the project was difficult due to other module lectures, assignments and part time work which limited the time available and made motivation difficult to obtain therefore most work was performed on the only day off available which shared space with other chores.

Module Lectures 20H
Documentation 60H
    Writing milestone drafts, making the report, referencing
Research 45H
    Searching for sources, reading documentation, compiling
Design 15H
    Webpage 5H
        Initial design sketches and flow
    Questionnaire 10H
        Question type and layout
Implementation 160H
    Webpage 80H
    Html 30H
    JavaScript 30H
    CSS 20H
Questionnaire writing 5H
    Writing questions 5H
Testing / fixing 80H
    Webpage 40H
    HTML validators fixes 20H
    CSS validators fixes 10H
    JS validator fixes 10H
Questionnaire 20H
    Sending out 15H
    Compiling 5H

6.4.2 Milestones, meetings & Feedback

Meeting 1

Discussed making interactive diagrams and presentations tailored to different business size types about how datacentres were used in the cloud and how their use could benefit them compared to their current infrastructure.

Feedback

Overall positive and accepting of the concept.

Milestone 1 - Uploaded

Feedback

“”

Meeting 2

Discussed changing the object of research to being an accessible interactive informative webpage on how datacentres work tailored to the public due to the lack of responses received from queries sent to business. As well as discussed, creating a form to use for testing the publics knowledge on datacentres and on the effectiveness of the webpage’s ability to portray information to prove that there was a gap in public knowledge thus justifying the necessity to create the webpage alongside proving that the webpage was informative.

Feedback

“No problem with the change and happy that progress was being made as they were worried that it was not started.”

Milestone 2 - Uploaded

Feedback

“” – No feedback

Milestone 3 - Uploaded

Feedback

“”– No feedback

Milestone 4- Uploaded

Feedback

“”– No feedback

Milestone 5- Not uploaded (Sent to supervisor but forgot to submit to Turnitin)

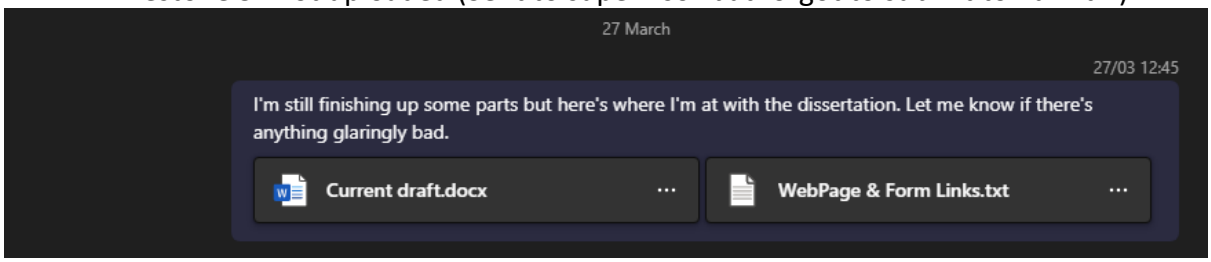


Figure 1 Draft to Supervisor

Feedback

“”– No feedback

6.5 Personal involvement

6.5.1 Research interest

I chose this subject as I believed that datacentres were the centre of cloud computing due to their increased presence over the years for storage, processing and hosting of various software or websites. Due to their lower costs and easy of deployment it has become the choice for any non-corporate business therefore resulting in many websites and services originating from datacentres.

Originally, I wanted to find out how datacentres in the cloud affected businesses and wanted to develop interactive diagrams to show how an information would flow. However, I had no response on their infrastructure from any business I contacted therefore I change the subject to how they worked generally and wanted to pass on the information to the general public through an easily digestible format.

6.5.2 Research Questions

I wanted to obtain first hand, accurate and in use business network structure from different business sizes to see their use of cloud infrastructure and lack of to compare their costs and benefits. This however fell through as no contacted businesses responded to my correspondence most probably due to legal and security issues.

I therefore instead researched about datacentres as I wanted to find out how they work due to my lack of knowledge on them. Furthermore, I concluded that others without my background in computing would hold even less knowledge on datacentres which is why I wanted to research this topic and answer questions they may have.

6.5.3 Data collection

I wanted to use various trusted sources such as education bodies and governmental bodies to have the most accurate reliable information to allow my work to be trustworthy. However, a lot of the documentation was specific to certain scenarios and some information wasn't well documented.

For the questions I wanted to use a variety of ages, educational backgrounds and work backgrounds however was limited to the people who wished to participate due to the allowed time, location, policies that restricted outside involvement resulting which in similar testers.

6.6 Stages of Work

6.6.1 Research

Many topics from infrastructure, power, layout, cooling, technology, etc. were researched in order to compile the very split information into one place.

6.6.2 Design

Next came design, how the content would look, how the user would interact with the content and how the content would look on the webpage. This included the sketches as seen in the design chapter which depict the simple designs for housing content and the general page layout. This evolved in later iterations due to the use of the agile methodology to improve the UX of the webpage.

6.6.3 Coding

Originally the project use Atom due to its simplicity and integration with the GitHub workspace however it became sunset due to security breach issues therefore it transitioned to Visual Studio Code which had similar integrations, so GitHub was then used for its various functions such as version control, branches, merging, history and kanban to keep track of coding tasks which could have been done on GitHub through labels and so forth but it felt easier to use a kanban board due to its easier view of progression and modification which ended been created using a Miro board to allow for easy updating and alterations.

Simultaneously to designing and creating the webpage, the design and creation of the questionnaire took place. The questionnaire questions were based on the knowledge gathered from the initial research and used in google forms to allow for ease of distribution, collection, and analytics.

7 Chapter 2 Literature Review

7.1 Location

7.1.1 Accessibility:

Being located near cities ensures convenient access to transportation networks, including highways, airports, and fibre optic communication lines. This facilitates the movement of equipment, staff, and data to and from the data centre.

7.1.2 Connectivity

Cities typically have robust telecommunication infrastructure, including high-speed internet connectivity and network providers. By locating data centres near cities, they can leverage these existing network resources, ensuring fast and reliable connectivity for their operations.

7.1.3 Customer Proximity

Many businesses and organizations that rely on data centres are situated in urban areas. By having data centres nearby, it becomes easier to establish low-latency connections between the data centre and its customers, resulting in improved performance and responsiveness.

7.1.4 Power Availability

Urban areas generally have a more reliable power supply and access to multiple power sources. This is crucial for data centres that require high levels of power to support their operations. Being close to cities allows data centres to tap into stable and diverse power grids, reducing the risk of prolonged outages.

7.1.5 Disaster Risk Mitigation

While data centres implement robust disaster recovery measures, including backup power and redundancy, being close to cities can provide additional advantages in terms of disaster risk mitigation. Urban areas often have better emergency response systems, such as fire departments and medical facilities, which can be crucial in case of emergencies.

7.1.6 Skilled Workforce

Cities offer a larger pool of skilled professionals, including IT specialists, engineers, and technicians. Proximity to urban areas allows data centres to attract and access a talented workforce, making it easier to recruit and retain skilled personnel.

7.1.7 Business Ecosystem

Cities serve as hubs for various industries and businesses. By locating data centres near cities, they can take advantage of the thriving business ecosystems, networking opportunities, and potential partnerships with other organizations.

7.2 Services

7.2.1 Server Hosting

Datacentres offer “stable environments, enhanced security, equipment and alarms, uninterrupted power (UPS and generators), high-speed network connectivity, and other features” (*Data Center Access* 2019) alongside hosting services for websites, software storage and virtualization of machines and processes which eliminates the need for companies to maintain their own server rooms providing lower costs.

7.2.2 Colocation

Datacentres provide colocation services, where the datacentre can “leases space, power, and cooling” (*Colocation Data Centers* 2021). Colocation enables companies to leverage the datacentre’s robust infrastructure without investing in their own facility.

7.2.3 Virtualization

Virtualization is the “simulation of the software and/or hardware upon which other software runs” (Scarfone et al., 2021) which is used in datacentres to optimize resource utilization and improve scalability as it enables the creation of virtual machines (VMs) that can run multiple applications on a single physical server.

7.2.4 Data Storage

Secure and scalable storage solutions. This includes options such as “network-attached storage (NAS)” (Krzyzanowski, 2021), “storage area network (SAN)” (*Continuing it training program - storage area networks* 2022), and object storage.

7.2.5 Network Connectivity

Robust network connectivity services, providing high-speed internet access and connectivity to multiple network providers.

7.2.6 Disaster Recovery:

Providing backup and recovery services by implement strategies to protect data from natural disasters, system failures, or human errors as seen in (AKILLI & Güneş, 2016).

7.2.7 Managed Services:

As seen in the example off (*Managed Services* 2023), datacentres provide proactive monitoring, maintenance, and management of IT infrastructure. This includes managing servers, networks, security systems, and backups, allowing businesses to focus on their core operations.

7.2.8 Security

Datacentres prioritize security measures to protect data and infrastructure. They implement physical security controls, such as access controls, surveillance systems, and biometric authentication as seen in the (*Data Center Operations* 2017). Datacentres also employ advanced cybersecurity measures, including firewalls, intrusion detection systems, and encryption, to safeguard against unauthorized access and data breaches.

7.2.9 Compliance and Regulations

Datacentres may provide compliance with industry regulations and standards, such as HIPAA (Health Insurance Portability and Accountability Act) for healthcare data or GDPR (General Data Protection Regulation) for European Union data. They implement security controls and practices to meet the specific compliance requirements of different industries.

7.3 Server Layout

7.3.1 Row Organization

"Datacentre equipment is laid out in rows of racks with alternating cold (rack air intake side) and hot (rack air heat exhaust side) aisles between them" (Lintner et al., 2011) allowing for efficient cooling and space efficiency.

7.3.2 Cabling Management:

Cables are neatly routed to avoid clutter, provide easy maintenance and preventing tangling and interference with airflow as "Jumbled, disorganized, "spaghetti" cabling and wires can clog air conduits, restricting desired airflow" (*Evidence-based best practices around Data Center Management* 2016).

7.3.3 Airflow Management

"Effective air management implementation minimizes the bypass of cooling air around rack intakes and the recirculation of heat exhaust back into rack intakes. When designed correctly, an air management system can reduce operating costs, reduce first cost equipment investment, increase the datacentre's power density (Watts/ square foot), and reduce heat related processing interruptions or failures." (Lintner et al., 2011)

7.3.4 Rack Identification and Labelling

To facilitate maintenance, management, and troubleshooting the datacentres "will label all equipment within the cabinets so that hardware is easily identifiable" (*IU Data Center standards* 2023). Labels are placed on servers, rack units, and power distribution units (PDUs) to provide information about their location, connectivity, and power requirements. This labelling system helps technicians identify and locate specific servers and troubleshoot any issues quickly.

7.3.5 Tiers

"Data center tiers are a standardized ranking system that indicates the reliability of data center infrastructure. This classification ranks facilities from 1 to 4, with 1 being the worst and 4 the best-performing level." (Velimirovic, 2023) this was developed by the Uptime Institute, a globally recognized authority in data centre design and management. It provides a framework for evaluating and comparing the resilience and performance of data centre facilities.

7.3.5.1 Tier I

Tier I data centres have basic infrastructure components and offer limited availability. They typically have a single path for power and cooling, which makes them susceptible to interruptions for maintenance or equipment failures. Tier I data centres provide an uptime availability of approximately 99.671%.

7.3.5.2 Tier II

Tier II data centres introduce a higher level of redundancy compared to Tier I. They have redundant components for power and cooling, allowing for scheduled maintenance and minimizing the impact of some equipment failures. However, Tier II data centres still

have a single path for certain infrastructure components. They provide an uptime availability of approximately 99.741%.

7.3.5.3 Tier III

Tier III data centres are designed to provide a higher level of availability and redundancy. They have multiple redundant components and distribution paths for power and cooling, allowing for maintenance without disrupting operations. Tier III data centres provide an uptime availability of approximately 99.982%. This tier is often the minimum requirement for critical applications and services.

7.3.5.4 Tier IV

Tier IV data centres are the most robust and fault-tolerant facilities. They have multiple independent paths for power and cooling, providing the highest level of availability and redundancy. Tier IV data centres offer a fault-tolerant infrastructure with no single points of failure and provide an uptime availability of approximately 99.995%. These data centres are typically used for mission-critical applications and services that require continuous operations without any downtime.

7.3.6 Racks

In racks, “Only height of the module is measured in U’s. 1U=1.75 inch, Width of the rack is standard 19 inch. 10”, 21”, and 23” racks are also used. Total height of the rack is also standard 42 U or 45 U” (Jain, 2021) This provides a standardized way to describe the vertical space within a server rack.

7.3.7 Form Factors:

Different types of equipment come in varying form factors, indicating their physical size and shape. Servers, for example, can be designed in different form factors such as 1U, 2U, or 4U, among others. The "U" designation corresponds to the number of rack units the equipment occupies.

7.3.7.1 1U

A 1U server is compact and occupies a single rack unit, which is equivalent to 1.75 inches or 44.45 millimetres in height. These servers are typically thin and horizontally mounted, making them space-efficient and allowing for high-density deployments.

7.3.7.2 2U

A 2U server is taller and occupies two rack units, or 3.5 inches or 88.9 millimetres in height. These servers offer more room for additional components or expansion options compared to 1U servers while still maintaining a relatively compact form factor.

