Enabling investment transparency by developing an interactive web-based dashboard to show data on various pension funds

[INDUSTRY PROJECT]

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Abstract

This project is based with a company that partners with UK's largest investment and pension platforms, empowering them to provide their investors with transparency over the companies they are invested in, and a shareholder voice on issues they care about at those companies, whether that be gender equality, climate change or others. Currently the company shows the user a flat list of all the companies in either a single fund, or an aggregated list of companies across a number of funds within that user's pension. The company would like to explore alternative ways of presenting the structure and contents to make the data more visually engaging and to show the interaction of different funds.

This project therefore explores the fields of data visualisation and financial visualisations to identify models that could be applicable to such a problem. These models are then presented to participants in a user research project to identify the most engaging and comprehensible option. A prototype based upon the selected design is developed and presented, which offers an interactive and engaging visualisation to present the structure of a user's pension funds. This prototype takes in data from the format used by the company's APIs and converts it into a data format suitable for the chart, offering compatibility with the company's data structures. The prototype also offers a number of additional features which have been based upon requirements scoping and feedback from the user research.

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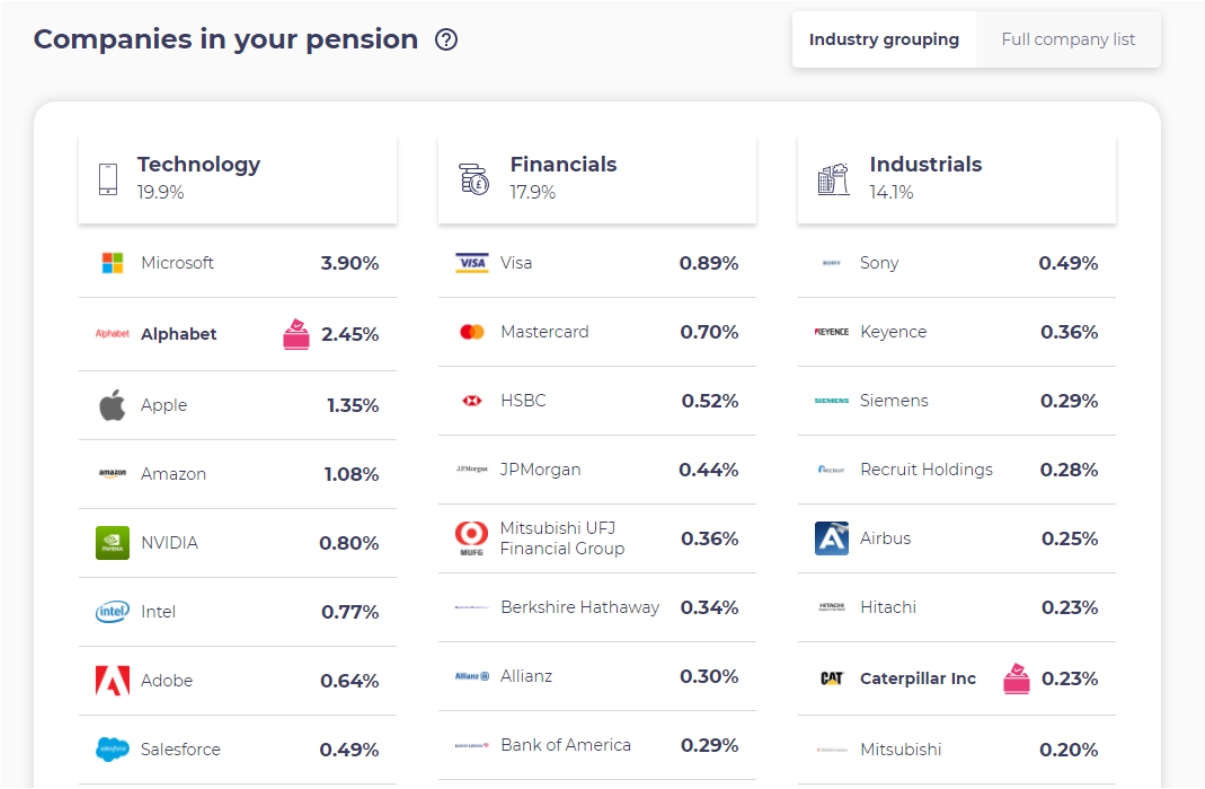
Section 1: Introduction

This project is industry-based, working with a company called Tumelo who build software to raise pension investors' awareness of how their funds are invested and to empower them to use their shareholder voice to influence decisions within these companies. This enables pension holders to have a voice about issues they care about, such as human rights or climate change, and to recognise the influence they have as investors. Currently Tumelo offers their users insights into their pension holdings via a web-based 'Member Dashboard' and this project is aimed at adding value to this dashboard by developing a more interactive interface. The existing platform gives users information about the companies invested in through their pension and also highlights any upcoming AGM votes. Users can then indicate how they would vote on these issues and this information is then fed to their pension Fund Manager to encourage them to vote in line with their Members' preferences.

The part of the dashboard that shows the user their investments currently holds a list of the companies invested in through their pension, and offers the option to group these by industry, a sample of which is shown below in Figure 1A. However, this doesn't demonstrate any of the structure of the pension fund or the reality that funds are often invested in other funds, meaning the pension actually forms a tree-structure of nested funds and their holdings. The data containing which companies are invested in within a particular pension is currently aggregated, so that the overall percentage invested in each company is shown. However, Tumelo would like to explore showing the hierarchical links between nested funds and companies to the user. They would also like to offer interactivity so that the user could explore the structure of their fund, for example by clicking on sub-funds to see which companies they contain.

Figure 1A: Current Member Dashboard



In addition to this Member Dashboard, Tumelo also offer a 'Stewardship Dashboard' that is used by Fund Managers and Pension Trustees. This offers these users information on the funds they oversee, such as the companies invested in, how their members voted on AGM topics, and how Fund Managers voted at the AGMs. The team at Tumelo also feel that an interactive chart showing the structure of a pension could be of use to Fund Managers and Pension Trustees via the Stewardship Dashboard, offering them a chance to explore the investments within the funds they oversee. Interactive charts could also be used to show other data to these users, such as information on AGM votes relating to the different companies within the funds they are responsible for, though this is not anticipated to be part of this particular project but may draw upon the system that is developed. The main focus of this project is to develop a system that could be used on the 'Member Dashboard', aimed at pension holders, so that user group will be the main focus but it's worth bearing in mind the needs of Fund Managers and Trustees also.

