**AN INTERNSHIP REPORT**

**submitted in partial fulfilment of the requirements for the Award of Degree of**

**BACHELOR OF TECHNOLOGY**

**in**

**ELECTRONICS AND COMMUNICATION ENGINEERING**

**on**

**VLSI SoC DESIGN USING VERILOG HDL**

**at**

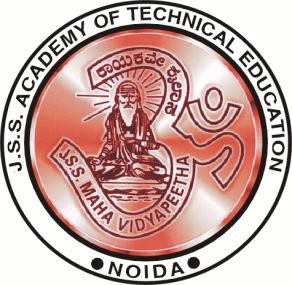
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***Internship Duration: 14 October, 2022 - 10 November, 2022***



**DEPARTMENT OF ELECTRONICS AND COMMUNICATION**

**ENGINEERING**

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# CERTIFICATE



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internship, and for that I am forever grateful.

I would also like to thank my brother, Anshul Verma for his continued support throughout the period of my internship and helping me every time I got stuck at a task (which was quite

often).

Next up, I would like to thank Akruti Agarwal, our team leader, for her constant support

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AMISH VERMA

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# ABSTRACT

Very large-scale integration (VLSI) is the process of creating an integrated circuit (IC) by combining millions or billions of MOS transistors onto a single chip. Before the introduction of VLSI technology, most ICs had a limited set of functions they could perform. An electronic circuit might consist of a CPU, ROM, RAM and other glue logic. VLSI enables IC designers to add all of these into one chip.

“VLSI SoC Design Using Verilog HDL” is an online training program by Maven Silicon – a VLSI training company based in Bangalore, India. This training program is beginner-friendly and introduces students to VLSI design and usage of Hardware Description Languages (HDL), particularly Verilog HDL. The program is hands-on and provides complete tutorials of writing, compiling and simulating VLSI designs with Verilog in Intel’s Quartus Prime software and Doulos’s EDA Playground.

This report outlines the above mentioned online training program from Maven Silicon taken by me from 14 October, 2022 to 10 November, 2022. I will give a brief overview of the training program, then a description of what I learned in the program and finally, the projects I created at the end of the program.

This program was a great opportunity for me to explore the fascinating world of VLSI design and all that goes into making a System on a Chip (SoC). I learnt a lot through this program and would like to recommend it to any one beginning their journey in the VLSI industry.

**Chapter 1**

## INTRODUCTION

The electronics industry has achieved a phenomenal growth over the last few decades, mainly due to the rapid advances in large scale integration technologies and system design applications. With the advent of very large scale integration (VLSI) designs, the number of applications of integrated circuits (ICs) in high-performance computing, controls, telecommunications, image and video processing, and consumer electronics has been rising at a very fast pace.

It would not be a stretch to say that VLSI technology has changed the world. It has enabled faster computations and miniaturisation of chips which has ultimately led to advancements in fields like artificial intelligence, self-driving cars, IoT devices, smartphone indutry and so much more. Apple’s new SoC M1 Ultra consists of 114 billion transistors, the most ever in a personal computer chip. This level of advancements have only been made possible due to VLSI technology.