7.3.7.3 3U

A 3U server is a mid-sized server that occupies three rack units, equivalent to 5.25 inches or 133.35 millimetres in height. These servers strike a balance between compactness and expansion capabilities, offering more room for additional components and features compared to 1U and 2U servers, while still being relatively space efficient.

4U

A 4U server is larger and occupies four rack units, or 7 inches or 177.8 millimetres in height. These servers are suitable for applications that require extensive computing power, storage capacity, or expansion capabilities. They provide more space for components, such as multiple processors, additional storage drives, or advanced cooling systems.

7.3.7.4 Open Rack

Open-frame racks without side panels or doors provide easy access to equipment and efficient cooling by allowing unrestricted airflow.

7.3.7.5 Enclosed Rack

Solid sides and doors provide physical security. They are used in data centres where security is a top priority.

7.3.7.6 Cabinet Rack

Enclosed racks with additional features such as cable management systems, adjustable mounting rails, and integrated power distribution units (PDUs). These offer enhanced organization and functionality.

7.3.7.7 Two-Post Rack

Known as relay racks or telco racks, two-post racks consist of two vertical posts and adjustable mounting rails. They are primarily used for network equipment, patch panels, and telecommunications devices.

7.3.7.8 Four-Post Rack

Four-post racks provide sturdy and stable support for heavy equipment. They have four vertical posts and adjustable mounting rails, offering flexibility in accommodating various server depths.

7.3.7.9 Blade Chassis

Blade chassis is a specialized rack arrangement designed for blade servers. They "provide a scalable means for combining multiple blade server or storage units in a single enclosure, and are designed to allow service technicians to easily add or replace (hot-swap) blades in the field" (*Server type* 2023).

7.3.7.10 Modular Rack

Self-contained, preconfigured units that combine server, storage, networking, and power components. These racks are designed for easy scalability and quick deployment.

7.4 Power Delivery

7.4.1 Backup Generators

Backup generators are installed to provide emergency power “to make up when the grid is not present” (Chalise et al., 2015). These generators are often fuelled by diesel or natural gas and can sustain the data centre's power requirements for extended periods, ensuring continuous operations.

7.4.2 UPS Systems

UPS” Uninterruptible power supply. It's a device that permits a computer keep running for a few hours during a blackout or when the primary power source is lost.” (*Importance of UPS for data centers* 2021) they act as a bridge between the utility power and backup generators and provide short-term power during the transition between the utility power outage and the generator startup. UPS systems also help regulate power quality by filtering out voltage spikes, sags, or other electrical disturbances that can harm the sensitive equipment.

7.4.3 Power Distribution Units (PDUs)

“PDUs are part of a data center’s electrical distribution system, which includes utility or generator-supplied power, building switchgear and transformers, and UPS systems.” (*Reduce energy losses from power distribution units (PDUS)* 2020). PDUs are used to distribute power from the main power sources to individual racks or equipment. They ensure that each server rack or cabinet receives the appropriate amount of power according to its requirements.

7.4.4 Electrical Panels

“Power to the racks was provided by a number of panel boards within the data center supplied from four distribution panels” (Xu & Greenberg, 2007) From this review, it can be seen how electrical panels are used to control and manage power distribution within the data centre. They house circuit breakers, fuses, and monitoring devices to regulate the flow of electricity, protect against overloads, and provide safety measures.

7.4.5 Scalability

Power infrastructure in data centres needs to be scalable to accommodate future growth and increasing power demands. As data centres expand, additional power capacity must be available to support the installation of new servers, storage systems, and networking equipment.

7.4.6 Automatic Transfer Switches (ATS)

Automatic transfer switches are used to manage the transition between utility power sources in the event of an outage assuring “that loss of power to critical loads and the resulting consequences will not occur” (*Automatic Transfer Switches (ATS) In Critical Applications* 1999). These switches automatically detect the loss of power from one source and seamlessly transfer the load to the backup power source, such as generators or UPS systems.

7.4.7 A-B Power Feeds

Redundant power paths are commonly referred to as A-B power feeds. A and B represent separate power sources that feed into different electrical distribution systems within the data centre. Each server rack or cabinet is connected to both A and B power feeds to ensure redundancy and fault tolerance. Furthermore, these power paths may have separate power providers connected to different substations.

7.4.8 Power Conditioning

Data centres employ power conditioning mechanisms to ensure the quality and reliability of the electricity received from the grid. Power conditioning equipment includes transformers, voltage regulators, and power filters.

7.4.9 Transformers

Transformers are used to step up or step down the voltage of the incoming power to match the requirements of the data centre's electrical infrastructure. They “converts one AC voltage to another AC voltage at the same frequency” (*Power Transformers* 2013) ensuring a stable voltage supply and potentiating against voltage fluctuations.

7.4.10 Voltage Regulators

“To maintain a constant voltage level” (Dhawale et al., 2019) voltage regulators are used. They help protect sensitive equipment from damage caused by voltage surges.

7.4.11 Power Filters

Power “filters are utilized to eliminate harmonics and enhance power quality of distribution system” (Hantouli, 2018) ensuring clean and reliable power for the data centre equipment preventing disruptions, data corruption, and performance issues caused by electrical disturbances.

7.4.12 Renewable

Some data centres also incorporate renewable energy sources, such as solar panels or wind turbines, into their power infrastructure as part of their sustainability efforts. These renewable energy sources can supplement the power drawn from the electrical grid and reduce the data centre's environmental footprint.

7.4.13 Load Transfer and Management

Once the backup generators are operational, the power load is transferred from the UPS system to the generators. The ATS controls this transfer and ensures a smooth transition of power supply. It is important to distribute the load evenly across the backup generators to prevent overloading and ensure optimal performance. Load management systems monitor and balance the power consumption of the data centre equipment to ensure efficient utilization of the backup generator capacity.

7.5 Connectivity

7.5.1 Load Balancing

Data centres utilize load balancing techniques to evenly distribute network traffic across multiple servers and network connections. Load balancers intelligently distribute incoming requests, optimizing resource utilization and preventing network congestion. Load balancing helps ensure smooth and efficient data transfer by preventing any single server or network link from becoming overwhelmed.

7.5.2 Peering and Internet Exchange Points (IXPs)

"An IXP is a data center with network switches through which ISPs exchange traffic (peer) with each other" (Alam et al., 2022). Peering allows for direct network connections between networks, improving latency and reducing the reliance on third-party transit providers and serve as meeting points where multiple networks interconnect, enabling efficient exchange of data traffic.

7.5.3 Content Delivery Networks (CDNs)

Data centres may incorporate CDNs into their network infrastructure to enhance content delivery and improve performance for users in different geographic locations. CDNs distribute content across a network of "geographically distributed servers that caches content so that users can access cached copies of the content instead of getting it from the original server" (Krzyzanowski, 2021).

7.5.4 Switches

Switches are devices that connect multiple servers and other network devices within a data centre. They operate at the data link layer (Layer 2) of the network protocol stack and "channels incoming data from any of multiple input ports to the specific output port that will take the data toward its intended destination" (Stouffer et al., 2019).

7.5.5 Routers

Routers are "gateway between two networks at OSI layer 3 and that relays and directs data packets through that inter-network" (Stouffer et al., 2019) that facilitate the exchange of data packets between different networks, including external networks outside the data centre.

7.5.6 Switching and Routing Protocols

Network switches and routers rely on various protocols to manage the flow of data within a data centre. They use protocols such as "Ethernet" (*Ethernet protocol* 2021) and "VLAN (Virtual Local Area Network)" (Editor, 2021), allowing switches to establish connections between devices and create logical network segments for improved network management and security.

7.5.7 Fiber Optic Cables

Fiber optic cables are "thin strands of coated glass fibers" (*Fiber Optics* 2023) that transmit data using pulses of light. They are designed to provide high-speed and long-distance data transmission capabilities. Within a data centre, fibre optic cables are used for

both interconnecting equipment within the same data centre and establishing connections to external networks.

7.5.8 Structured Cabling Systems

Structured cabling involves the use of standardized cabling components, including fibre optic cables, patch panels, connectors, and cable management systems, to create a unified and organized cabling infrastructure. They adopt industry-standard cabling specifications, such as the "TIA/EIA-568-B" (*Interconnecting your hubs, transceivers, and Nic Cards* 2023) or "ISO/IEC 11801" (*Subject: Data Communications Cabling FAQ* 1995), to ensure compatibility, scalability, and maintainability of the cabling infrastructure.

7.5.8.1 Fiber Optic Connectivity:

Fiber optic cables can establish direct connections between two network devices, such as servers, switches, or routers. This provides dedicated and high-speed links for specific applications or services. They also can use channels "designed to significantly improve the speed at which data is transmitted" (Burton, 1195).

7.5.9 Protocols

Routing protocols, such as "Border Gateway Protocol (BGP)" (Dordal, 2023) and "Open Shortest Path First (OSPF)" (Brad, 2021), enable routers to exchange routing information and determine the most efficient paths for data packets. Additionally, network switches and routers support protocols like "Quality of Service (QoS)" (*QoS (quality of service)* 2023) to prioritize certain types of traffic, ensuring optimal performance for critical applications or services.

7.6 Cooling

7.6.1 Air Conditioning Units (CRAC/CRAH)

Computer Room Air Conditioning (CRAC) or Computer Room Air Handler (CRAH) units are commonly used in data centres "to maintain the server and switch gear inlet temperatures and moisture content within an acceptable envelope" (Meadows, 2017). These units use refrigeration technology to cool the air and maintain the desired temperature and humidity levels within the data centre. CRAC units typically blow cool air from under the raised floor or overhead, while CRAH units release cool air from above. They are often connected to the data centre's overall HVAC (Heating, Ventilation, and Air Conditioning) system.

7.6.2 Chilled Water Systems

"Chilled water" (Ling et al., 2018) systems involve circulating chilled water through a network of pipes to remove heat from the data centre. These systems use chillers to cool the water, and the chilled water is then distributed to air handling units or cooling coils located within the data centre. The chilled water absorbs heat from the air, and the warm water is returned to the chillers for re-cooling. Chilled water systems offer high cooling capacity and energy efficiency, making them popular in large-scale data centres.

7.6.3 Direct Expansion (DX) Cooling

DX cooling systems, also known as direct expansion or refrigerant-based cooling, use a “refrigerant” (Choudhury, 2023) to directly cool the air within the data centre. These systems utilize indoor units, like air conditioning units, to blow cold air directly into the data centre space. DX cooling is often used in smaller or modular data centres where the cooling load is relatively low.

7.6.4 Liquid Cooling

In Liquid cooling systems “coolant is passed over vital components, draws away heat, has this heat dispersed by means of a radiator, and continues through the cooling circuit again” (Ellsworth, 2012). These systems can be either direct-to-chip (D2C) or immersion cooling. D2C cooling uses liquid-cooled plates or heat exchangers to cool specific components within servers, while immersion cooling submerges entire servers or racks in non-conductive cooling liquids such as mineral oil. Liquid cooling systems offer higher cooling efficiency and can handle high-density computing environments but may require additional infrastructure and maintenance considerations.

7.6.5 Free Cooling

Free cooling utilizes the natural environment to cool the data centre instead of relying solely on mechanical cooling systems. This approach takes advantage of “ambient temperatures” (Li, 2014) especially during cooler seasons or in regions with favourable climates. Air economizers or evaporative cooling techniques are used to draw in outside air and cool the data centre without the need for traditional cooling equipment, reducing energy consumption.

7.7 Hardware & Software:

7.7.1 Storage Devices

"Traditional hard disk drives (HDDs) are used in datacenters" (*Datacenter Resource Management* 2023) "solid state devices (SSDs) emerge as a viable storage alternative" (*Datacenter Resource Management* 2023) and are used in network-attached storage (NAS) or storage area network (SAN) systems. Although old, magnetic tape continues to be utilized for long-term data archival and backup purposes due to its durability, cost-effectiveness, and high storage capacity.

7.7.2 Virtualization Platforms

Virtualization software, such as VMware vSphere or Microsoft Hyper-V, enables the creation of virtual machines (VMs) for efficient utilization of server resources.

7.7.3 Operating Systems

Servers in data centres run different operating systems, including Linux distributions (e.g., Ubuntu, CentOS), "Unix and Windows Server" (*Usage of operating systems broken down by data center providers* 2023).

7.7.4 Management Tools

Data centre management tools monitor and control infrastructure, automate provisioning and deployment, and provide insights into performance and resource utilization.

7.7.5 Orchestration and Automation

Tools like Ansible, Puppet, or Kubernetes orchestrate and automate the deployment, scaling, and management of applications and services in the data centre.

7.7.6 Storing data across multiple datacentres

Sharding: Sharding involves dividing the data into smaller subsets or shards and distributing these shards across "multiple datacentres" (*Multi-data Center consistency* 2013). Each datacentre is responsible for storing and managing a specific subset of the data. Sharding enables parallel processing and improves performance by distributing the workload across multiple locations.

7.7.7 Distributed File Systems

Distributed file systems like Hadoop Distributed File System (HDFS) and Google File System (GFS) are designed to store and process large amounts of data across multiple datacentres. "Files distributed across multiple servers appear to users as if they reside in one place on the network so that users do not need to know the specific computer files are on to access them" (*Setting up the distributed file system (DFS) in UMROOT* 2019) providing availability and fault tolerance.

7.7.8 Erasure Coding

"Erasure coding provides the fundamental technology for storage systems to add redundancy and tolerate failures" (Plank & Huang, 2022) through a technique that

breaks down data into smaller fragments and adds redundant information (parity) to create encoded blocks. These encoded blocks are then distributed across multiple datacentres. Even if some Datacentres experience failures or data loss, the original data can be reconstructed using the encoded fragments and parity information.