Section 2: Aims and Objectives

The overall aim of this project is to encourage pension holders to engage with how their pension is invested and to make decisions to bring their pension investments more in line with their values. In order for pension holders to feel more engaged with their pension, and to make informed choices about it, Tumelo wants to offer a visually-engaging, interactive platform for users to explore their pension and its holdings. Part of the complexity of this project is in developing something that will engage a variety of users as some users will have very limited knowledge with respect to pensions and investments while others may be highly informed. If used on the Stewardship Dashboard, users such as Fund Managers and Pension Trustees will naturally have particularly high levels of understanding regarding pensions. Offering something that is easy to understand for the inexperienced user, with the ability to dig deeper to those who would like to, will be important.

In order to meet this overall aim, there are a number of specific objectives for the project. These are:

- To demonstrate the structure of investments within a given pension fund, including nested funds, in a visual way
- To offer interactivity, allowing the user to explore the data
- To find out, through user research, what users would like to see displayed about their pension and what style of interface they find most engaging and informative
- To find out about the data Tumelo holds about companies within pension funds, in order to make decisions about what it might be possible to present
- Drawing upon the results of research and information about the available data, to develop a system that presents the relevant data in a style that users find engaging
- To appropriately represent instances where the company's data regarding a specific pension fund is incomplete

To ensure I conduct effective and relevant research, I have formed two key research questions based upon the objectives, as advised by White, who suggests, 'objectives identify the desired outcomes (or 'goals') of your research and point to the kinds of question that would need to be asked in order to achieve these outcomes' (2017, pp.39-40). To help meet

the objectives of this project, therefore, it will be necessary to research the following two questions:

1. What data would users like to see displayed about their pension holdings?
2. What visualisation would be most engaging to the widest range of users?

Answering these questions through this research will enable me to meet the objectives of finding out users preferences and responding to these in the data presented and design of the interface.

In order to meet the aims and objectives listed, this project will evaluate the wider field of research that relates to this subject and draw upon relevant projects and literature to propose solutions and approaches to the problem presented here. This will ensure that products developed are in line with up-to-date scholarship and practice and ensure that the most well-thought-of and robust approach is taken. This next section will set out the research problem to be addressed in more detail, highlighting the particular complexities of this project. The following section, Section 4, will undertake a critical evaluation of the current field of research within Data Visualisation, particularly as relates to pensions, and then a literature review that draws out the most relevant learning from key texts and projects.

Section 3: Problem Description

The problem to be addressed in this project is how to present the structure of a pension fund in a way that is engaging to users. In the business context, the purpose of this feature for Tumelo is to encourage pension holders to discover more about their investments and make decisions to ensure these are in line with their values. In the academic context this problem sits within the broader field of data visualisation, which will be explored further in the next section.

There are several aspects to this problem that make this project challenging and these will be addressed throughout this report. In particular, the following key points are areas of complexity:

1. Understanding the users
   Tumelo have two different platforms: a 'member dashboard' aimed at pension holders and a 'stewardship dashboard' aimed at Pension Fund Managers and Pension Trustees. The feature being developed in this project is hoped to be used on the member dashboard and potentially the stewardship version. This adds complexity in terms of developing a clear picture of the end user and their needs. This will be addressed in Section 4.2.1.
2. Compatibility
   As this is an industry-based project, another area of complexity is ensuring what is developed is compatible with the company's existing systems. In particular, for this feature, this means compatibility with the existing React applications which form the two dashboards. This will be addressed further in Section 6.1.
3. Data conversion
   Linked to the previous point, pension fund data is accessed via Tumelo's APIs and an additional challenge will therefore be to import data from the API, or in the format the API uses, and to convert this into a useable format for the chart. This will be addressed in Section 8.3.2.
4. Learning React
   In order to make the product I will be developing compatible with the existing platforms, I will need to use React for this project. This is a new library to me and so

learning React will be an essential component of this project, and an added challenge. My approach to this is set out in Section 6.1.1.

5. Working with the wider team at Tumelo
   One of the complexities of undertaking an industry-based project is managing the additional aspect of communication with the company team and managing their expectations and requirements for the project. My approach to this is set out in Section 6.4 and interactions with team members, and presentations I gave, are also referenced throughout Section 7.2 on Design Decisions.
6. Balancing university and company requirements
   As well as working with the wider team at Tumelo and responding to their requirements and working practices, this project also involves meeting university procedures and requirements for the dissertation. Whilst the expectations of Tumelo and the university are generally in line, it will be important to ensure that both are kept in view. In particular, there are areas where working procedures from both sides need to be met, such as in respect to user research, as addressed in Section 10.1.

Benefits:

The main expected benefits from this project are:

1. An interactive visualisation of a pension structure that allows users to explore their investments, measured through acceptance testing against requirements
2. A set of recommendations for further development of this project, measured by submission to the Tumelo team
3. A write-up of the project for the dissertation, measured by submission to the university
4. A shorter write-up for the Tumelo team, measured by submission to the Tumelo team
5. Development of my personal skillset including use of React, measured by completion of a working React application

Section 4: Background Material

4.1 Critical Evaluation of Field

In this section, the context of this project will be evaluated and a review of relevant literature within the field of research that this project fits within will be undertaken. This will begin with the area of Data Visualisation, then narrow to an overview of the field of Financial Visualisations before exploring the specific subject of Pension Visualisations.

4.1.1 Data Visualisation

The broader field that this dissertation sits within is that of data visualisation and there are many existing texts, articles and projects within this area. From this field of research, there is much that can be drawn upon for this project, especially in terms of general principles of effective data visualisation and examples of models that may be relevant. This broader research is explored in the next section which undertakes a critical review of this literature and its relevance to this project. Prior to that, I will explore the more specific areas of finance visualisations and pension data, to demonstrate the particular gap in research that this project seeks to fill.

4.1.2 Finance Visualisations

Within the more specific field of financial visualisations, there are broadly two types of projects. One is a comparative type and involves projects that survey data visualisations within the financial field, comparing different approaches. The second are projects that undertake a particular representation of financial data, applying a chosen approach that suits the specific aims of the project.