**1.1 WHAT IS VLSI?**

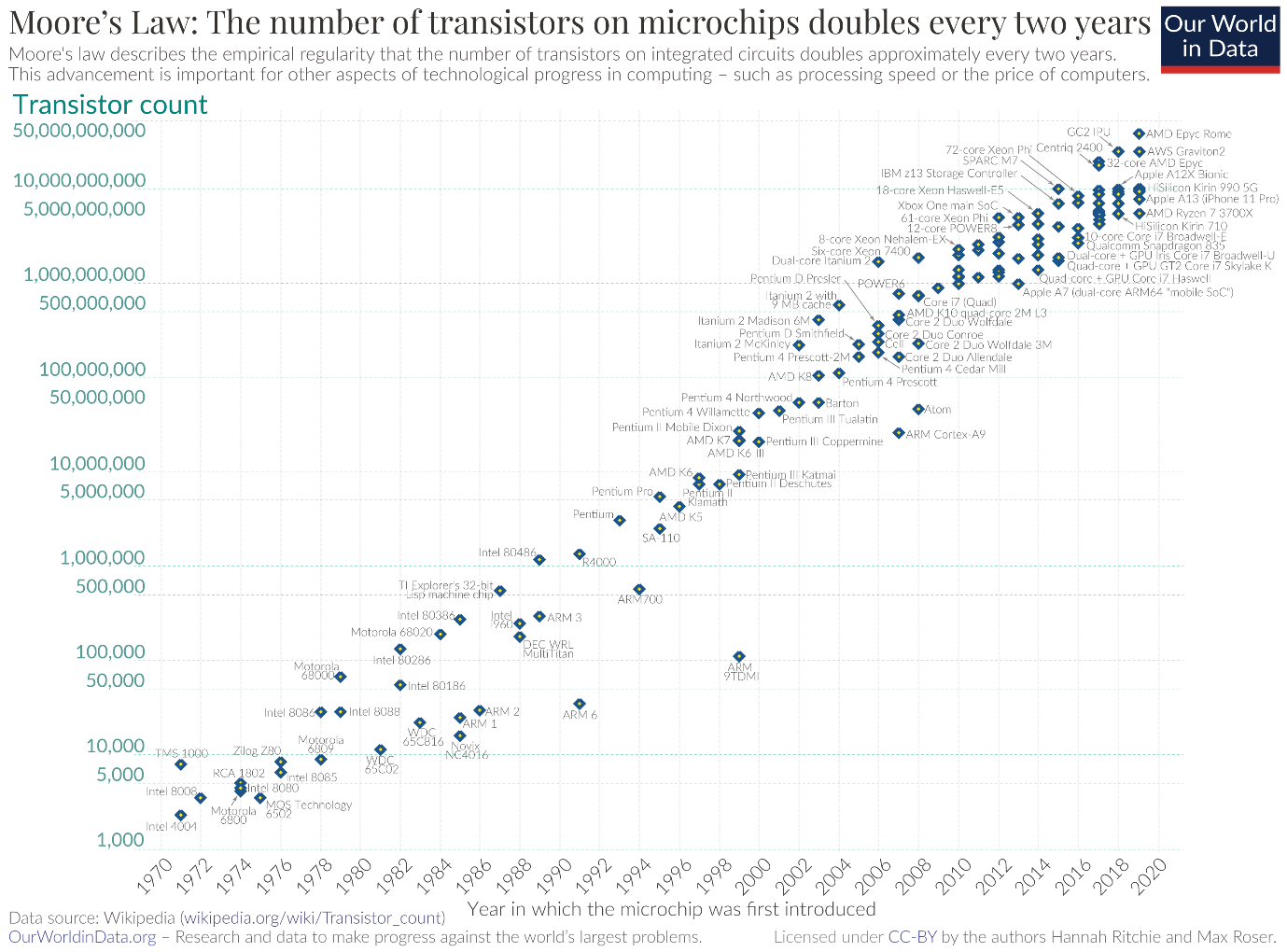
VLSI stands for Very Large Scale Integration. It refers to an integrated circuit creation technology with a very large number of transistors on a single chip. Typically, the number of these transistors on a single chip have to be greater than 1 million for the chip to be called a VLSI chip, but there is no universally accepted, clear distinction among various generations of integration technologies based on the number of transistors on a single chip.

**1.2 HOW IS DATA ANALYTICS DIFFERENT FROM DATA ANALYSIS?**

It is very confusing to spot the difference between both the terms, “data analytics” and “data analysis” because they almost sound as if they are the same thing. But there is a

difference.

Data analysis can be thought of as a slice of big pie which is Data analytics. The main goal of data analytics is to explore datasets to derive informed decision-making. That process may involve various steps - from asking the right questions to finally presenting a solution. Sometimes, there might not even be a solution. The path to reach that end-point, whether we conclude with the fact that we have the solution or not, involves data analysis. In Data analysis, we try to make sense of the data that is given to us by modelling it to our needs. Now, it must be said that both the terms do not have a fixed definition as are sometimes used interchangeably, even by industry professionals. Also, different organizations have different needs for different data so it is hard to provide the exact difference between these two terms. Sometimes, they might even overlap. The main thing though, is to understand the process through which data goes to give us a meaning. Throughout this report, I have used the term “data analysis” even where “data analytics” could have been more appropriate. This is because data analysis is a much more familiar term and is used more commonly than data

analytics. 

### 1.3 DATA ANALYTICS AND DATA SCIENCE

We can differentiate between data analytics and data science by examining what the industry professionals related to these two fields, namely data analysts and data scientists, do

with data. It must be noted here that there might also be some deviations as to what a data analyst and a data scientist’s job is. Usually these deviations are dependent on the organization these professionals are working for. Thus, we are talking in general terms when

we say data analyst and a data scientist.

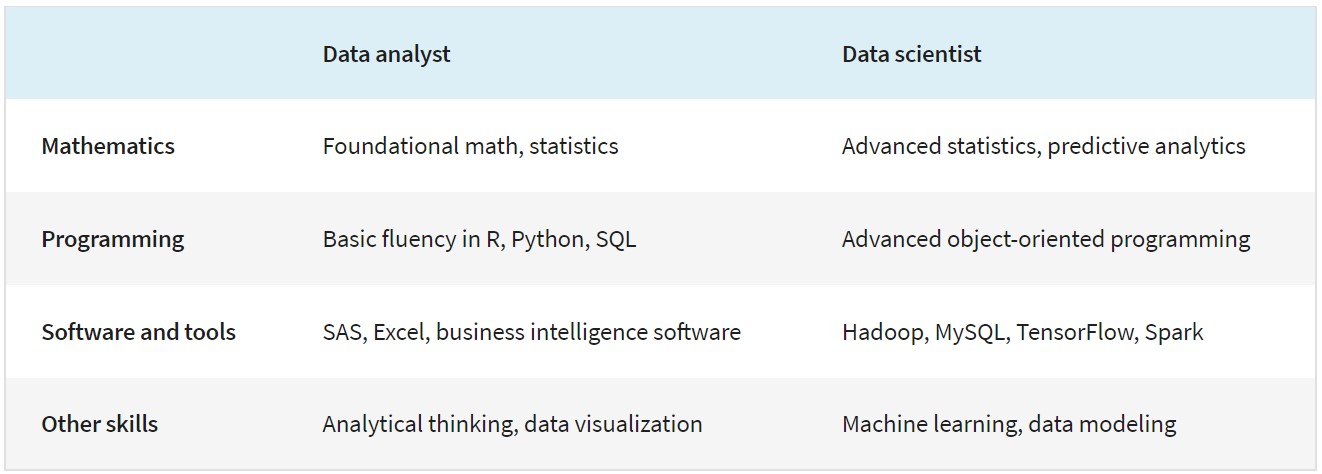
Data analysts typically work with structured data to solve tangible business problems using tools like SQL, R or Python programming languages, data visualization software, and