7.8 Security:

7.8.1 Physical Security

Access control systems, including biometric authentication, keycards, and surveillance cameras, limit unauthorized access to the data centre facility.

7.8.2 Fire Detection and Suppression

Data centres have fire detection systems, such as smoke detectors and fire alarms, along with fire suppression systems to mitigate the risk of fire-related damage.

7.8.3 Security Monitoring and Incident Response

Data centres have security operations centres (SOCs) that monitor network activity, detect threats, and respond to security incidents promptly.

7.8.4 Disaster Recovery

Redundant Hardware: Critical systems and components are often duplicated or deployed in a redundant configuration to minimize single points of failure.

7.8.5 Backup Systems

Regular data backups are performed and stored in separate systems or off-site locations to facilitate data restoration in case of data loss or corruption.

7.8.6 Business Continuity Planning

Data centres have comprehensive disaster recovery plans that outline procedures, responsibilities, and processes to recover operations and services efficiently.

7.8.7 Testing and Simulations

Disaster recovery plans are regularly tested through simulations and drills to identify any weaknesses and ensure their effectiveness.

7.8.8 Auditing

7.8.8.1 Internal Auditors

Internal Auditors: Data centres may have internal audit teams that conduct regular assessments of their operations, processes, and security controls. Internal auditors evaluate the effectiveness of controls, identify potential risks, and make recommendations for improvement.

7.8.8.2 External Auditors

Independent third-party auditing firms or consultants may be engaged to perform external audits of data centres. These auditors assess the data centre's compliance with industry standards, regulatory requirements, and security frameworks. They provide objective evaluations and issue audit reports highlighting areas of strength and areas that require improvement.

7.8.8.3 Regulatory Bodies

Data centres may be subject to audits by regulatory bodies depending on the industry they operate in. For example, in the financial sector, data centres may undergo audits by financial regulatory authorities to ensure compliance with specific security and privacy regulations.

7.8.8.4 Certification Bodies

Data centres can pursue certifications to demonstrate their adherence to industry standards and best practices. Certification bodies, such as the Uptime Institute, ISO (International Organization for Standardization), and BSI (British Standards Institution), conduct audits to assess the data centre's compliance with specific certification criteria.

7.8.8.5 Customers and Partners

Data centres may also be audited by their customers and business partners. Customers, especially those with stringent security and compliance requirements, may conduct audits to ensure that their data is being stored and processed in a secure and compliant environment. Similarly, business partners may perform audits to assess the data centre's suitability for hosting their applications or services.

7.8.9 Encryption

7.8.9.1 Data-at-Rest Encryption

Data-at-rest encryption involves encrypting data when it is stored on storage devices, such as hard drives or solid-state drives. This encryption ensures that even if the physical storage media is compromised, the data remains encrypted and unreadable. “Advanced Encryption Standard (AES)” (Kak, 2023) is a widely used symmetric encryption algorithm for data-at-rest encryption.

7.8.9.2 Database Encryption

Data centres may apply encryption techniques at the database level to protect sensitive information stored within databases. This involves encrypting specific fields, columns, or entire databases. Encryption methods like Transparent Data Encryption (TDE) or column-level encryption can be utilized to secure data within databases.

7.8.9.3 Application-Level Encryption

In some cases, data centres may employ application-level encryption, where sensitive data is encrypted before it is stored in the database or transmitted over the network. This can be done using encryption libraries or frameworks provided by programming languages or utilizing specialized encryption APIs.

7.8.9.4 Disk Encryption

Datacentres often utilize disk encryption to protect data at rest on hard drives and solid-state drives (SSDs). Disk encryption involves encrypting the entire storage device or individual partitions, making the data inaccessible without the appropriate decryption key. This helps safeguard data in case of physical theft or unauthorized access to the storage media.

7.8.9.5 Transport Layer Security (TLS)

When data is transmitted between Datacentres or between clients and Datacentres over networks, TLS is commonly employed. “TLS” (*What is Transport Layer Security (TLS)?* 2022) is a cryptographic protocol that establishes an encrypted connection, ensuring data confidentiality and integrity during transmission. It utilizes symmetric encryption for bulk data encryption and asymmetric encryption for secure key exchange and authentication.

7.8.9.6 Virtual Private Networks (VPNs)

Datacentres may use “VPNs” (*About VPNs* 2023) to create secure and encrypted connections over public networks. VPNs provide an additional layer of security by encrypting all data passing between the datacentre and remote users or other datacentre s, protecting it from eavesdropping and tampering.

7.8.9.7 Key Management

Encryption in Datacentres relies on secure key management practices. This includes generating strong encryption keys, securely storing, and distributing keys, and regularly rotating or updating keys. Key management systems and protocols ensure that encryption keys are properly protected and accessed only by authorized personnel.

8 Design

8.1 Methodology

"Agile and DevOps" (*Understanding the differences between Agile & DevSecOps - from a business perspective* 2023) are two methodologies that could have been used in the software development of the projects, and both had their strengths and suitability. While DevOps focused on the collaboration and integration of development and operations in large teams, Agile emphasizes flexibility, iterative development, and continuous improvement in smaller teams. As agile "encourages changes", was better suited for small teams and shared similarities in approaches with the scientific methodology especially around iteration and flexibility as seen between figure 2 and figure 3, resulting in the agile methodology having suited the project better.

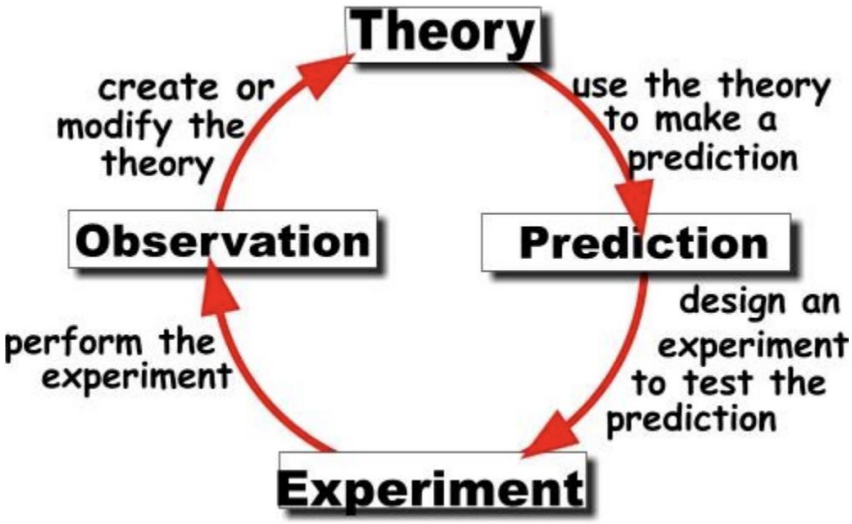


Figure 2 Scientific Method Cycle

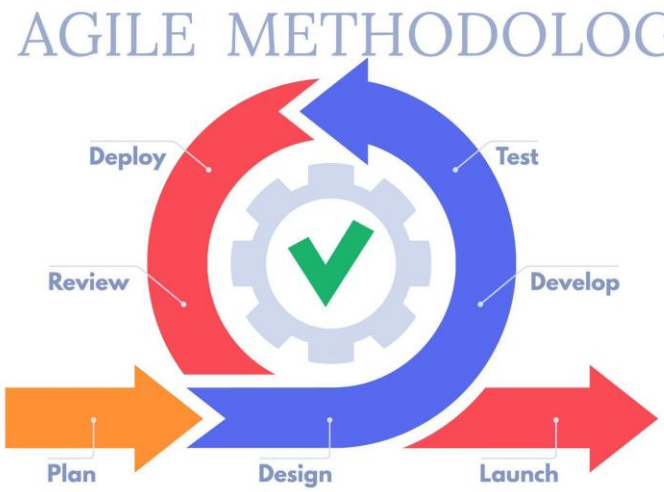


Figure 3 (Agile Methodology)

8.2 Coding software

Originally Atom was used to code the webpage due to its extreme simplicity and excellent integration with GitHub as it was created by them and allow quick and easy setup alongside management of requests. However, due to security issues caused by a breach the software was sunset through the duration of the project and an alternative had to be found. The alternate used was visual studio code, like Atom it had GitHub integration although had a more complicated file structure and clutter due to its multipurpose design.

Figure 4 (Atom)

Figure 5 (GitHub Mark)

*Figure 6 (*Visual Studio Code *2023)*

To host the finished artifact, GitHub pages was used due to its lack of cost and easy redeployment as unlike the proper method of hosting it on sever with an official domain would create cost. Furthermore, other hosting services such as Plesk require migrating the folders and certifying the webpage to allow it to be hosted, whereas GitHub pages simply requires a repository to work which was much easier to deploy and allow for continuous updating as it would update automatically from the repository whereas Plesk would require re-uploading the folders.

8.3 Management

Coding tasks were kept track using a kanban board as seen in figure 8, although GitHub allowed for the use of labels for tasks as seen in figure 7, merge request, pull request and so forth, a kanban board was quicker and easier to deploy, maintain and adjust as having to create custom labels, create the tasks and apply the labels to the tasks although making a neater and more organised system would have taken up the limited time the project had.

For long term goals such as milestone submissions, as seen in figure 9. a Gantt chart was used as it better displayed the time available due to its calendar view that spanned remaining task time across dates.

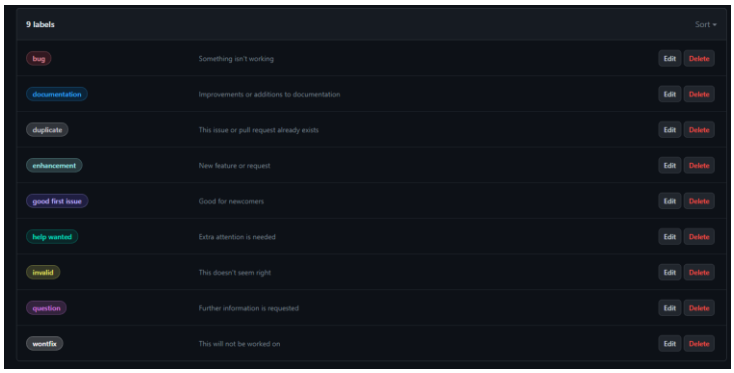


Figure 7 GitHub Labels

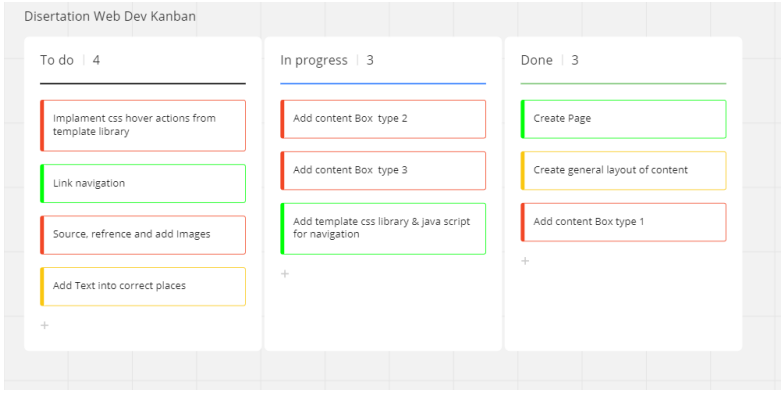


Figure 8 Example Kanban

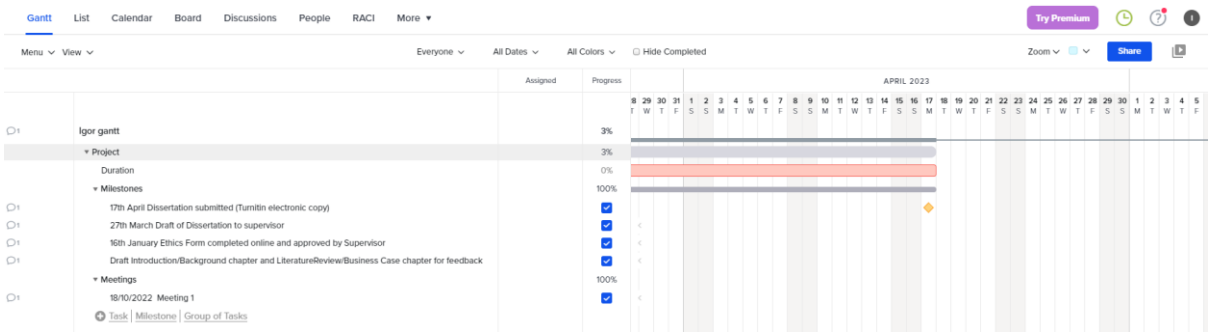


Figure 9 Gantt Chart

8.4 Designs

8.4.1 Page layout

As seen in figure 10, the page layout was kept simple with a navigation followed by a title header and then the body that would one after another display the content boxes. The content boxes were designed to be shuffled using different types of content boxes to prevent the page from becoming a block of text.