In terms of the former, a number of relevant articles exist including Ko et al's 'A Survey on Visual Analysis Approaches for Financial Data' (2016), where the authors explore a number of chart types but also include a section on interactive models of visualisation, which is particularly relevant to this project. In this section they highlight that as well as different styles of visualisation, there are different approaches to interaction within financial visualisations. Utilising the seven categories developed by Yi et al (2007), they offer a means of comparing various interaction methodologies. Ko et al's survey suggests that the 'Abstract/Elaborate' and 'Filter' methods are the most popular within the financial sector

(2016, section 8.2) and this is likely to align with the approach taken in this project. The 'Abstract/Elaborate' method is used where there's a need to offer some kind of overview of a set of data, with the opportunity to go into more details on specific sections where needed (such as by zooming in) (Ko et al 2016, section 8.1). The 'Filter' method is used to sift the data according to specific conditions (Ko et al 2016, section 8.1). This project will require an 'Abstract/Elaborate' approach to present the overall structure of a pension and to allow the user to explore subsets in more detail. Desirable functionality that has also been requested by the Tumelo team includes allowing users to search for data within their pension or to explore the data by specific criteria such as geographical location (see Section 6.2). These functions would require a 'Filter' method in order to display certain aspects of the data according to the specified criteria.

Marghescu (2007) offers another comparative paper in which she explores the capabilities of various visualisation techniques, which are summarised in Table 3 and Table 4 (p.23) where Marghescu shows the strengths of each method. The author then shows how differing visualisation techniques could be combined to complement one another's strengths and give a more robust analysis of the data. As her project seeks to compare the performance of various businesses, this breadth and accuracy is important. This project is not seeking to analyse data or inform judgements in the same way, so combining techniques in order to ensure various attributes of the data are not missed is less important.

Another interesting project that seeks to categorise visualisations of financial data is financevis.net (Dumas et al 2014). This project takes the form of a website where the authors offer examples of a wide variety of forms of financial data visualisations. The models included have been categorised so that they are searchable, meaning that you can find visualisations that might be relevant to a particular project. You can, for example, search by date, author, type of visualisation, relevant area of finance or various variables within the data. Of particular relevance to this project, they include a number of Treemaps that focus on the display of stock market and mutual fund portfolio data.

In terms of projects that undertake a particular financial data visualisation, Rybak's dissertation, *Financial Information Extraction and Visualization*, is especially relevant (2013). This project sought to extract financial data from news articles and to present these in a way that was engaging to users. In particular, the visualisation part of this project is highly

relevant to this project as it seeks to present financial information in a visually stimulating way. Rybak settles on a Treemap model for his visualisation, demonstrating how this approach can communicate categorised financial data in a clear way (2013, p.77). Specific models such as the Treemap will be explored in more detail in the following sections.

4.1.3 Pension Visualisations

In the specific area of pension fund visualisations, there does not seem to be as much of relevance in terms of existing literature or projects. Rodriguez offers a chapter on pensions in *Visualizing Financial Data*, showing a number of visualizations of aspects of pension data (2016, pp. 195 – 244). These, however, are from the perspective of a pension provider and communicate data such as the demographics of pension holders, their survival rates, and contributions versus benefits. In this project, the data is from the perspective of the pension holder and relates to the companies invested in within their funds. This kind of data would probably lend itself to quite a different form of visualisation to those set out by Rodriguez.

This project therefore offers a unique contribution to the field of financial visualisation and the broader context of data visualisation by exploring the specific area of pension fund data. This will draw on learning relating to effective visualisation tools, the communication of financial data and means of representing hierarchical data structures. These will then be applied to a particular use case of an interactive user platform for pension holders to explore their funds. The learning from this particular case will then offer its own conclusions back to the broader field.

From this evaluation of the fields of financial visualisations and pension visualisations, it is clear that the material relating specifically to pension data is limited but, whilst the area of financial visualisations broadly offers comparative evaluations or specific applications, there are take homes from this field. In particular, this overview has highlighted certain chart types that are frequently used, with the Treemap being often utilised for hierarchical financial data. The comparative texts also provide useful examples, such as the approaches to interaction set out by Ko et al (2016), which will be drawn upon later in this report (see Section 4.2.6). What the more specific fields of financial or pension visualisations don't seem to offer though is more general principles on how to visualise data, such as aspects of design, use of colour and accessibility. These can be drawn from the broader area of

research into Data Visualisation and the next section will evaluate this wider context, highlighting principles drawn from this research that are of particular relevance to this project.

4.2 Problem Context & Literature Review

This section sets out points raised by various authors, in the field of Data Visualisation, that will shape the implementation undertaken in the project. These are summarised under the headings 'Understand the User', 'Keep it Simple', 'Use Colour Wisely', and 'Take advantage of Visual Hierarchy'. There are then two sub-sections about particular visualisation types, the first focused on different ways to represent overarching data structure, titled 'Visualising Overall Data Structure' and the second on particular visualisation models, setting out why certain ones have been selected as most relevant to this project, titled 'Specific Visualisation Styles'.

4.2.1 Understand the user

One of the central challenges of this project is to communicate data in a way that is engaging to the intended audience, which is further complicated by the breadth of users in terms of levels of knowledge of pension funds and their structures.

The Gemignani brothers explore the importance of beginning with an understanding of the data's audience in their book 'Data Fluency' (2014). They state,

> Often there will be multiple audiences for a data product…The structure of a data product can help. For example, separating the executive summary from an appendix allows the executive and the data analysts to both get what they want. Interactive data products allow users to drill into areas where they want to find out more. (Gemignani 2014, p. 86-87)

This ability to offer different levels of engagement and the use of interaction to offer opportunities for interested parties to discover more, is key to the success of this project as it is hoped that the finished platform could offer interest to users with low levels of pension knowledge through to more informed users. This is central to the aims of the project, as set out in Section 2.

In order to assist with development of a system that is suitable for this range of users, I decided to use personas to represent some of the types of user that will interact with the platform. Personas 'help project participants identify with users and think of these instead of themselves' (Nielsen 2019) by providing a specific, hypothetical example of an end user.

On discussing the use of personas for this project with Tumelo team members, I discovered that Tumelo already use a specific style of persona and also use overarching 'Archetypes' which set out broader types of user, compared to the more specific personas. I therefore decided to use existing Archetypes and Personas that have been drawn up to represent Tumelo's users and used their documentation to select those that are most relevant to this project. Tumelo have developed five archetypes that represent certain categories of user that they understand interact with their platform. The one they are most focused on attracting is the 'Trending Newcomer' and the second is the 'Quietly Established' as these are the main user groups their clients are seeking to attract to their pension schemes. Details of these two archetypes are given in Appendix 1. There are specific personas that represent hypothetical users from these two archetypes, so these are the personas I selected as they represent target users. The first persona, 'Holly' is an example user of the 'Trending Newcomer' archetype, as is 'Jack', the second, see Appendix 2. The third, 'John', see Appendix 3, is from the 'Quietly Established' group.