statistical analysis [2].

Data scientists often deal with the unknown by using more advanced data techniques to make predictions about the future. They might automate their own machine learning algorithms or design predictive modeling processes that can handle both structured and

unstructured data [2].

Table 1.1 - Skills required for a data analyst and a data scientist [2]



### 1.2 VARIOUS JOB ROLES ASSOCIATED WITH DATA ANALYSIS

The data analyst role is one of many job titles that contain the word “analyst.” To name a few

others that sound similar but may not be the same role [3]:

* **Business analyst** — analyzes data to help businesses improve processes,

products, or services

* **Data analytics consultant** — analyzes the systems and models for using data
* **Data engineer** — prepares and integrates data from different sources for

analytical use

* **Data scientist** — uses expert skills in technology and social science to find

trends through data analysis

* **Data specialist** — organizes or converts data for use in databases or software

systems

* **Operations analyst** — analyzes data to assess the performance of business

operations and workflows

Data analysts, data scientists, and data specialists sound very similar but focus on different tasks. In fact, sometimes companies’ job descriptions seem to combine these roles or look for candidates who may have overlapping skills. Thus, it is very important to look closely at the job description even if we’re familiar with the job title, to see if our skills match the ones

required for the job.

Table 1.2 [3] illustrates some of the overlap and distinctions between three job titles\*.

\*In Table 1.2 [3], we used the role of data specialist as one example of many specializations within data analytics, but specializations can take a number of different turns. For example,

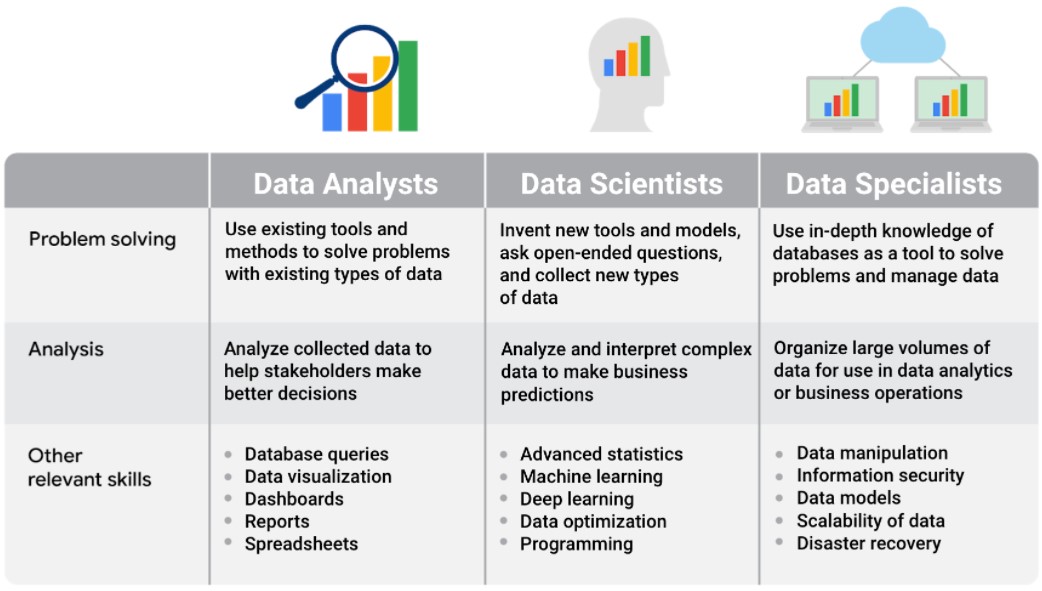
one can specialize in developing data visualizations and likewise go very deep into that area.

#### Job specializations by industry

We saw that the data specialist role concentrates on in-depth knowledge of databases. In similar fashion, other specialist roles for data analysts can focus on in-depth knowledge of specific industries. For example, in a job as a business analyst one might wear some different hats than in a more general position as a data analyst. As a business analyst, one would likely collaborate with managers, share one’s data findings, and maybe explain how a small change in the company’s project management system could save the company 3% each quarter. Although one would still be working with data all the time, you would focus on using the

data to improve business operations, efficiencies, or the bottom line.