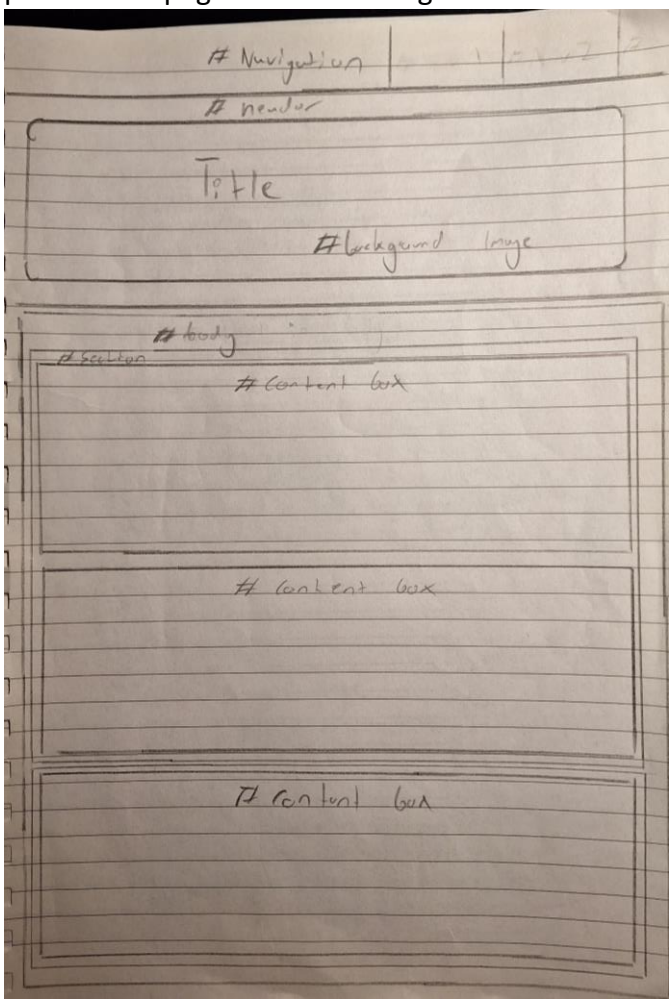


Figure 10 Page Layout Design

8.4.2 Navigation

As seen in figure 11, the idea for the navigation was to be fixed at the top for always easy access as well as incorporating a search box which although redundant most of the time would allow for easier access to the search function and allowed for the search function to work even if the user were having issues that prevented them from having one in their browser. This could be the browser not having a search function, their browser-add Ons or software blocking the search function, etc. Furthermore, this search box would work differently, as the regular search function only highlighted text, it would not highlight hidden text that required interaction. Therefore, the search box would be designed in a way where instead of highlighting text that was hidden it would highlight the content box instead.

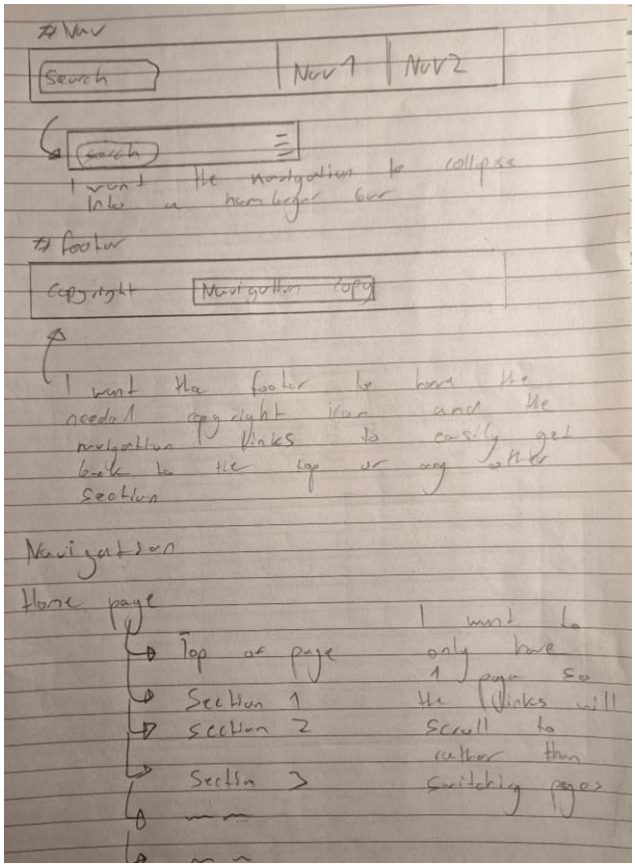


Figure 11 Navigation Design

8.4.3 Content boxes

As seen in figure 12, there were three main ideas for the content boxes, the first being a simple image and text for the larger or standalone pieces of information. This type of emphasis the content of the box whilst referencing an image which although not the best option it was better than just plain text.

Another type involved an image which when hover over created an overlay with the relevant text. This allow large amounts of text to be hidden de-cluttering the page of items to better adhere to the UX laws of such as millers law which govern that many people can only keep track of around 7 items at a time otherwise, they get confused.

The next content box involved the image sliding away to reveal a name or a quick description, this would be rarely utilised as it would fit little text however it would work well for linking an image of an item to its name to give the user better recognition of it.

Lastly, the idea of adding a video instead of an image came about, it would have continuous playback instead of an image for some of the content.

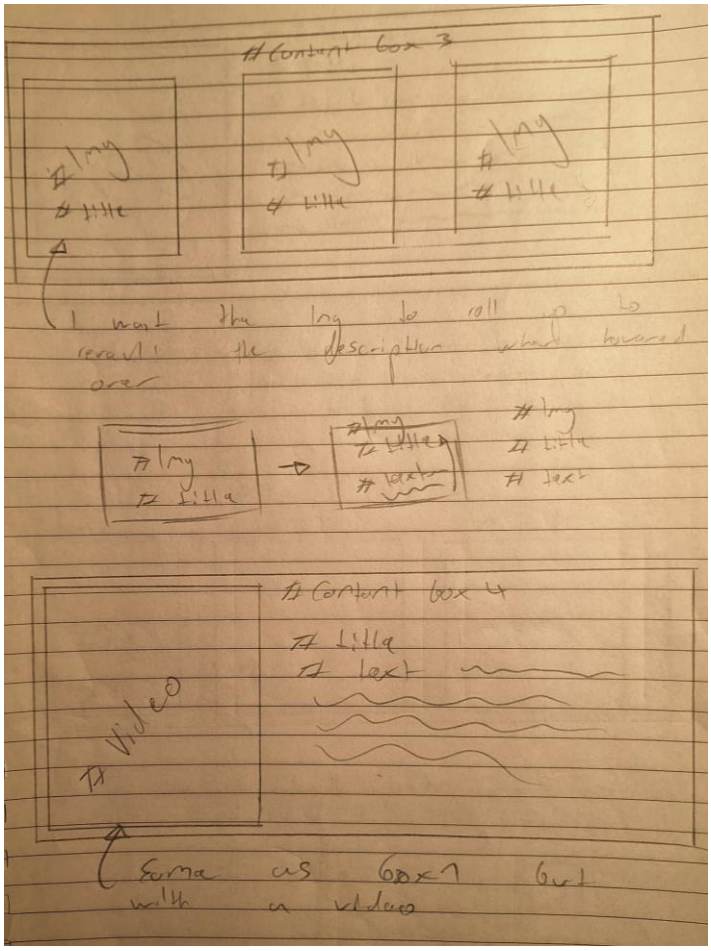


Figure 12 Content Box Designs

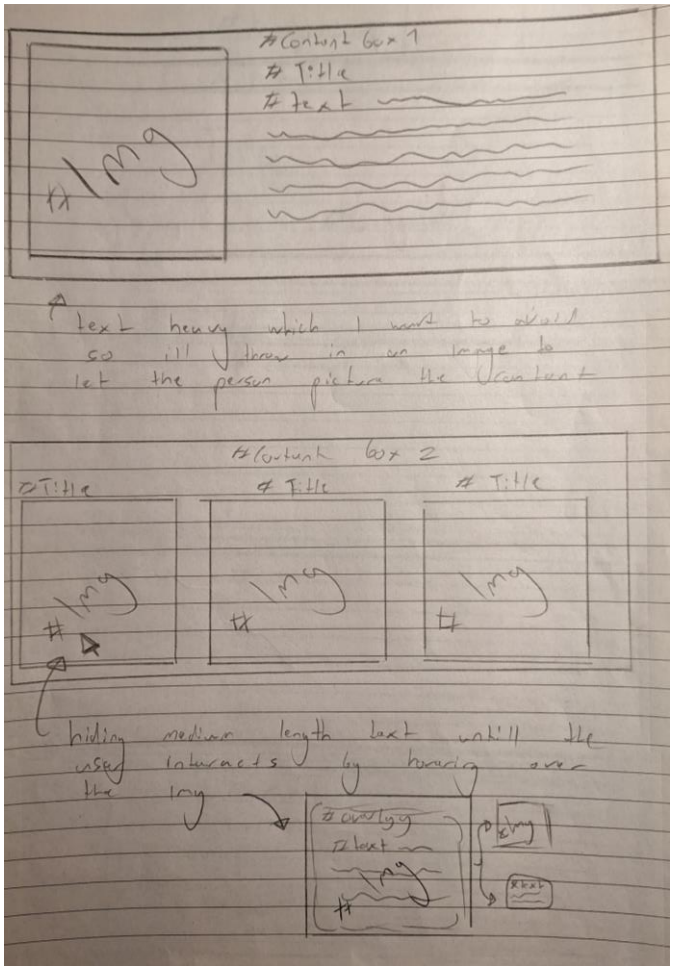


Figure 13 Content Box Designs 2

8.4.4 Content Layout

More information was available on the internet however due to the time provided the research was limited to the topics seen in figure 14 which were organized into categories that would be sectioned off making it easier to search though the information.

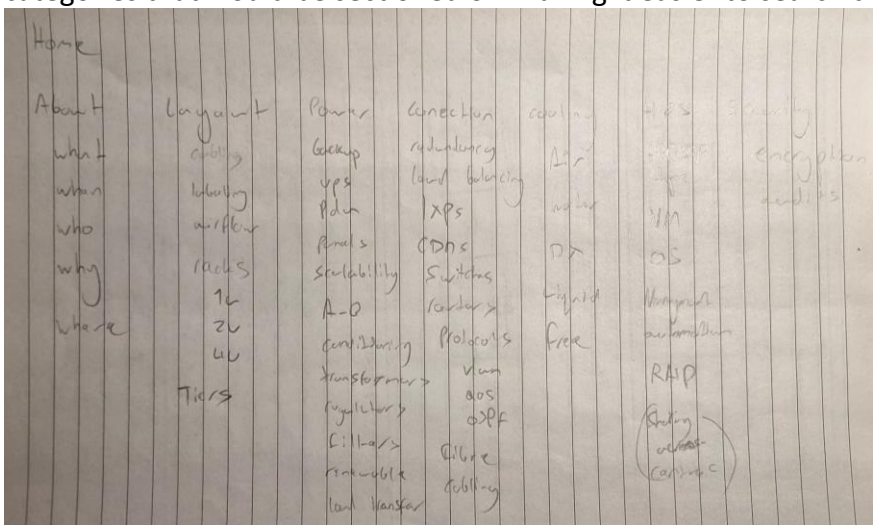


Figure 14 Content Layout Design

8.4.5 Colour scheme

The background colour was kept white without a background image apart from the banner to provide the best contrast possible to the text whose colour was kept black to best contrast the white background. #4169e1 – light blue accents in banner image and progress bar were used to add flair to the page. #b80f0a – dark red was used in the progress bar as it contrasted the blue due to being on opposite on the colour wheel allowing it to transition to provide clear contrast as the user scrolls down the page. #dee2e6 – light white was used in the image overlays to provide better contrast for text when the user hovers over.

9 Implementation

9.1 Development

9.1.1 HTML

The navigation was coded using an unordered list with links to each section on the page using href tags. The list then had a label attached to it and was hidden until the label was pressed.

Figure 15 Hamburger Icon

Figure 16 Navigation Expanded

The page layout was designed with the head for the meta tags, body to house everything then the navigation that would float on top of everything. After this came the header, it was used more like a banner than a header.

The first content box was a container with an image. When hover over, an overlay would appear over the image with text on top of it. This was done by using the active element.

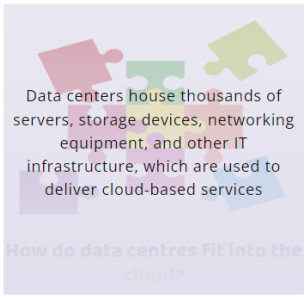


Figure 17 Example content box 1

The next content box was a container with an image and title that when hovered over would reveal more text again using the active element.

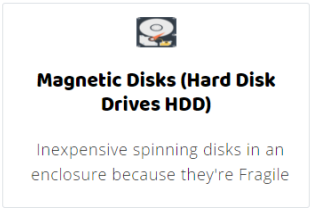


Figure 18 Example content box 2

The third content box was designed as a card with an image on the left and text on the right filing the rest of the space.

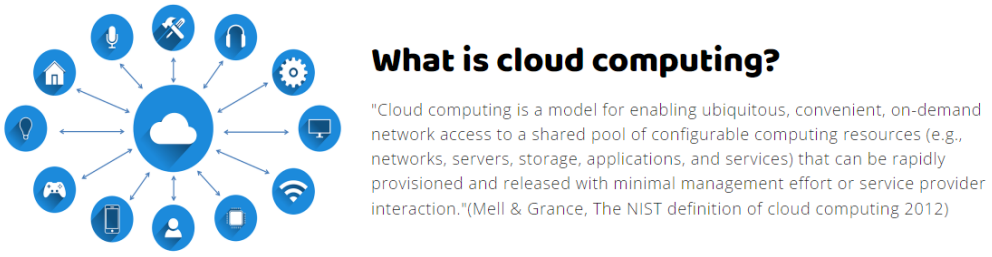


Figure 19 Example content box 3

Images were given a size the allowed the aspect ratio to be kept in order to prevent the images from stretching and pushing on loading the page which would have happened if the sizes weren't assigned.