For each of these personas, it is important to consider what their intended use of the platform is likely to be and how much prior knowledge of pension funds they hold and to allow this to guide the development of the system. Drawing upon the archetypes and personas, I have listed a few key points for these different user groups below, which will be important to bear in mind when designing my system.

For Holly and Jack, the 'Trending Newcomers', the key points will be:

- They are 'tech-native', highly comfortable with tech and the use of apps
- They are ethically aware and particularly interested in issues relating to climate change, sustainability and social justice

- They are heavily influenced by social media – this may mean a particular interest in companies that appear in the news
- They need accessible and engaging education around pensions & investments
- Frustrations may include that pensions are too abstract and a sensed lack of control and transparency

For John and the 'Quietly Established' archetype, the main points will be:

- They are reasonably comfortable with technology
- They may have multiple pension pots
- They may need clarity on the big picture of their finances
- Their main concern is stability for their family, but they may invest ethically if they can see that this will not incur greater risk
- Frustrations may include technical jargon, being time poor, and wanting to know if investments are really ethical/eco

F**und Managers / Pension Trustees**

For the Stewardship dashboard there is a different user group that consists of pension Fund Managers and Trustees. As these users are interacting with the dashboard as part of their jobs, a persona that highlights characteristics such as personal interests or family situation is less relevant compared to the Member Dashboard user group, who access the platform for personal use. There is also currently less user research to draw on relating to the Stewardship dashboard, although some research is currently being done into their needs. For these reasons, rather than focusing on Archetypes or Personas, I have highlighted the key point points from Tumelo's research into the needs of Fund Managers and Trustees so far:

- They "need to get a high-level view of something that is inherently granular" (Goodwin 2021, *Internal report on development opportunities for Stewardship Dashboard*)

- A user might have a particular interest in a particular company or vote. We need to allow them to search for these items. (Goodwin 2021, *Internal report*)
- Most trustees are likely to want 'big picture', eg one screen with a chart … in diagrammatic format, ie making their lives as easy as possible. This is a natural lead in to the further detail they may ask.
  (Goodwin 2021, *Internal report*)
- A direct quote from some user research was “For Trustees, the main thing would be the dashboard with an aggregated view and possibly questioning the data. As part of that, would you have the ability to classify stocks etc into broad industry sectors? “ (Goodwin 2021, *Internal report*)

Some of these points particularly highlight the business need for a chart that could summarise the overarching pension data whilst allowing the user the ability to explore and search within this to access more detail. Whilst the data included is likely to be different to that accessed by pension holders, the overall approach of this project, to develop an interactive, visually-engaging way of presenting pension data is likely to produce something highly relevant to this business need.

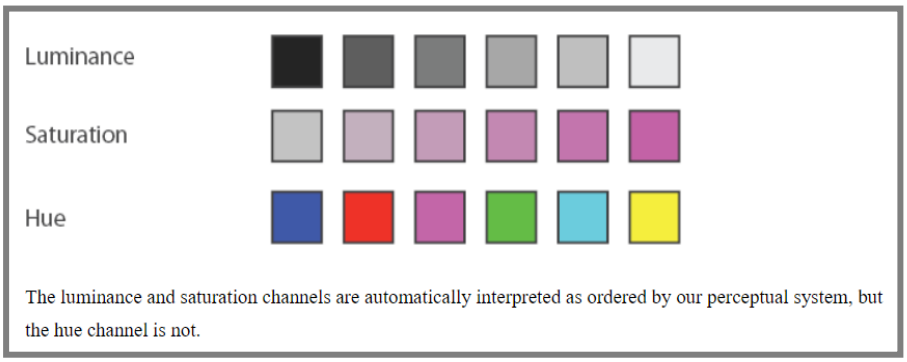
4.2.2 Keep it simple

In Tufte's 'The Visual Display of Quantitative Information', (2001) the author sets out the development of data graphics and puts forward his central argument for simplicity of presentation and the removal of extraneous ink (such as annotation or over-complicated chart graphics), which he refers to as 'chart junk' (p.107). He even sets out a formula for calculating the data-ink ratio of a graphic as a means of ensuring that any superfluous ink is removed (p.93). This is a helpful warning against over-complication of design but needs to be weighed against the need for the user to comprehend the data that is being communicated. A study by Inbar et al (2007) suggests that when presented with a minimalist graph visualisation versus one with more annotation (which could potentially class as 'chart junk'), those participating expressed preference for the version with more ink, on all six aspects of the graphs they were asked about.

4.2.3 Use colour wisely

One consideration in visualisations, that a number of authors pick up on, is how to effectively use colour. Munzner, for example, compares the use of hue, luminance and saturation in diagrams (see Figure 4A) and also contrasts the use of sequential colour schemes to divergent ones (2015, pp. 224-226).

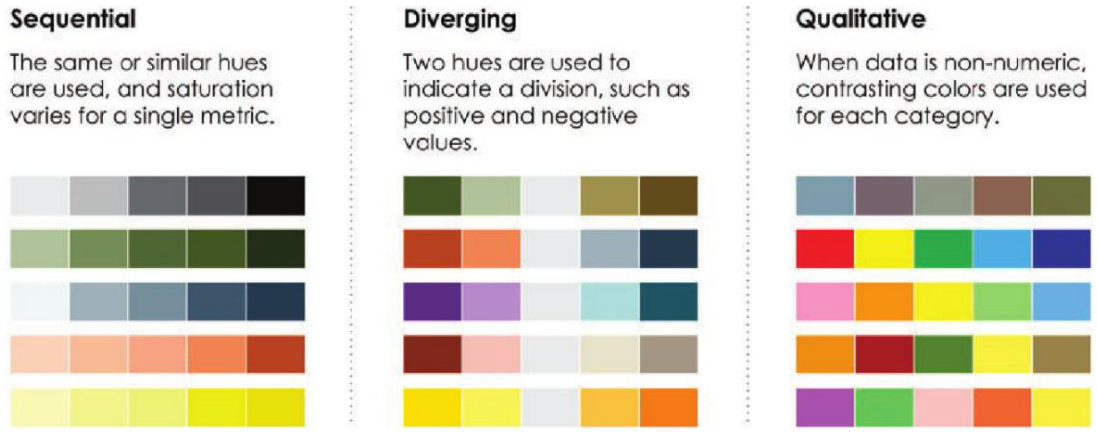
Figure 4A: Luminace, Saturation and Hue (Munzner 2015, p. 224)



Yau (2013) suggests these may each be suitable to particular representations – for example diverging hues can be used to show a division, such as positive and negative values and contrasting hues may be used to show different categories within qualitative data (Yau 2013, p.212), see Figure 4B below. It will be important to consider the most effective use of colour in my visualisations, for example colours hues could be used to highlight different

categories of companies within a fund, whereas sequential saturations could be used to demonstrate percentages of investment in specific companies.