Table 1.2 - Overlaps and distinctions between three job titles [3]



Other industry-specific specialist positions that we might come across in our data analyst job

search include [3]:

* **Marketing analyst** — analyzes market conditions to assess the potential sales of

products and services

* **HR/payroll analyst** — analyzes payroll data for inefficiencies and errors
* **Financial analyst** — analyzes financial status by collecting, monitoring, and

reviewing data

* **Risk analyst** — analyzes financial documents, economic conditions, and client data to help companies determine the level of risk involved in making a

particular business decision

* **Healthcare analyst** — analyzes medical data to improve the business aspect of

hospitals and medical facilities

Key takeaway from all of this is that the job of a data analyst varies widely with industry and

organization needs. So one must clearly read the job description before applying for a job.

### 1.3 PHASES OF DATA ANALYSIS

While the data analysis process is well known among experts, there isn't a single defined structure of those phases. There might not be one single architecture that’s uniformly followed by every data analysis expert, but there are some shared fundamentals in every data

analysis process. Generally, all the data analysis processes involve roughly four steps -

1. Data Collection
2. Data Cleaning
3. Data Analysis, and
4. Data Visualization

From our journey to the pyramids and data in ancient Egypt to now, the way we

analyze data has evolved (and continues to do so). The data analysis process is like real life architecture, there are different ways to do things but the same core ideas still appear in each

model of the process.

The key takeaway from all of that is this - even though the exact path taken in the data analysis process might be different, all of them go through some of the same general steps,

and the ultimate goal of data analysis is to help organizations make better business decisions.

Analysts use data-driven decision-making and follow a step-by-step process. Here is a

six-step path that Google teaches in its Data Analytics course on Coursera:

1. **Ask questions** and define the problem.
2. **Prepare data** by collecting and storing the information.
3. **Process data** by cleaning and checking the information.
4. **Analyze data** to find patterns, relationships, and trends.
5. **Share data** with your audience.
6. **Act on the data** and use the analysis results.



Fig. 1.1 - The six-step Data Analysis process taught by Google [4]

# Chapter 2

## ABOUT THE INTERNSHIP

### 2.1 KPMG DATA ANALYTICS VIRTUAL EXPERIENCE PROGRAM

KPMG Data Analytics Virtual Internship Program is provided by KPMG via

www.theforage.com (more about KPMG and www.theforage.com is given in later sections of this chapter). It is a free online program, where one can get to complete work similar to what

graduates do at KPMG. One can get a feel of the work done at KPMG’s Data Analytics

division, and build skills required to excel as an analytics consultant.

The process to complete the program is pretty simple - one can enroll in the program after signing up on www.theforage.com, then one can start a module where they’ll get video instructions about the task from the KPMG supervisor along with some hints and resources to guide in the task completion process. After completing the module, one can upload it on the platform and unlock KPMG model answers, with which one can compare their own work. In this way one can complete all the modules of the program after which a completion

certificate will be issued to the person. One can also submit the tasks as many times as they want making their solutions better and better after comparing them with the model work

unlocked earlier.

It is not the intention for KPMG to hire students based on their performance in this virtual internship and completing the program is not a prerequisite when applying for their current vacancies. This virtual internship is an opportunity for one to demonstrate one’s

interest in KPMG and they will consider students favourably who complete the program [5].

Due to the number of participants potentially completing this program, KPMG will not be able to assess one’s individual work or provide one with specific feedback. However, after submitting their completed work, one will be able to access model work prepared by KPMG’s consultants so one can see how someone from KPMG would approach the task [5].

#### 2.1.1 ABOUT THE FORAGE

Forage started as a mentoring startup in 2017, whose goal was to help students from all backgrounds discover careers and land jobs. Currently, they have “helped over 1.7 million students, worked with over 100 companies, and helped students become up to 5 times more

employable” [6].

Forage is an open platform which is 100% free and focuses on giving students a chance to learn and experience what it is like to work at a Fortune 500 company. They provide

virtual experiences (KPMG Virtual Internship is one of them) from Fortune 500 companies that simulate actual work done at those companies. Fig. 2.1 - Logo of The Forage [7]

Moreover, Forage’s programs are completely online and self-paced so there is no hassle. This gives students a unique opportunity to upskill themselves at the comfort of their

homes at a Fortune 500 company. There is also no interview or selection process to go through. You just sign up on Forage and join any of their programs for free. That is what

makes Forage such an interesting and unique website.

#### 2.1.2 ABOUT KPMG

 KPMG International Limited is a

British-Dutch multinational professional services

network, and one of the Big Four accounting

organizations (the other three being Deloitte, Ernst &

Young and PwC). They provide Audit, Tax and

Advisory services. Fig. 2.2 - Logo of KPMG [8]

One of KPMG’s many divisions include the Data Analytics division whose main

purpose is to help organizations make better decisions by using data, i.e. data-driven decision making. They help organizations make sense of their data, enabling them to learn from and use it to make better business decisions, grow revenue, enhance operational capabilities, and manage enterprise risks and compliance mandates.

### 2.2 TASKS INVOLVED IN THE INTERNSHIP

There were 3 tasks in total to complete the internship. The details of each task is given below.

#### 2.2.1 DATA QUALITY ASSESSMENT

This task required the assessment of data quality and completeness of the dataset provided in

preparation for the analysis.