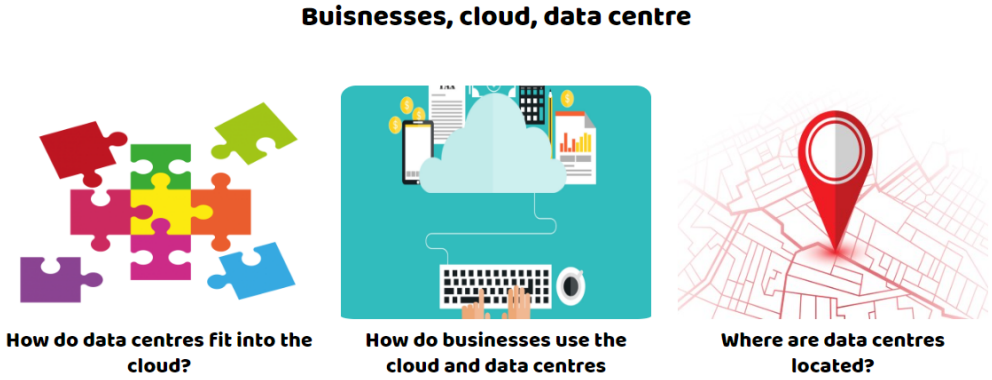


Figure 20 Example image use

9.1.2 CSS

The page uses sections to separate information alongside with margins and padding to provide adequate space between sections and boxes. Furthermore, the @media size tags were used to set new rules on the page layout if the screen size became small as it would squish the images and text. This results in the adherents of laws of proximity by making the section content look like its grouped together making its recognition easier.

The content boxes were sized using grid sizes to evenly separate most content boxes. They have their own padding and margins to fit appropriately and a @media setting to collapse the grids into individual rows to make the images and text fill the width of the screen to make the information more readable on smaller sized screens.

9.2 Iteration

Following the agile methodology, the webpage was tested and redesigned to include additional features and fixes. It didn't require new designs as the assets were kept the same and instead added onto the existing assets.

9.2.1 Code Checkers & Validators

9.2.1.1 Wave

The web accessibility evaluation tool showed many errors within the hierarchy, not suitable enough alternative text, and code errors. These were all address by redoing the headings to use the proper structure rather than going by size and furthermore adding appropriate alt text and aria labels for things like the navigation to help users using screen readers.

9.2.1.2 Html Checker

HTML checkers showed many syntax errors and size adjustments needed to allow the page to work correctly, these were adjusted and fixed allowing the page to work correctly.

9.2.1.3 JS Checker

JS checkers showed many redundant pieces of code and slight improvements that could be made however due to the time limitations they had to stay as there were not severe enough to cause the page to break or slow it down.

9.2.2 Progress bar

Due to the large amount of information on the page it was possible to easily get lost therefore a progress bar was added to make it easier to indicate how far down the page the user is. Furthermore, to make it clearer when the user is nearing the end of the page alongside increasing in size, the colour of the bar would transition to the colour opposite itself on the colour wheel to create contrast thus making a clear change.

The Progress bar actively monitors the scroll position of the page and updates the JS which changes the size of the progress bar as the scroll position increases.

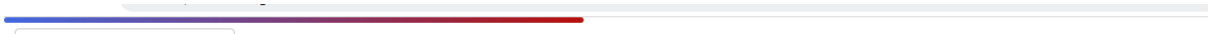


Figure 21 Example progress bar

9.2.3 Collapsible navigation

The increased amount of information and therefore sections which are included in the navigation required the navigation to collapse in order to prevent the text from spilling out. This was done through a minimum width that changed the navigation list into a hamburger icon that when pressed would reveal the list under t the navigation thus allowing for all the links to fit without spilling over.

Figure 22 Example open navigation

Figure 23 Example collapsed navigation.

Figure 24 Example mobile navigation

9.2.4 Search box

The search box was added to more easily find information on the webpage as well as working differently to the browser search function as the search function would not highlight text inside interactive elements. To perform this the JS code instead of highlighting the text would highlight its parent class with a border as giving an image / content box a yellow hue due to a highlight would make the text harder to read when the user would interact with it.

The search box works by using JS to iterate through matching text that then gets highlighted. Then, separately the “current highlight” code iterates to find the matches and allows the user to move through them whilst highlighting the current index which they’re on. This could possibly be combined with the previous iteration however it was easier to code this way.

Furthermore, currently the elements around the search function are created in the JS so that if the JS file doesn’t load, the function is not there cluttering the screen.

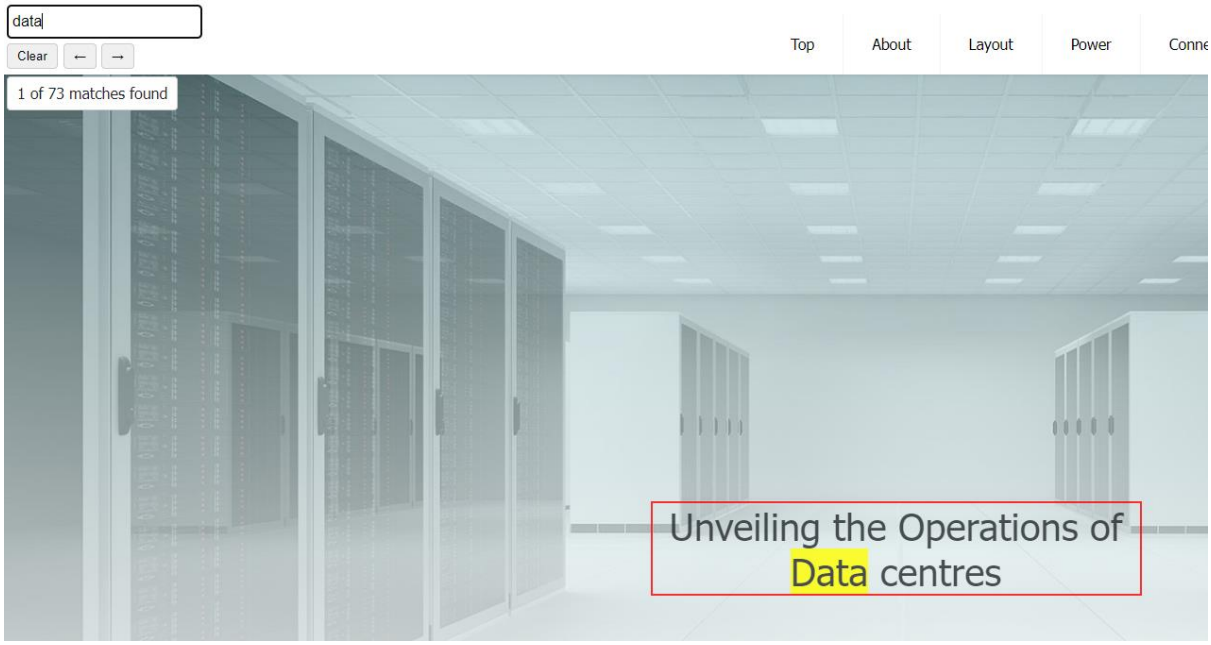


Figure 25 Example search function

9.2.5 More diverse content

More diverse content was added to provide better information. This information was sourced mostly from trusted sources such as education and governmental bodies and was compiled into quick snippets of information.

9.2.6 Suitable images

Previously, many images were black and white clip art to make it easy on the eye, provide good contrast and be simple this however made the webpage less professional, and less attention grabbing therefore more colourful images and real images / diagrams and not clip art images were included for items that would be better related to though them.

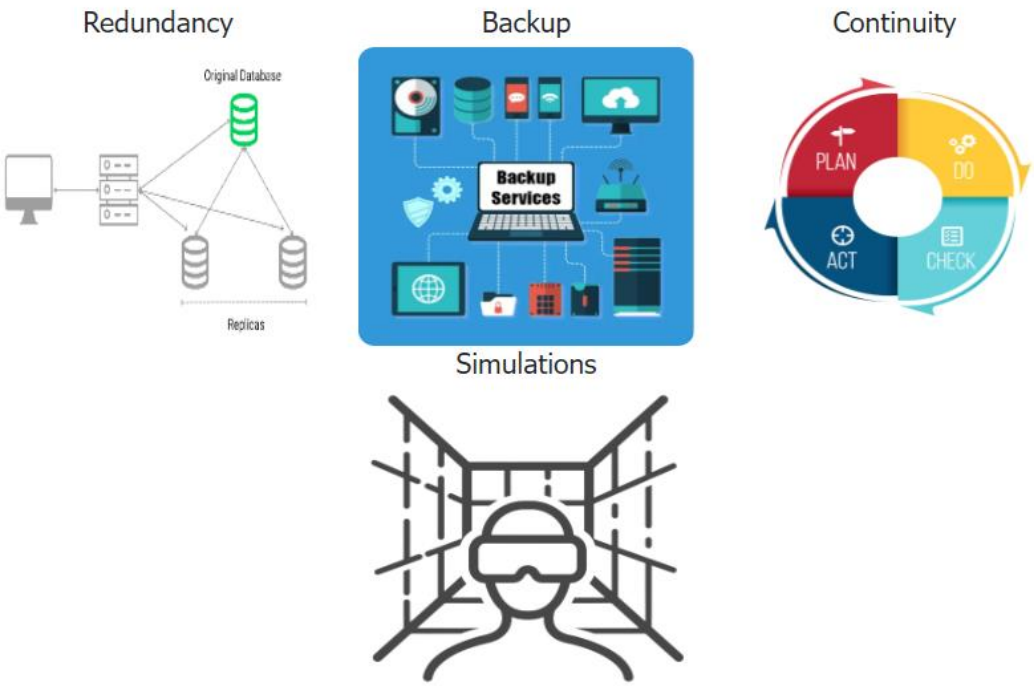


Figure 26 Example image use

9.2.7 Subtle content box layout design

One of the observations were that when in rows all the content looked very clustered and therefore it was hard to know when it started and ended. Therefore several this were done to combat this, firstly the margins and paddings were adjusted to leave gaps and furthermore the content boxes instead of being split evenly in rows were placed so that the end always had one standalone box creating a downwards arrow shape that would lead to the next section or heading which would start with an even row again creating subconscious for the user a clear indication of direction on the webpage.

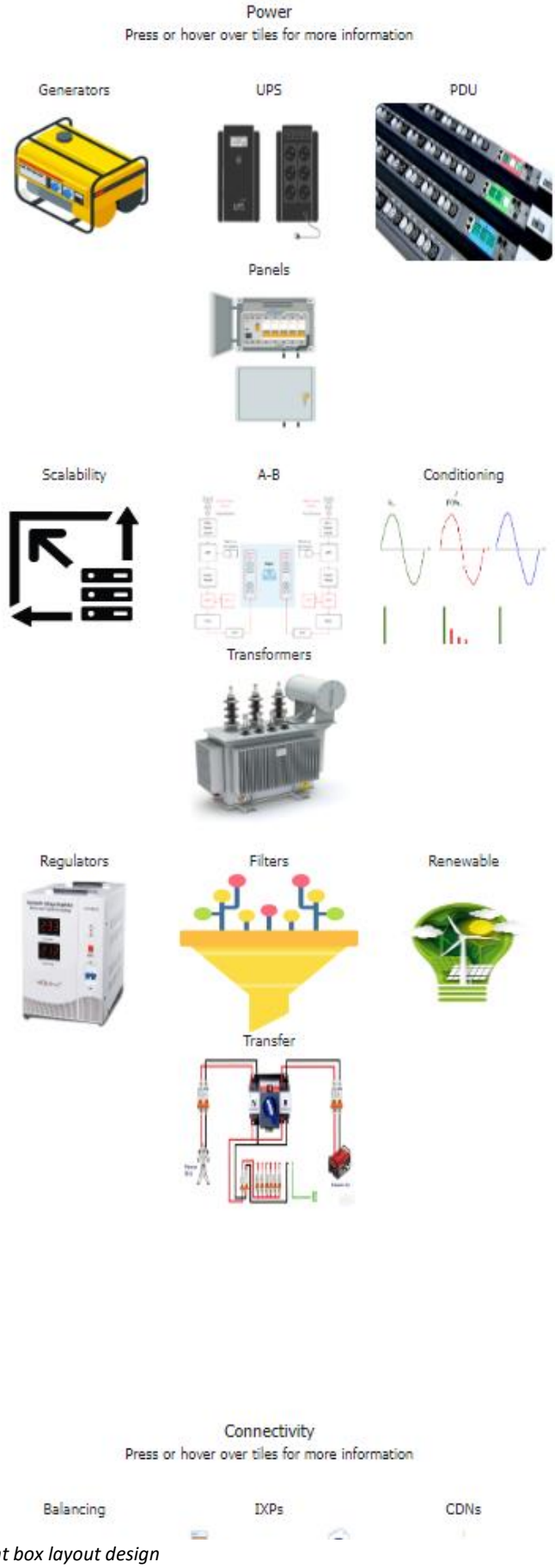


Figure 27 Example content box layout design

9.2.8 Slideshow

The Slideshow of the third content box types was created to better adhere to millers' law by reducing the number of items seen at one time. The JS for it hide the other boxes to only show one. It then creates buttons that will allow the user to switch between the active box and the inactive ones. The JS then represents this by updating dots at the bottom of the slide to indicate the position of the slide.