Figure 4B: Different ways to use colour within charts (Yau 2013, p.212)



Another important consideration relating to use of colour is the issue of colour blindness, which affects around 8% of males and 0.5% of females and most commonly affects the ability to perceive the red-green colour axis (Munzner 2015, p.235). Munzner offers the following advice: 'the safest strategy is to avoid using only the hue channel to encode information: design categorical colormaps that vary in luminance or saturation, in addition to hue. Clearly, avoiding colormaps that emphasize red-green, especially divergent red-green ramps, would be wise.' (2015, p.235). For this project, it will therefore be important to take this on board and to avoid red-green colour scales and to ensure saturation or luminance are used, as well as hue, to emphasise differences in data.

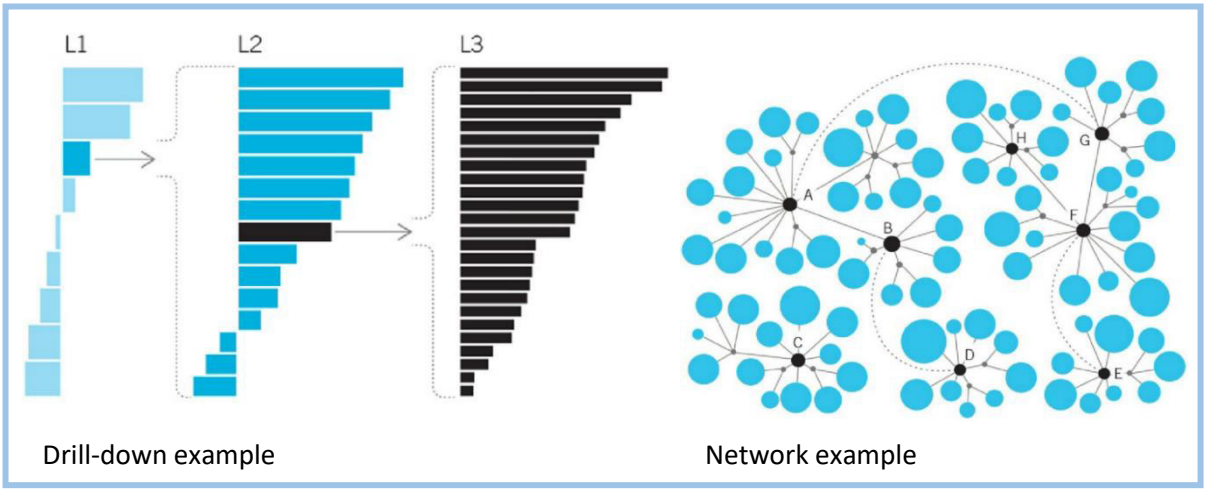
4.2.4 Take advantage of Visual Hierarchy

Another consideration that relates to the use of colour is the notion of visual hierarchy. As Yau points out, 'when you look at anything, you tend to spot things that stand out, such as bright colors, shapes that are bigger than the rest, or people who are on the long tail of the height curve' (2013, p.202). In designing a visualisation, therefore, it is important to consider how to use this to your advantage to encourage people to focus first on the most important aspects of the data. This can be done through use of colour, size, arrows and lines and so on.

4.2.5 Visualising Overall Data Structure

One of the complicated aspects of this project is not just how to effectively visualise the contents of a pension fund (such as the type of companies invested in) but how to communicate the structure of the fund so that a user could explore funds nested within funds and the data within. This would give a more accurate sense of how the pension is invested than the aggregated list of companies currently presented. This involves demonstrating the relationships between different aspects of the data, something that Rodriguez explores in the section 'Establishing Connections' in their book 'Visualizing Financial Data' (2016, pp.29-32). They offer some examples of visualisations that portray such connections, including what they call a 'drill-down' example and a 'network' example (2016 pp.29-31), as shown in Figure 4C. The drill-down example shows a way of demonstrating nested data where, in the example, one of the pieces of data in L1 is shown in greater detail in L2 and again the nested data for an item in L2 is shown in L3. The network example shows the links between various nodes of data in a visual way.

Figure 4C: 'Drill-down' and 'network' models



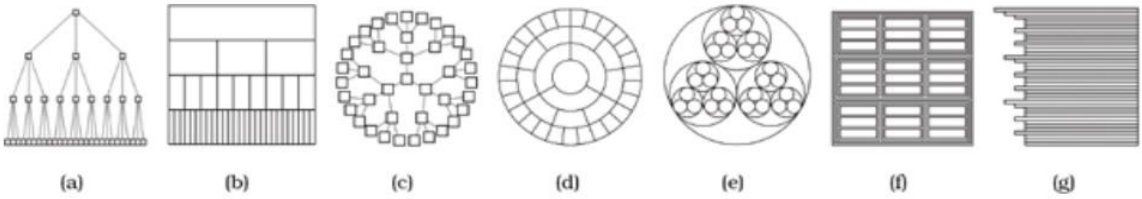
These two examples demonstrate two different options for representing the structure of data, such as that of pension funds. The drill-down example does not represent the entire data or all of the links there within, but rather shows the current path through the data, showing where the user is at present and how this links to the preceding layers within the structure. This pared back approach allows space for representation of the data within the relevant layers, shown in the example by the inclusion of three bar charts. The network example, in contrast, shows the entire layout of the data and its links, giving an overview of

the structure but not giving any breakdown of data within. The visualisation is therefore much more focused on giving a picture of the whole data than on the contents of the layers it contains or on a specific path through it.