**The task:**

Draft an email to the client identifying the data quality issues and strategies to mitigate these

issues.

**Background information on the task:**

Sprocket Central Pty Ltd is a medium size bikes & cycling accessories. They need help with their customer and transactions data. The organisation has a large dataset relating to its

customers, but their team is unsure how to effectively analyse it to help its marketing strategy.

The client has provided 3 datasets to us:

* Customer Demographic
* Customer Address
* Transactions data in the past 3 months

As a data analyst intern, I need to start the preliminary data exploration and identify ways to

improve the quality of Sprocket Central Pty Ltd’s data.

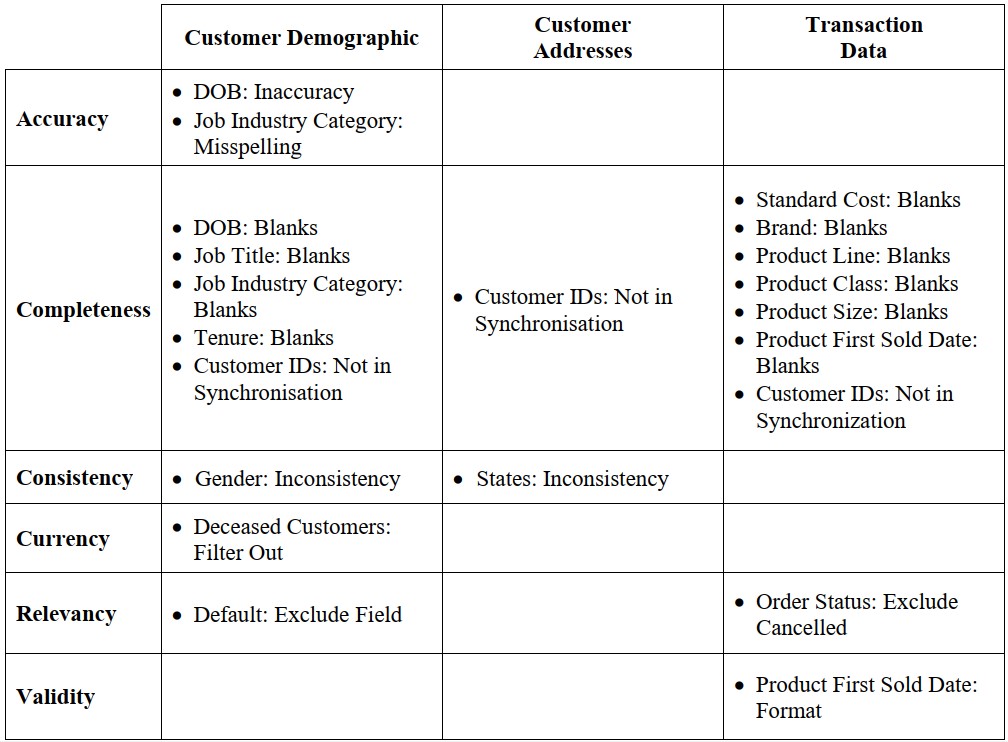
**My approach to solve the task:**

I first used Microsoft Excel to get a general understanding of the dataset and its rows and columns. Then I used pandas, numpy, matplotlib and seaborn libraries of the Python programming language to further explore the data, noting down every data quality issue with the data along with possible ways to mitigate these issues. I used Jupyter Notebook to do the data exploration. Finally, I wrote an email to the client, Sprocket Central Pty Ltd, highlighting the data quality issues and the possible ways to mitigate them. Given below is a link to a GitHub repository where I have uploaded my solution of the task. I have also attached a table

of the data quality issues that I found, just for a reference.

**Solution:** [**https://github.com/thisisamish/kpmg-data-analytics-virtual-internship.git**](https://github.com/thisisamish/kpmg-data-analytics-virtual-internship.git)

Table 2.1 - Data quality issues found in the first task



#### 2.2.2 DATA INSIGHTS

In this task, targeting of high value customers based on customer demographics and attributes

was to be done.

**The task:**

Prepare a detailed approach for completing the analysis of the newly acquired data along with the previous data including activities - understanding data distributions, feature engineering, data transformations, modelling, results interpretation and reporting. This detailed plan needs

to be presented to the client to get a sign-off. Please advise steps you would take.

**Background information on the task:**

Sprocket Central Pty Ltd has given us a new list of 1000 potential customers with their demographics and attributes. However, these customers do not have prior transaction history

with the organisation.

The marketing team at Sprocket Central Pty is sure that, if correctly analysed, the data would reveal useful customer insights and which could help resource allocation for targeted

marketing.

As a data analyst intern, I need to start with a PowerPoint presentation which outlines the approach which I will be taking. The client has agreed on a 3 week scope with the following 3 phases as follows - Data Exploration, Model Development and Interpretation.

**My approach to solve the task:**

**Data Exploration:**

I first used Microsoft Excel to get a general understanding of the newly acquired dataset and its rows and columns. Then I used pandas, numpy, matplotlib and seaborn libraries of the Python programming language to further explore the data and note down the data quality

issues.