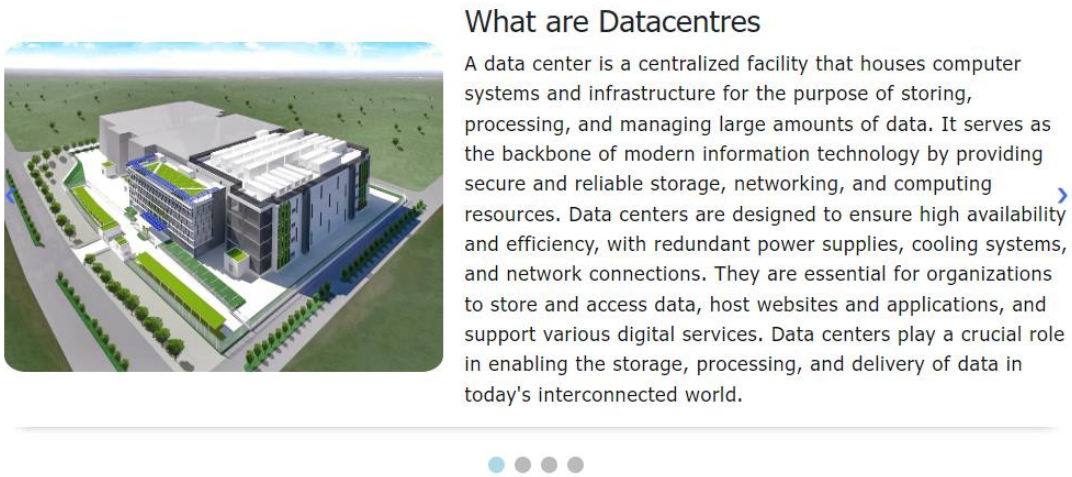


Figure 28 Example slideshow

9.2.9 iframe

A big part of users not knowing off or about datacentres is due to not being able to see one for themselves which is why an iframe containing a 360 tour of a datacentre was included. Firstly, to be accessible to subtitles are automatically on. However, to prevent a scare or inconvenience to the user, the sound is automatically muted. Furthermore, the play back starts automatically in order to interest the user. Then, if the user has issue with the controls for the video, the playback is set to loop to make it easier for them. Lastly, in the mobile screen size version, the video is removed as it requires suitable controls and screen size to be usable and therefore would simply clutter the screen for those users therefore it is hidden at smaller screen sizes.

9.2.10 Accessibility Result

9.2.10.1 W3

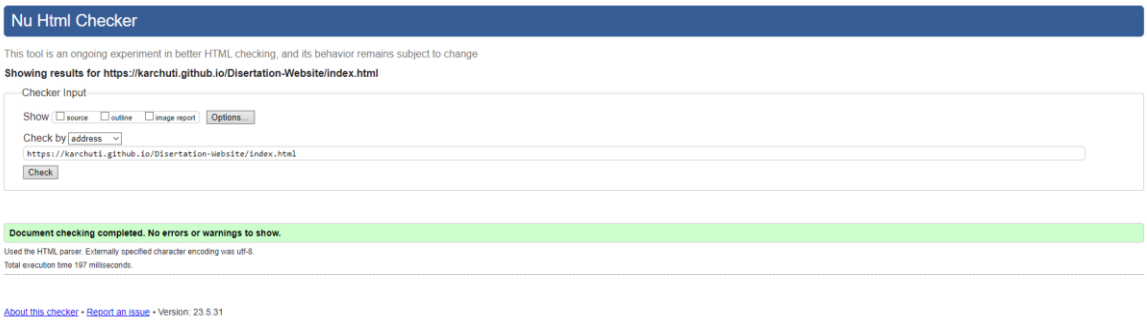


Figure 29 W3 results

9.2.10.2 WAVE

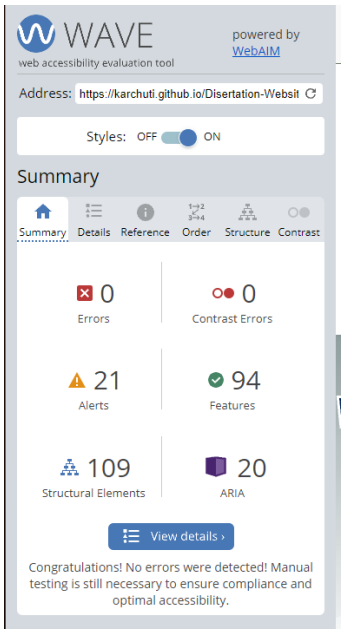


Figure 30 Wave results

Webpage Link: https://karchuti.github.io/Disertation-Website/index.html

9.3 Form

9.3.1 Google Forms

Google forms were used to create the questionnaire due to the simplicity of adding, modifying, and removing questions. Furthermore, graphics and additional prompts could have been added if time allowed to make the questionnaire engaging which could only be achieved by making an online questionnaire. The drawback of this however was that it removed physical distribution as without the appropriate features such as resizing boxes to fit user input or prompts for data the questionnaire design wouldn't be suitable.

9.3.2 Questions

The questions were made to address the information present on the webpage to see if the user already knew it, if they did not then it would prove the hypothesis. These questions were meant to be qualitative however these resulted in the questions having lengthy choices and checks on the user's knowledge which could have become discouraging. Therefore, questions were reduced to a scale of how well they thought they knew about the subject.

9.3.3 Collecting Results

By using google forms, the result could easily be collected and compiled to an excel spreadsheet due to the integration with Microsoft office having tested the data easy through excels graph maker.

9.3.4 Finished Forms

https://forms.gle/yJ8bqZjPgSRndBbD9 Form Before Using Webpage
https://forms.gle/2GcpUidFVrarj5uA7 Form After Using Webpage

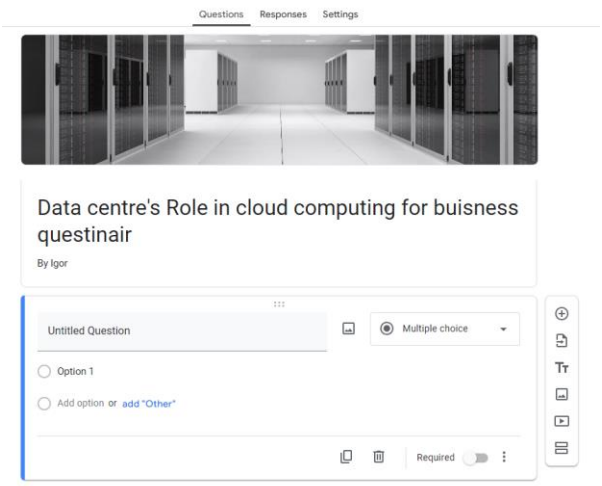


Figure 31 Google forms

Figure 32Example questions

10 Testing and Evaluation

The participants responses were collected in google forms from google docs which allowed for the use of integrated google sheets thus allowing me to transfer the data from each response onto a spreadsheet. This automatically collated the data on the spread sheet in separate tables and allowed me to average out the response scores to see overall what the users scored. This was accurate as there weren't any large outliers that would skew the data incorrectly.

To visually compare the averages, a bar chart was used as seen in figure 33 to see the average scores before and after using the informative site. The result seen from this was that the site was indeed informative as both on an individual level and average across the participants as seen through the averages, their scores improved after using the site thus meaning that they were more confident and informed in their answers.

Furthermore, to gain their opinion on if the site was informative, the question "Was the site informative?" was used which all participants answered with the highest score thus meaning that the information provided was useful and improved their understanding.

This however could be due to the skewed scope of testing due to the limited resources and time as firstly, the project did not receive as many responses as anticipated, it only received 5 which is preferred when performing heuristic testing however the project would have benefited from more quantitative data as the aim was between 10 – 20. Furthermore, the age range was very similar with the participants, being early adults. Thus, testing on different generations could have resulted in a different outcome.

Furthermore, my participants were already either studying computers science or had good background knowledge of computing, therefore if people from different professions were to undertake it the outcome could again have been different.

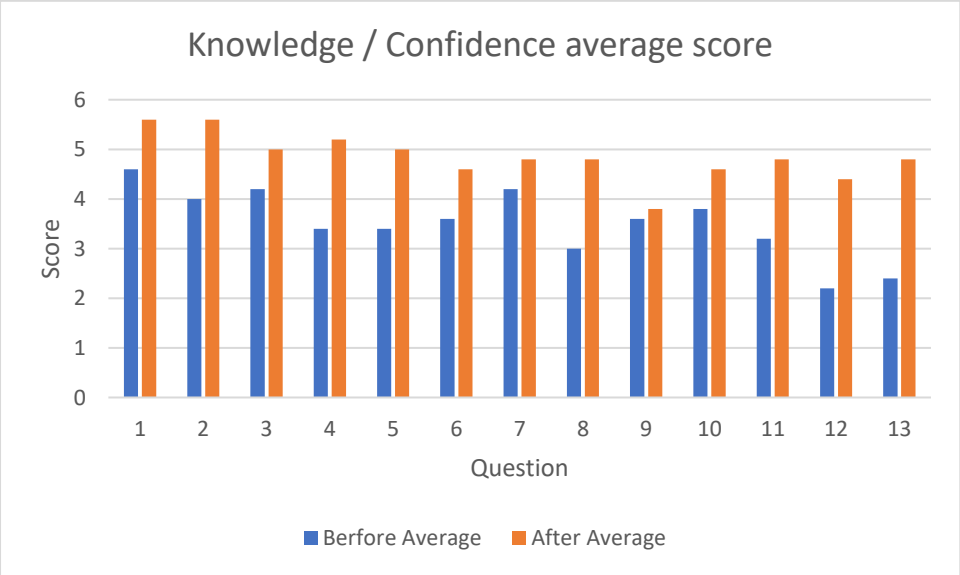


Figure 33 Results graph

11 Conclusions

11.1 Strengths

One strength of the project is that it succeeds in fulfilling its purpose, the purpose being informative, responsive, and interactive. This is seen by the testing thus far in the information provided on the webpage which users feel education them. Responsive as it works across multiple browsers and device types effectively by resizing to fit the desired resolutions with little no visual bugs. And lastly, interactive by having required the user to add their input to get the information which resulted in a less cluttered and more visually appealing design.

Furthermore, this time the project correctly followed the agile methodology especially through the iteration process that took the already made assets and redesigned them to improve them. Though, following this these would require retesting to make sure that the information and webpage looks / design are still appealing to the users.

Lastly, the management of the project was acceptable, although there was less than ideal planning and design due to the time available to work on the project, the overall idea of the project and execution that matched this deliverable were in line with each other resulting in an informative, responsive, and interactive accessible webpage.

11.2 Weakness

The planning and design of the project should have taken more time and care, a high-fidelity prototype should have been created using tools like Figma and Miro to better plan the looks of the webpage which could have reduced the need for the iteration process as issue in the designs could have been addressed before their execution through the visual representation that the programs provide.

Furthermore, the project should have been managed better, although there was little personal time available to work on the project, a portion of that should have been allocated to scheduling and contacting meetings with the supervisor to get them to check the project which could have provided me with feedback other than the feedback from the milestone submissions.

11.3 Hypothesis - Confirmed

"Developing an accessible, interactive, and responsive informative webpage about datacentre will significantly reduce the knowledge gap among the general population regarding datacentres and their fundamental aspects."

Was this met, the artifact was designed using aria labels, alt text, structured hierarchy, and imagery to make moving through the webpage using accessibility software such as screen readers or the keyboard easier. Furthermore, to combat the most common accessibility issue, leaning difficulties autism, sublime directions using patters were used to both reduce the amount of text on screen making it easier to read alongside the patters which users with autism have a strong possibility to be affected by making it easier to understand for them the information hierarchy.

Was the webpage interactive, by featuring several interactive elements such as the slideshows, clickable containers, sliding containers and the interactive iframe the webpage provide many interactive elements.

Was it responsive, the webpage used grids and @media to create criteria for the screen size to make certain elements change size such as the grid to collapse into a larger and more readable size for smaller screens. Furthermore, the interactive elements were designed to still work on the mobile versions of the browser by allowing the same interactive elements and transitions to be trigger through taping the element over hovering on it.

Was it informative, from the limited initial testing the information seemed to be informative hover due to the poor testing methods and with the iterative process improving on the content the testing required re-doing in order to definitively show that the webpage is informative.

11.4 Future Developments

11.4.1 Hosting

A future development would be moving the webpage from being hosted on GitHub pages to a rented server space that would keep the webpage up forever. Furthermore, this would require a or multiple suitable domain names that would make the webpage easier to find. It would also entail adding the webpage to search engines sitemaps which has already been attempted in this project as seen in figures, x through x however requires a proper hosting service for it to work properly.