The contrast between these approaches is also picked up by Munzner who compares two design mantras, the first being 'Overview First, Zoom and Filter, Details on Demand [Schneiderman 96]' and the second 'Search, Show Context, Expand on Demand [van Ham and Perer 09]' (Munzner 2015, p.137). Munzner suggests the latter may be more relevant to larger data sets where a meaningful overview may be harder to develop. In these cases, giving context to a particular subset of data may be more appropriate. In contrast, the first mantra, which suggests offering an overview first, may be more suited to smaller data sets with less complexity.

Although the node-link diagram, shown in the Network example in Figure 4C, is a commonly used way to represent hierarchical data, there are other options, such as using containment rather than connection to representing such data (Munzner 2015, p.213). A Treemap is an example of containment as data is shown nested within its containing category, rather than linked via a connection. Treemaps can therefore be used to show hierarchical structures as well as categories within one layer of data. There is however, a limit to how many levels of data can be demonstrated within one Treemap as elements would get too small to be readable and the overall image would get too complex if multiple nested layers of data were to be included. However, this can be an effective and space-efficient means of communicating some level of hierarchy. The Treemap model will be discussed further in the next section and two examples are included there (Figure 4I and Figure 4J). Other means of demonstrating hierarchy and nested data are offered by Munzner in a diagram shown in Figure 4D. These include models that use containment as well as some that use connection to show links between data.

Figure 4D: Models of visualising hierarchical data (Munzner 2015, Figure 9.9



Seven visual encoding idioms showing the same tree dataset, using different combinations of visual channels. (a) Rectilinear vertical node–link, using connection to show link relationships, with vertical spatial position showing tree depth and horizontal spatial position showing sibling order. (b) Icicle, with vertical spatial position and size showing tree depth, and horizontal spatial position showing link relationships and sibling order. (c) Radial node–link, using connection to show link relationships, with radial depth spatial position showing tree depth and radial angular position showing sibling order. (d) Concentric circles, with radial depth spatial position and size showing tree depth and radial angular spatial position showing link relationships and sibling order. (e) Nested circles, using radial containment, with nesting level and size showing tree depth. (f) Treemap, using rectilinear containment, with nesting level and size showing tree depth. (g) Indented outline, with horizontal spatial position showing tree depth and link relationships and vertical spatial position showing sibling order. From [McGuffin and Robert 10, Figure 1].

4.2.6 Specific Visualisation Styles

Yau explores a number of ways to visualise categorical data (2013, pp. 143-153), contrasting approaches that include bar charts, pie charts, tree maps and mosaic plots (2011, p.146). He also highlights the 'visual cues' (2013, p.95) that each uses to highlight aspects of the data, such as length, angle, area or colour (p.144-145). He then focuses on three main means of representing categories, namely 'categories', 'parts of a whole' and 'subcategories' (p.146).

The data dealt with in this project is categorical as investments at each layer of a pension fund will be grouped into nested funds and 'direct investments' (investments in companies at that level), to show the different types of investment at each level. In addition, during a conversation with the Product Manager for the user dashboard at Tumelo (Sage 2021) it was highlighted that, on the current dashboard, users generally prefer the listing of companies by industry over the listing of individual companies. As a result, I have opted to focus on these industry groupings in visualising the data. This means that at each layer of a pension, 'direct investments' in companies will be shown as industry categories, with specific company lists being displayed if industries are clicked upon. As the data is therefore

categorical, Yau's three models for visualising categorical data are highly relevant, so I have decided to use these three groupings as the basis of my user research for this project.

The first grouping Yau offers is that of 'Categories' (2013, p. 146) which he suggests are amenable to straightforward data sets. An example he gives is a Symbol Plot, which, when circles are used, is also called a Bubble Plot. I am therefore proposing using a Bubble Plot as one of the options I will present to participants in my research project. A Bubble Plot can also be used to represent hierarchical data by using 'nested circles' (Munzner 2015, Figure 9.9), as highlighted in example (e) in Figure 4D above.

Figure 4E: Symbol plot, Yau 2013, p.146

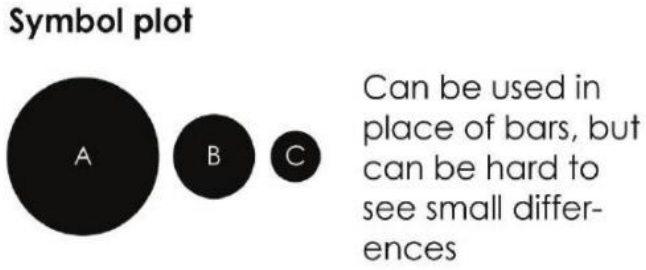
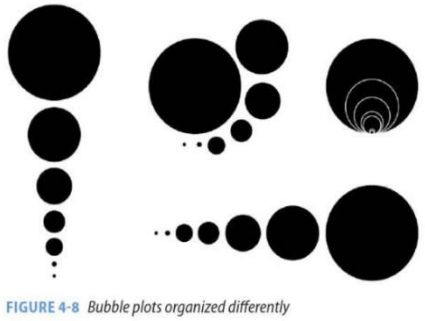


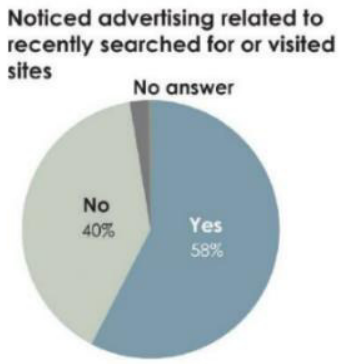
Figure 4F: Bubble plot, Yau 2013, p.149



The second grouping used by Yau is that of 'Parts of a whole' (2013, p. 146), often used to show proportions within a data set. A well-known example of this is a pie chart where 'angle is the visual cue' (Yau 2013, p.147). I will be using the modified version 'doughnut chart' in my research to offer a second visualisation option to research participants.