After this, I started cleaning the new and the old customers' data. Here are the steps I took -

* Records with missing fields were dropped.
* Join keys between tables were considered and conflicting records were dropped.
* Age, Last Purchase (Days Ago) and Profit fields were added.
* Records pertaining to deceased customers were dropped.
* Transactions more than a year old were dropped.

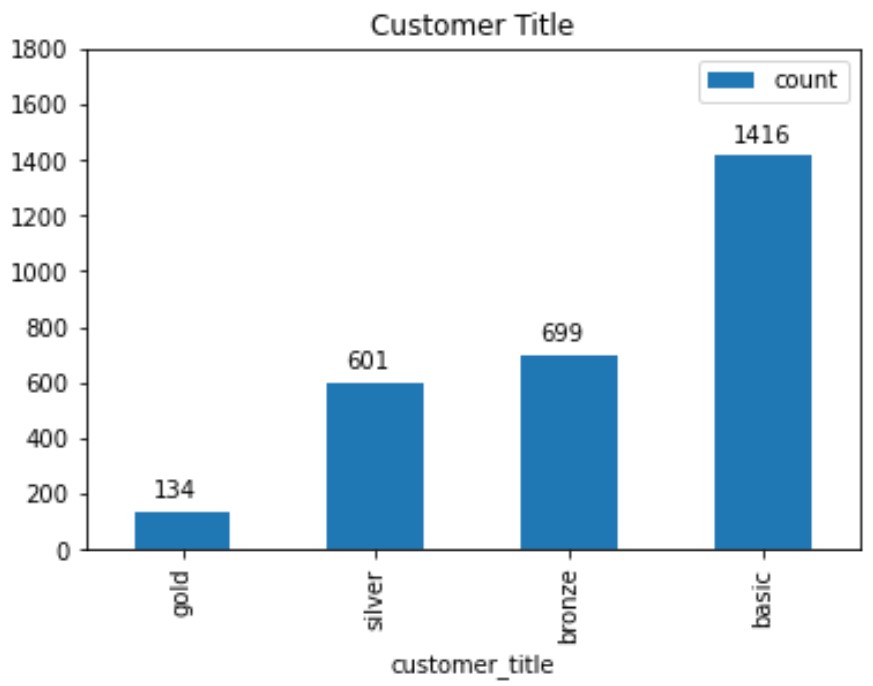
Then with the use of the aforementioned libraries of Python, I plotted graphs and found similarities between the new and old data. After this, Data Exploration was done and I moved to Model Development.

**Model Development:**

I used RFM Analysis for customer segmentation. Based on RFM Analysis, four customer

tiers were identified.

1. Gold Class: These customers Fig. 2.3 - Customer tiers based on RFM Class

 have recently made a

purchase, are frequent and

are most profitable.

1. Silver Class
2. Bronze Class
3. Basic Class: These customers

have not made any recent

purchase, are not frequent

and do not contribute

majorly.

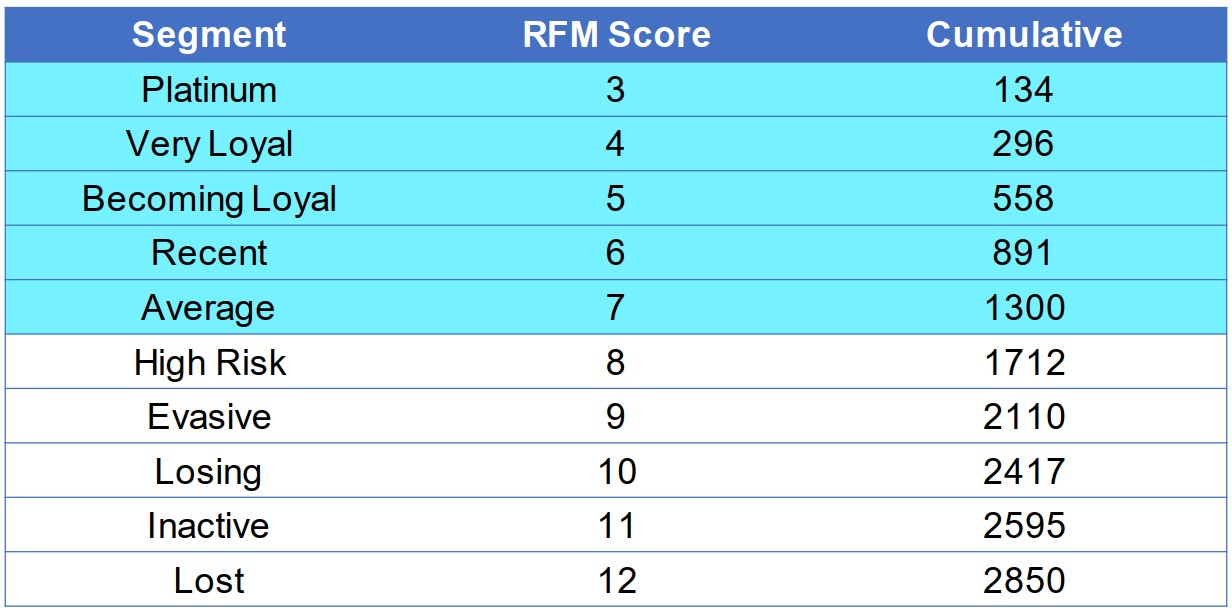
**Interpretation:**

Based on the RFM Analysis, customer segments were divided (as shown in the table on the next page). Thus, customers having high RFM scores can be filtered and targeted to boost.