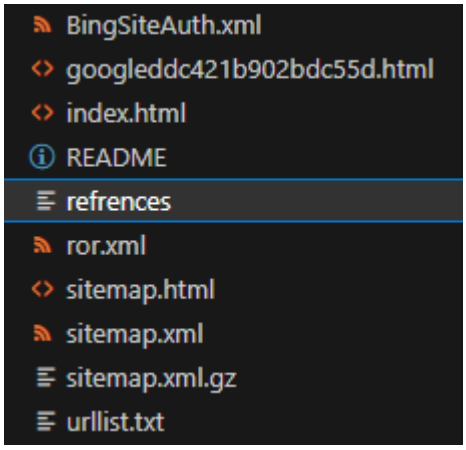


Figure 34 Example sitemap files

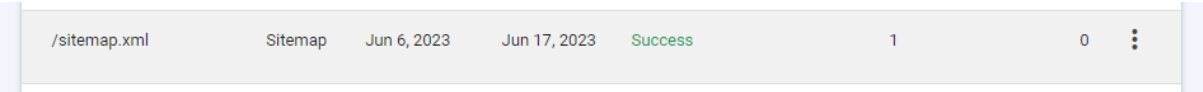


Figure 35 Google sitemap submission

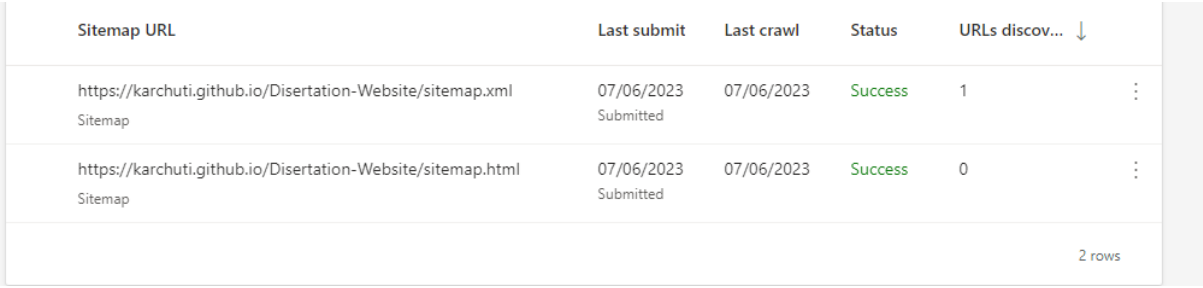


Figure 36 Bing sitemap submission

11.4.2 Form

A revision of the form as seen in figure 37 has been made, this form has redesigned questions better suited for checking user knowledge which was one of the problems from the previous iterations. It aims to gather more qualitative data by providing the user with the ability to write their own believes of how data centres work that would allow for marking for correctness. This although not a full proof way of checking their knowledge is still a better option than performing a full test on the user as those would discourage their participation.

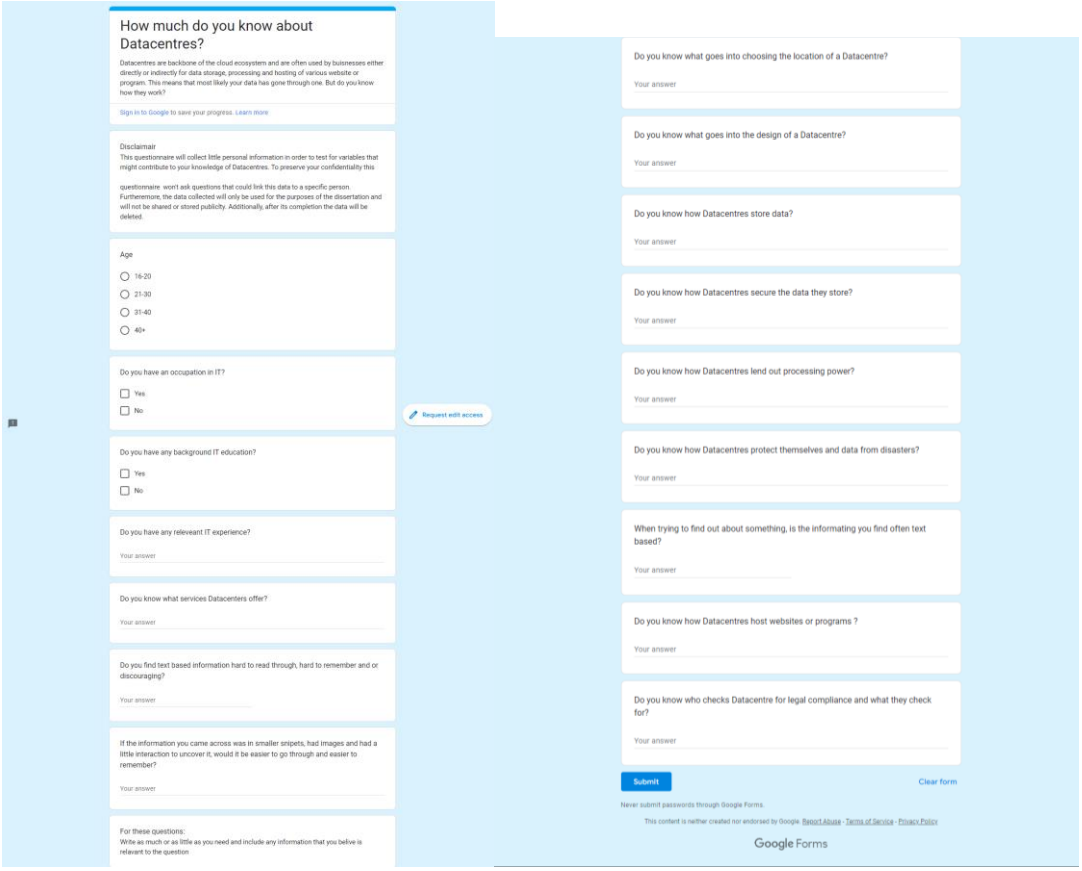


Figure 37 Example revised form.

11.4.3 Testing

Following the revised form, the testing would need to be performed on a more diverse scale, this would entail various ages, professions, and educational backgrounds to get a better picture of people's understandings as well as proving information on any attributes that may increase a testers knowledge on datacentres.

11.4.4 Coding

Although the code works without crashing and display nicely, as seen in various code checkers, there are certain standards that the code doesn't meet therefore requiring the code to undertake certain changes such as removing unused elements, removing code that affects the same item redundantly, using values unnecessarily and using adjoining classes instead of separating them. Furthermore, the slideshows on the webpage need their buttons to be re-coded as they aren't accessible enough for keyboard users.

12 References

(No date) *What is object storage?* Available at: https://idrive.cwru.edu/object-storage-e2/what-is-object-storage (Accessed: 29 June 2023).

AKILLI, Y. and Güneş, A. (2016) *Disaster recovery planning for data centers and IT services, IARJSET*. Available at: https://www.academia.edu/29711795/Disaster_Recovery_Planning_for_Data_Centers_and_IT_Services (Accessed: 29 June 2023).

Colocation Data Centers (2021) *Colocation Data Centers | Better Buildings Initiative*. Available at: https://betterbuildingssolutioncenter.energy.gov/data-center-toolkit/colocation (Accessed: 29 June 2023).

Continuing it training program - storage area networks (2022) *Continuing IT Training Program - Storage Area Networks*. Available at: https://www.fdic.gov/regulations/examiner/it/san.html (Accessed: 29 June 2023).

Data Center Access (2019) *Policy Library*. Available at: https://www.stmarytx.edu/policies/it-services/data-center-access/ (Accessed: 29 June 2023).

Data Center Operations (2017) *Share Data Center Operations*. Available at: https://www.doi.gov/ocio/customers/datacenter-operations (Accessed: 29 June 2023).

Krzyzanowski, P. (2021) *Network Attached Storage, Network attached storage*. Available at: https://people.cs.rutgers.edu/~pxk/417/notes/nas.html (Accessed: 29 June 2023).

Lintner, W., Tschudi, B. and VanGeet, O. (2011) *Best practices guide for energy-efficient data center design, Best Practices Guide for Energy-Efficient Data Center Design*. Available at: https://www.energy.gov/femp/articles/best-practices-guide-energy-efficient-data-center-design (Accessed: 29 June 2023).

Managed Services (2023) *INFORMATION TECHNOLOGY SERVICES*. Available at: https://its.ucsc.edu/data-center/managed-services.html (Accessed: 29 June 2023).

Scarfone, K., Souppaya, M. and Hoffman, P. (2021) *Guide to security for Full Virtualization Technologies - NIST, Guide to Security for Full Virtualization Technologies*. Available at: https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-125.pdf (Accessed: 29 June 2023).

(1999) *Automatic Transfer Switches (ATS) In Critical Applications*. Available at: https://llis.nasa.gov/lesson/821 (Accessed: 29 June 2023).

(2023) *IU Data Center standards*. Available at: https://kb.iu.edu/d/avng (Accessed: 29 June 2023).

Chalise, S. *et al.* (2015) *Data Center Energy Systems: Current technology and future direction, Data Center Energy Systems: Current Technology and Future Direction.* Available at: https://www.eecs.ucf.edu/~weisun/papers/conferences/date-center-review.pdf (Accessed: 29 June 2023).

Evidence-based best practices around Data Center Management (2016) *EVIDENCED-BASED BEST PRACTICES AROUND DATA CENTER MANAGEMENT*. Available at: https://datacenters.lbl.gov/sites/default/files/DCOI_BestPractices92016.pdf (Accessed: 29 June 2023).

Jain, R. (2021) *Data Center network topologies - CSE.WUSTL.EDU, Data Center Network Topologies*. Available at: https://www.cse.wustl.edu/~jain//cse570-21/ftp/m_03dctz.pdf (Accessed: 29 June 2023).

Marco (2021) *Importance of UPS for data centers*. Available at: https://blogs.salleurl.edu/en/importance-ups-data-centers (Accessed: 29 June 2023).

Reduce energy losses from power distribution units (PDUS) (2020) *Reduce Energy Losses from Power Distribution Units (PDUs).* Available at: https://www.energystar.gov/products/reduce_energy_losses_power_distribution_units_pdus (Accessed: 29 June 2023).

Server type (2023) *Center of Expertise for Energy Efficiency in Data Centers*. Available at: https://bedes.lbl.gov/bedes-online/server-type (Accessed: 29 June 2023).

Velimirovic, A. (2023) *Data Center Tiers Classification explained: (tier 1, 2, 3, 4), Data Center Tiers Explained*. Available at: https://phoenixnap.com/blog/data-center-tiers-classification (Accessed: 29 June 2023).

Xu, T. and Greenberg, S. (2007) *Data Center Energy Bencmarking - UNT Digital Library, Data Center Energy Benchmarking:* Available at: https://digital.library.unt.edu/ark:/67531/metadc898380/m2/1/high_res_d/926298.pdf (Accessed: 29 June 2023).

(2023) *Fiber Optics*. Available at: https://divediscover.whoi.edu/hot-topics/fiberoptic/ (Accessed: 29 June 2023).

Alam, M.I.I., Kar, K. and Anshelevich, E. (2022) *Balancing traffic flow efficiency with IXP revenue in internet peering*. Available at: https://sites.ecse.rpi.edu/~koushik/mypapers/Globecom2021.pdf (Accessed: 29 June 2023).

Dhawale, Prof.P.G. *et al.* (2019) *Automatic Voltage Regulator*. Available at: https://www.academia.edu/39391741/Automatic_Voltage_Regulator (Accessed: 29 June 2023).

Editor, C.C. (2021) *Securing Small-Business and Home Internet of Things (IoT) Devices: Mitigating Network-Based Attacks Using Manufacturer Usage Description (MUD), NIST SPECIAL PUBLICATION 1800-15*. Available at: https://csrc.nist.gov/glossary/term/vlan (Accessed: 29 June 2023).

Ethernet protocol (2021) *Ethernet Protocol - Computer Networking 0.5 documentation*. Available at: https://cot-cn.cougarnet.uh.edu/docs/compnet/012-ethernet.html (Accessed: 29 June 2023).

Hantouli, N. (2018) *Design of Acive Power Filter with Active and Reactive Power Injection Capabilty, Usiing Multilevel Inverter and Photovoltaic Arrays*. Available at: https://repository.najah.edu/server/api/core/bitstreams/e4e01871-300f-4e37-beeb-64c8401c5612/content (Accessed: 29 June 2023).

Interconnecting your hubs, transceivers, and Nic Cards (2023) *EIA/TIA 568A & 568B Standard*. Available at: https://www.utm.edu/staff/leeb/568/568.htm (Accessed: 29 June 2023).

Krzyzanowski, P. (2021) *Content Delivery, Content delivery*. Available at: https://people.cs.rutgers.edu/~pxk/417/notes/cdn.html (Accessed: 29 June 2023).

Power Transformers (2013) *EE 340 Power Transformers*. Available at: http://www.egr.unlv.edu/~eebag/TRANSFORMERS.pdf (Accessed: 29 June 2023).

Stouffer, K. *et al.* (2019) *Cybersecurity Framework Manufacturing Profile - NIST, NISTIR 8183*. Available at: https://nvlpubs.nist.gov/nistpubs/ir/2017/nist.ir.8183.pdf (Accessed: 29 June 2023).

(2023) *QoS (quality of service)*. Available at: https://www.uwlax.edu/its/network-telecom/qos-quality-of-service/ (Accessed: 29 June 2023).

Brad (2021) *OSPF (open shortest path first) - IOS, OSPF (Open Shortest Path First) - IOS | Network Command Reference*. Available at: https://netref.soe.ucsc.edu/node/24 (Accessed: 29 June 2023).

Burton, R.C. (1195) *FIBRE CHANNEL, Fibre Channel*. Available at: https://www.cse.wustl.edu/~jain/cis788-95/ftp/fiber_channel/index.html (Accessed: 29 June 2023).

Choudhury, Dr.I. (2023) *HVAC EQUIPMENT: COOLING SOURCES*. Available at: http://people.tamu.edu/~i-choudhury/335_10.html (Accessed: 29 June 2023).