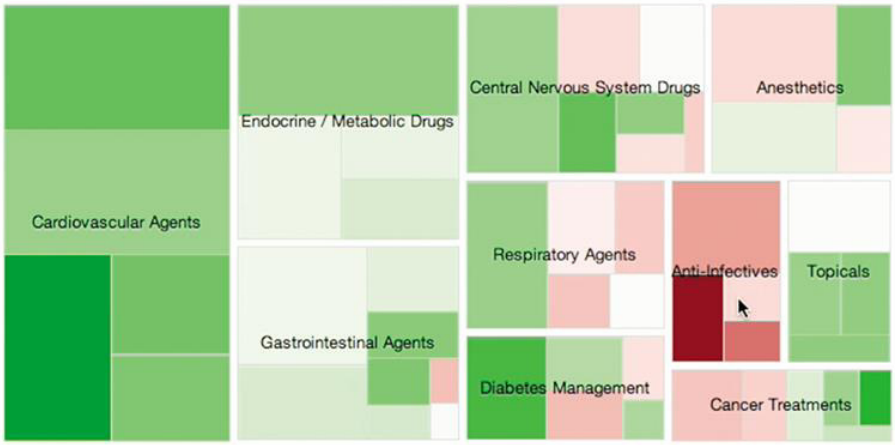
Figure 4G: Pie chart, Yau 2013, p.146

Figure 4H: Pie chart example, Yau 2013, p.149



The third grouping suggested by Yau is that of 'subcategories' (2013, p.146). This is where hierarchical data is presented, meaning that categories nested within other categories need to be visualised. One particular visualisation type that is highlighted as being able to represent hierarchical structure is a Treemap. As Ko et al state in their section on 'Stacked displays', 'Treemaps are a popular technique in this category whose goal is to visualize the hierarchy of multidimensional data' (2016, p.609). Yau shows a basic example (2013, p.151) but a more useful one is offered by the Gemignani brothers, where they communicate data on the drivers of costs to a health insurance provider, as seen in Figure 4I.

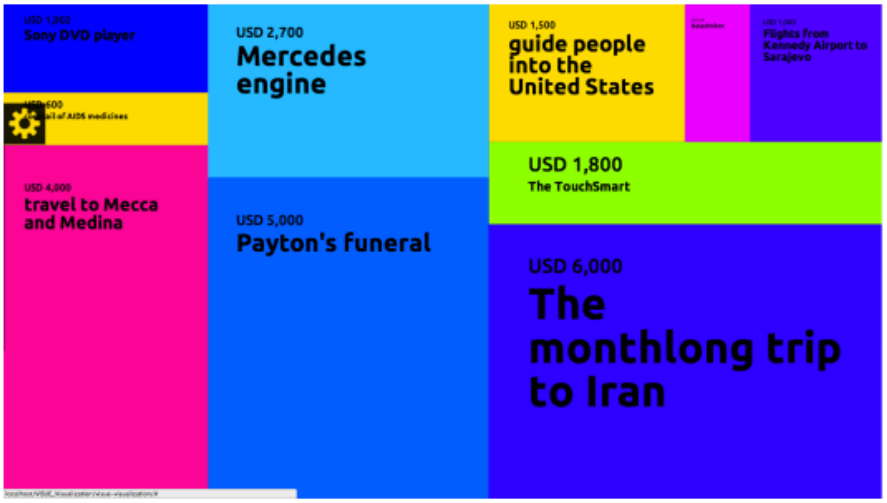
Figure 4I: 'A treemap visualization allowed healthcare executives to focus on the drivers of costs'



(Gemignani 2014, p.132).

Treemaps are also the methodology used by Rybak (2013) in his research project where he communicated financial data through use of a Treemap.

Figure 4J: TreeMap by Rybak (2013, p.88)

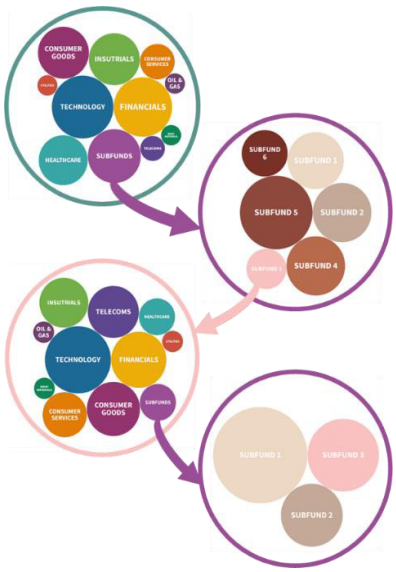


A critique of the example given by Rybak is the use of colour in the design, which does not adhere to the guidance given above on use of saturation or luminance as well as hue to distinguish sections. The colours are also bright and the wording harder to read as a result, which also does not make good use of visual hierarchy as the eye is drawn away from the key data provided in the text. The use of the Treemap model works well here but, in my project, I would want to use colour in a more effective way.

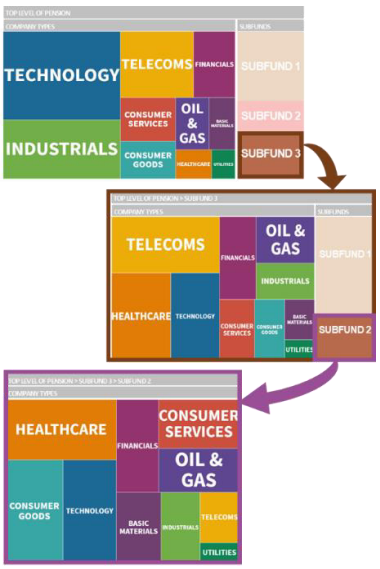
Drawing upon these three approaches to categorical data, I have designed three possible layouts for the data visualisation being developed in this project. These will be presented as options in user research, allowing me to see how potential users respond to each and which is the preferred design. How this research will be conducted will be discussed in the next section.

Figure 4K: Mock-ups of the three visualisation styles to be presented in user

Option 1: Bubble Plot



Option 2: TreeMap



Option 3: Doughnut Chart

From this research, a number of key points have been highlighted that will be essential to this project. The first is to ensure a focus on the end-user, which is aided by the archetypes, personas, and summary points included. The second is to prioritise making the chart visually engaging through using simplicity, colour and visual hierarchy to create a clear and compelling design. Thirdly, the structure of the data being used determines the style of chart

that will be most suitable and, in this project, styles that suit hierarchical and categorical data, presented using a ‘drill-down’ approach (Rodriguez 2016 pp.29-31), will be needed. This has led to the selection of three possible chart types, the Bubble Plot, TreeMap and Doughnut Chart which will be presented to participants in the user research element of this project to determine which they find to be visually engaging and informative.

Section 5: Approach

5.1 User Research

As mentioned earlier, a core aspect of this project is conducting user research to answer the two following key research questions:

- What data would users like to see displayed about their pension holdings?
- What visualisation would be most engaging to the widest range of users?