These customers have made recent purchases, are frequent, and provide the most profits. The full presentation is uploaded on a GitHub repository and the link is given below.

**Solution:** [**https://github.com/thisisamish/kpmg-data-analytics-virtual-internship.git**](https://github.com/thisisamish/kpmg-data-analytics-virtual-internship.git)

Table 2.2 - Customer Segments on the basis of RFM Score



#### 2.2.3 DATA INSIGHTS AND PRESENTATION

This task required using visualizations to present insights.

**The task:**

Develop a dashboard that we can present to the client at our next meeting. Display your data summary and results of the analysis in a dashboard. Maximum of 3 dashboard views/tabs,

creativity in layout and presentation is welcome.

**Background information on the task:**

The client is happy with the analysis plan and would like us to proceed. After building the model, we need to present our results back to the client. Visualisations such as interactive dashboards often help us highlight key findings and convey our ideas in a more succinct

manner.

It is important to keep in mind the business context when presenting our findings. We need to look at the underlying trends in the data and customer segments and propose a proper marketing and growth strategy to Sprocket Central Pty Ltd. Specifically, our presentation should specify who Sprocket Central Pty Ltd’s marketing team should be targeting out of the

new 1000 customer list.

**My approach to solve the task:**

I used Power BI software to develop interactive dashboards out of all the analysis results in the last module. First I plotted 4 charts - Customer Segments by Wealth Segments, Avg Profit by State and Industry, Avg Profit by Age and Gender, and Avg Sales per month of the various customer segments. Then in the next dashboard, I tabulated the Top 1000 customers that the client must target to maximise revenue. Alon with the table, I also included a breakup of

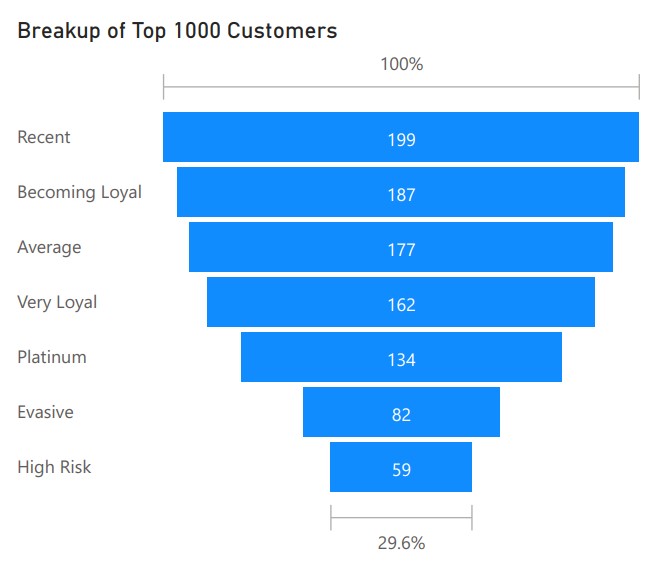
these Top 1000 customers on the basis of the customer segments derived earlier.

I am including the link to the final dashboard uploaded on a GitHub repository. Also included in the report itself is the customer segment wise breakup of The Top 1000 Customers table,

for reference.

**Solution:** [**https://github.com/thisisamish/kpmg-data-analytics-virtual-internship.git**](https://github.com/thisisamish/kpmg-data-analytics-virtual-internship.git)

Fig. 2.4 - Breakup of Top 1000 Customers



**Chapter 3**

## WHAT I HAVE LEARNED

While completing the KPMG Data Analytics Virtual Experience Program, I learnt a great deal about the fascinating world of data science, all of the various jobs related to this field, the cutting edge softwares used to create beautiful visualisations, the sheer power of Python language when used with all of its libraries, and extremely valuable soft skills like email writing, creating presentations and last but not the least, being a detective and uncovering the mystery behind a spreadsheet of data.I have listed all of these invaluable

learnings down below and explained them in detail.

### 3.1 ABOUT DATA SCIENCE AND THE JOBS ASSOCIATED WITH IT

Data Science is a vast field with many sub-branches that often get confused with each other. It is also a relatively new field with numerous ongoing research. I got to understand what all comes under the umbrella of Data Science and how to distinguish its various

sub-fields.

I also got to learn about the various jobs associated with Data Science. This knowledge about the various job fields will immensely help me in forging a career in the world of Data Science. I have listed all of the terms frequently used in Data Science and how to distinguish between them, along with the job fields associated with them in the

introduction of this report.

### 3.2 TOOLS/SOFTWARES USED

I used a lot of softwares and technologies to successfully complete this internship. I have

given a brief description of all of them below.

#### 3.2.1 MICROSOFT EXCEL

Microsoft Excel is a spreadsheet tool developed by Microsoft. It uses rows and columns to store data, like all spreadsheets. It also provides handy features to do data

cleaning and data analysis, along with some functionality to do data visualization.