Dordal, P.L. (2023) *15 border gateway protocol (BGP)¶, 15 Border Gateway Protocol (BGP) - An Introduction to Computer Networks, desktop edition 2.0.10*. Available at: https://intronetworks.cs.luc.edu/current/html/bgp.html (Accessed: 29 June 2023).

Ellsworth, S. (2012) *Applied computer cooling - digitalcommons.calpoly.edu, Applied Computer Cooling*. Available at: https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1012&context=laessp (Accessed: 29 June 2023).

Li, L. (2014) *COORDINATING LIQUID AND FREE AIR COOLING WITH WORKLOAD ALLOCATION FOR DATA CENTER POWER MINIMIZATION*. Available at: https://etd.ohiolink.edu/apexprod/rws_etd/send_file/send?accession=osu1395743682&disposition=inline (Accessed: 29 June 2023).

Ling, L., Zhang, Q. and Zeng, L. (2018) *Performance and energy efficiency analysis of data center cooling plant by using lake water source*. Available at: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1123&context=archengfacpub (Accessed: 29 June 2023).

Meadows, D. (2017) *Regulations determining computer room cooling selection, Regulations Determining Computer Room Cooling Selection*. Available at: https://dmacc.edu/programs/hvac/Documents/stulzWhitePaper.pdf (Accessed: 29 June 2023).

Subject: Data Communications Cabling FAQ (1995) *LANs/cabling-FAQ*. Available at: https://www.d.umn.edu/~tkwon/other/cabling-faq.html (Accessed: 29 June 2023).

(2021) *SOC 2 & ISAE 3000*. Available at: https://soc2.co.uk/soc-2 (Accessed: 29 June 2023).

(2023) *About VPNs*. Available at: https://www.citethisforme.com/harvard/source-type (Accessed: 29 June 2023).

Datacenter Resource Management (2023) *Datacenter Resource Management | Northeastern University Computer Systems Research Laboratory*. Available at: http://nucsrl.coe.neu.edu/node/80 (Accessed: 29 June 2023).

ISO/IEC 27001 Standard – information security management systems (2023) *ISO/IEC 27001 Information security management systems*. Available at: https://www.iso.org/standard/27001 (Accessed: 29 June 2023).

Kak , A. (2023) *Lecture Notes on "Computer and Network Security", Lecture 8: AES: The Advanced Encryption Standard*. Available at: https://engineering.purdue.edu/kak/compsec/NewLectures/Lecture8.pdf (Accessed: 29 June 2023).

Multi-data Center consistency (2013) *MDCC: Multi-Data Center Consistency*. Available at: http://mdcc.cs.berkeley.edu/ (Accessed: 29 June 2023).

Plank, J.S. and Huang, C. (2022) *Tutorial: Erasure Coding for Storage Applications, Tutorial: Erasure coding for storage applications*. Available at: http://web.eecs.utk.edu/~jplank/plank/papers/FAST-2013-Tutorial.html (Accessed: 29 June 2023).

Setting up the distributed file system (DFS) in UMROOT (2019) *Setting Up the Distributed File System (DFS) in UMROOT | ITS Documentation*. Available at: https://documentation.its.umich.edu/node/1059 (Accessed: 29 June 2023).

Usage of operating systems broken down by data center providers (2023) *W3Techs*. Available at: https://w3techs.com/technologies/cross/operating_system/data_center (Accessed: 29 June 2023).

What is Transport Layer Security (TLS)? (2022) *What is TLS (Transport Layer Security)?* Available at: http://euro.ecom.cmu.edu/program/law/08-732/Courts/TLS.pdf (Accessed: 29 June 2023).

Understanding the differences between Agile & DevSecOps - from a business perspective (2023) *Understanding the Differences Between Agile & DevSecOps - from a Business Perspective - Tech at GSA*. Available at: https://tech.gsa.gov/guides/understanding_differences_agile_devsecops/ (Accessed: 29 June 2023).

Daigle, B. (2021) *Data Centers Around the World: A Quick Look*. Available at: http://large.stanford.edu/courses/2022/ph240/ashai2/docs/usitc-may21.pdf (Accessed: 29 June 2023).

Data Centers and servers (2023) *Data Centers and Servers*. Available at: https://www.energy.gov/eere/buildings/data-centers-and-servers (Accessed: 29 June 2023).

See what's new and browse our innovations (2022) *Innovations – Data Centers*. Available at: https://www.google.co.uk/about/datacenters/innovations/ (Accessed: 29 June 2023).

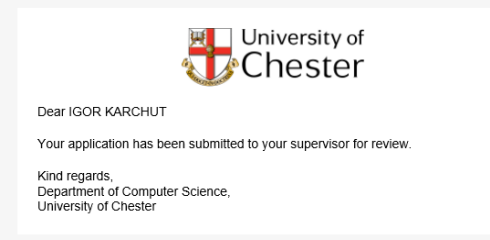
Git Hub. (n.d.). *Atom*. Atom. Retrieved March 25, 2023, from https://github.com/atom

Git Hub. (n.d.). *Github Mark*. https://github.com/logos. Retrieved March 25, 2023, from https://github.com/logos

Visual Studio Code (2023) *File:Visual Studio Code 1.35 icon.svg*. wikimedia. Available at: https://commons.wikimedia.org/wiki/File:Visual_Studio_Code_1.35_icon.svg (Accessed: 02 July 2023).

13 Appendices

13.1 Ethics application


University of Chester

Dear IGOR KARCHUT

Your application has been submitted to your supervisor for review.

Kind regards,
Department of Computer Science,
University of Chester

Figure 38 Ethics application submitted.

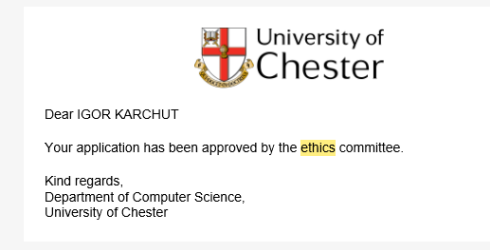

University of Chester

Dear IGOR KARCHUT

Your application has been approved by your supervisor and has now been submitted for review by the ethics committee.

Kind regards,
Department of Computer Science,
University of Chester

Figure 39Ethics application approved by supervisor.

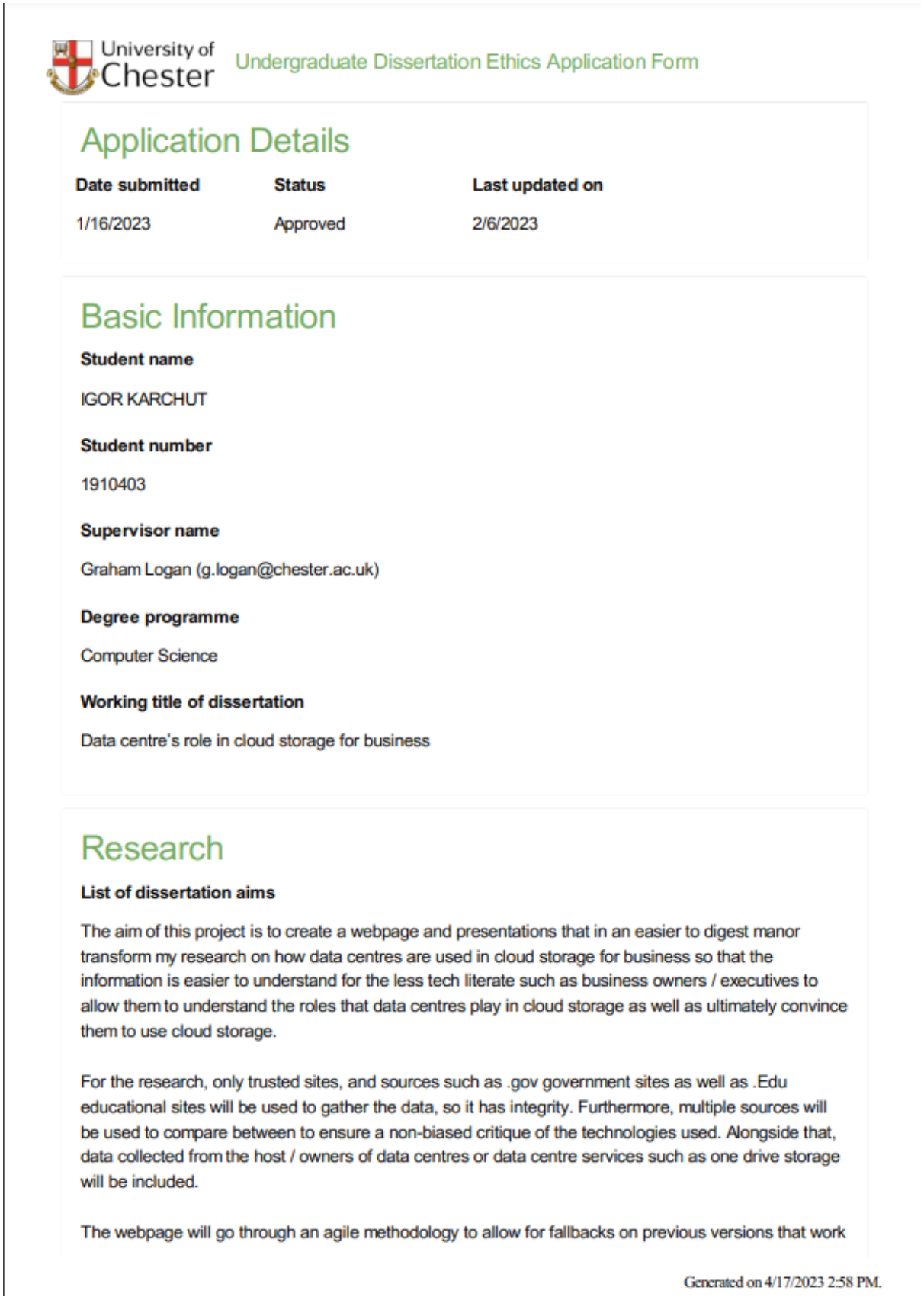

University of Chester

Dear IGOR KARCHUT

Your application has been approved by the ethics committee.

Kind regards,
Department of Computer Science,
University of Chester

Figure 40 Ethics application approved.



University of Chester

Undergraduate Dissertation Ethics Application Form

Application Details

Date submitted	Status	Last updated on
1/16/2023	Approved	2/6/2023

Basic Information

Student name

IGOR KARCHUT

Student number

1910403

Supervisor name

Graham Logan (g.logan@chester.ac.uk)

Degree programme

Computer Science

Working title of dissertation

Data centre's role in cloud storage for business

Research

List of dissertation aims

The aim of this project is to create a webpage and presentations that in an easier to digest manor transform my research on how data centres are used in cloud storage for business so that the information is easier to understand for the less tech literate such as business owners / executives to allow them to understand the roles that data centres play in cloud storage as well as ultimately convince them to use cloud storage.

For the research, only trusted sites, and sources such as .gov government sites as well as .Edu educational sites will be used to gather the data, so it has integrity. Furthermore, multiple sources will be used to compare between to ensure a non-biased critique of the technologies used. Alongside that, data collected from the host / owners of data centres or data centre services such as one drive storage will be included.

The webpage will go through an agile methodology to allow for fallbacks on previous versions that work

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Figure 41 Ethics application part 1/3

if a design fails as well as allowing for testing and iteration to improve on the initial design to ensure that it is built to function in a timely manner.

The presentations will go through the same agile methodology as the website to ensure that the content of the slides is easy to digest as well as providing a functional draft at each stage.

To test that the content is digestible and understandable compared to the raw information, a questionnaire will be used to collect quantitative data.

List of dissertation objectives

Research, Website presenting research, powerpoints conveying findings, questionair

Main methodology for testing your research

qualatitive data from multiple trusted sources such as .gov and .edu sites as well as other scholars / researchers for the research. Quantative data collecting from a questionair that I'll create and send out to as many people as i can to get some feedback to test my hypothesis

Will your research use participants?

Yes

What is your sample size?

20

How have you arrived at this number? Please explain:

Sample of convenience

What age group(s) will you be working with?

18 or over

Are you working with children or vulnerable adults?

No

Do you require a DBS check?

No

How will you recruit your participants?

Don't require proof as the participants infromation is not important to the hypothesis but rather their interaction with the material and how well they can undestand it.

Will you be providing a participant's information sheet?

Yes

Will you make your participants aware of their right to withdraw from this study at any time?

Yes

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Figure 42 Ethics application part 2/3

Are you using a questionnaire as part of your study?

Yes

Issues

Please summarise any relevant legal issues

I won't be performing any malicious activities when it comes to my website and questionnaire so the computer misuse act won't affect me.
As the questionnaire will be anonymous and hosted through google questionnaire which means that there won't be any sensitive data transferred and the participants connection will be secure.

Please summarise any relevant social or environmental issues

The social benefit of the project is a that buisnesses will be better informed about the topic which will allow them to be more confident in using as well as switching to it wich would create more buisness for the groupes involved as well as providing the many benefits of cloud computing.

Please confirm that you agree to abide by the BCS code of practice throughout this study.

Yes

Declaration

Please confirm that this application is correct to the best of your knowledge.

Confirmed

Supervisor Comments

Supervisor confirms they have discussed the ethical issues with the applicant.

Confirmed

Comments

None entered

Ethics Committee Comments

Ethics committee is satisfied with this application.

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Figure 43 Ethics application part 3/3

14 One Drive Link

Dissertation Submission One Drive