I used Microsoft Excel to do the initial data exploration. I got a feel of what the datasets contained before moving forward with pandas and matplotlib to do the actual data

cleaning.

#### 3.2.2 JUPYTER NOTEBOOK

It is essentially a web-based interactive computational environment for creating

notebook documents. A Jupyter Notebook document is a browser-based REPL

(read-eval-print loop) containing an ordered list of input/output cells which can contain code, text (using Markdown), mathematics, plots and rich media. Underneath the interface, a notebook is a JSON document, following a versioned schema, usually ending with the

".ipynb" extension [9].

I used Jupyter Notebook to pretty much do all the data exploration, data cleaning, data

analysis and preliminary data visualization.

#### 3.2.3 PYTHON PROGRAMMING LANGUAGE AND IT’S LIBRARIES

Python is an interpreted high-level general-purpose programming language. Its language constructs as well as its object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects. Python is dynamically-typed and garbage-collected. It supports multiple programming paradigms, including structured (particularly, procedural), object-oriented and functional programming [10], [11].

I used Python, along with its libraries - NumPy, pandas, Matplotlib and Seaborn to do data exploration, data cleaning, data analysis and preliminary data visualization. Brief

description of these libraries is given below.

* **NumPy** is the fundamental package for scientific computing in Python. It is a Python library that provides a multidimensional array object, various derived objects (such as masked arrays and matrices), and an assortment of routines for fast operations on arrays, including mathematical, logical, shape manipulation, sorting, selecting, I/O, discrete Fourier transforms, basic linear algebra, basic statistical operations, random

simulation and much more [12]. NumPy is open-source.

* **pandas** is an open source, BSD-licensed library providing high-performance, easy-to-use data structures and data analysis tools for the [Python](https://www.python.org/) programming

language [13].

* **Matplotlib** is a comprehensive library for creating static, animated, and interactive

visualizations in Python [14]. It is open-source.

* **Seaborn** is a library for making statistical graphics in Python. It builds on top of [matplotlib](https://matplotlib.org/) and integrates closely with [pandas](https://pandas.pydata.org/) data structures. Its plotting functions operate on dataframes and arrays containing whole datasets and internally perform the necessary semantic mapping and statistical aggregation to produce informative plots. Its dataset-oriented, declarative API lets you focus on what the different elements of

your plots mean, rather than on the details of how to draw them [15]. Seaborn is

open-source.

#### 3.2.5 POWER BI DESKTOP

**Power BI Desktop** is a free application you install on your local computer that lets you connect to, transform, and visualize your data. With Power BI Desktop, you can connect to multiple different sources of data, and combine them (often called *modeling*) into a data model. This data model lets you build visuals, and collections of visuals you can share as reports, with other people inside your organization [16]. Power BI Desktop is a part of Power BI software by Microsoft.

I used Power BI to create the interactive dashboard required for module-3 of the

internship.

### 3.3 DATA ANALYTICS IN THE ELECTRONICS INDUSTRY

Data Analytics is the science of data. When properly analysed, raw data can give meaningful information which can be taken into consideration while making business decisions. Electronics industry, too, can benefit from incorporating data-driven decision making in their various areas of business like supply chain management, customer analytics,

marketing etc.

In even the most simple decisions, having solid data is always beneficial. Hence be it any industry, data analysis is always important. But especially in the electronics industry in this age of **Industry 4.0 or the Fourth Industrial Revolution**, data can be used to create better **AI** models and better **automation** and **robotics** systems that move the industry forward. The term Industry 4.0 encompasses a promise of a new industrial revolution - one that marries advanced manufacturing techniques with the **Internet of Things (IoT)** to create manufacturing systems that are not only interconnected, but communicate, analyze, and use

information to drive further intelligent action back in the physical world [17].

We can use data analytics to better target customer demographics, create better workplace conditions for employees, predict trends in the demand and supply of electronic

components and so much more. The possibilities are endless.

**Chapter 4**

**CONCLUSION**

VLSI technology is a fascinating area in engineering. The technological advancements in this field have had major impacts in almost every other industry in the world and in our lives too. It is the backbone of our digital economy.

With the new technologies in software domain like Machine Learning, Web3 and Quantum Computing, VLSI is easily overlooked. But it must be remembered that it’s the VLSI technology that is powering all the software technologies. The extensive computing power that machine learning algorithms require or the chips in commercial personal computers that allow us to write these algorithms, all are powered by integrated circuits, which are in turn are created using VLSI technology.

In this one month online training by Maven Silicon, I learnt a lot about how chips are designed and how engineers use tools like Quartus Prime, ModelSim and EDA Playground to create, simulate and test chip designs. I learnt in detail about the hardware description language Verilog and then used it to create my very own circuit designs. I then wrote test-benches to test my designs by simulating them. It was a fun and rewarding experience and I cannot wait to put my skills to test by creating more complex circuit designs.

With the knowledge I have gained in this online training, I would create circuit designs of digital signal processing systems that I am studying in my fifth semester course “Digital Signal Processing”. I would implement FIR and IIR filters in ModelSim, write test-benches for these circuit implementations and finally, I would like to synthesise these circuits on an actual FPGA (Field Programmable Gate Array).

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