The first phase of user research to answer these questions will involve drawing upon relevant pre-existing user research conducted by the company to discover what existing data may be relevant to these research questions. This may also help shape the questions that will be asked to users in the further research for this project, so that repetition is avoided and may highlight areas where previous user responses could be drawn out in more detail.

For the user research for this project, I wanted to draw upon the company's target user base to gain responses on the questions set out above, in order to gather perspectives from those who represent the demographic that Tumelo hope will use their platform. In conversation about this with Tumelo's user research team, I found out that they use an external organisation to source participants. This organisation, called People for Research, will find research participants based on specific criteria, meaning that you can specify if you wish to recruit participants from, for example, certain age groups or socio-economic backgrounds or if you wish to have diversity within the group on criteria such as gender or ethnicity. This means that you are able to gather information from the most relevant participants, especially compared to recruiting from your own contacts who may be from less diverse backgrounds. I therefore decided that, in order to ensure the product developed was designed in a way that is engaging to the typical users of Tumelo's platform, I would use People for Research to source participants for this research project.

Feedback will be gained using questionnaires which will draw out participants' responses to specific questions, and also offer a chance for wider comments. To answer the first research question, users will be asked which data they would find informative regarding their pension and will be given a range of options to select from, as well as the opportunity to suggest

others. For the second research question, three visualisation mock-ups will be presented in picture form and participants will be asked to rate the visualisations on a range of factors (eg. how easy they are to understand, how visually engaging they are).

The visualisations that will be presented to users in the questionnaire are those that have been narrowed down through my literature-based research. These are shown in Section 4.2.6, 'Specific Visualisation Styles' along with some of the research that led to choosing these three models. I have selected styles that are the most robust and well-thought of, as well as those that are most relevant to the categorical and hierarchical kind of data I am dealing with.

In order for this research to be as effective as possible, I am drawing upon relevant literature on research methods for human-computer interaction. Sharp et al (2019) offer some useful guidance on the design and use of questionnaires, highlighting the importance of clearly structuring questions and rating scales to ensure correct data is gathered and that the user experience is smooth.

> It can be harder to develop good questionnaire questions compared with structured interview questions because the interviewer is not available to explain them or to clarify any ambiguities. Because of this, it is important that questions are specific; when possible, ask closed-ended questions and offer a range of answers, including a "no opinion" or "none of these" option. (Sharp et al 2019, p. 279)

Sharp et al also offer specific advice on the design on rating scales, offering the example of Likert scales, which 'rely on identifying a set of statements representing a range of possible opinions' (2019, p.280). Likert scales involve offering a short statement and a scale giving possible answers which respondents are asked to choose between.

Drawing on this, I have decided to design some questions using a Likert scale, which I will use to ask participants to respond to a number of statements relating to the visualisations they will be presented with. I will also use a check box question to ask users to select the kinds of data they would like to see displayed. There will also be open-ended questions where users can give any other written feedback that they wish

to include. This should provide me with data that is easy to process and highly relevant to my research questions and the company.

To effectively conduct user research, it is also important to consider the ethical issues involved. This includes ensuring that participants are engaged with in a professional manner and their data is used and stored appropriately. Sharp et al state,

> One significant aspect of any data gathering is the relationship between the person (people) doing the gathering and the person (people) providing the data. Making sure this relationship is clear and professional will help to clarify the nature of the study… In the United States and United Kingdom, for example, it is achieved by asking participants to sign an informed consent form… (2019, p.262).

This is taken further by Adams and Cox who stress the wider issue of trust between participants and those conducting the research. This relates to giving consent as stated above but also to their understanding of how their data will be used and how long it will be stored for. 'Participants also need assurance of confidentiality – details of how the information is going to be stored and who will access it' (Adams and Cox 2008, p.26).

In order to ensure the issues raised here are addressed appropriately in this research project, I will be complying with all university policies and guidance on these matters. In particular, I have completed the provided training on ethical research and an application for ethical review for this user research element of the project. This involves submitting information about how data will be used and stored as well as providing the consent forms, user information sheets and questionnaires that will be used to ensure they meet university standards and policies.

5.2 Project Management and Working Practices

To successfully deliver this project, I decided to use Agile development methodologies for two main reasons. The first is that Agile project management uses an iterative model whereby the overall product is broken down into small components that can be developed within a short timeframe known as a 'Sprint' (Schwaber and Sutherland 2020, p.7). This

enables a basic product to be produced reasonably quickly with additional features being added in later Sprint cycles. The second reason is that Agile practices include 'having a customer advocate work hand-in-hand with the development team' (Sutherland 2015). This means that clients are closely involved in the project and on-going decision-making around the project is made smoother. This iterative way of working coupled with regular communication with the client ensures that developers are able to 'satisfy the customer through early and continuous delivery of valuable software' (Beck et al. 2001). As I wanted to deliver a useful product as early in the project as possible and to then add functionality in consultation with the team at Tumelo, Agile working seemed the best fit.

In order to also work in a way that enables me to collaborate well with the wider team at Tumelo, I will be participating in their fortnightly, end of Sprint cycle, meetings but am not expected to attend their daily stand-ups in order to avoid filling my diary. The entire team at the company also participate in a short meeting on a Monday morning and a debrief on a Friday afternoon and I will also be attending these to get a sense for the wider direction of the company and to share updates on my work. A further discussion of Tumelo's application of Agile practices and the approach taken in this project is given in Section 6.4.

5.3 Development

As this is an industry-based project, it is important that the developed solutions are compatible with the company's existing system. An essential part of initial research for this project was therefore to find out about the technology used at the company. Tumelo's current user dashboard is a React app developed using TypeScript. For this project, therefore, I will be building my user interface in React. React is not a technology I have used before so I have been undertaking some online study and will also have support from the tech team at the company to help ensure that what I build will integrate with their system. I have also had conversations with the team at Tumelo about libraries to ensure that any external libraries I use are ones that the company will support the use of. Their general policy is to use those that are well-maintained and have a good community around them.

Application of the Chosen Approach

Sections 6 and 7 will set out what happened in the project, from initial decision-making through to implementation of the final product. Section 6 focuses on the earlier phases, setting out initial technology decisions, the scoping process, requirements for the project and the chosen approach to project management. Section 7 sets out how more specific design decisions were made in consultation with the Tumelo team, and gives the results of the human research element. Throughout Section 6 and 7, McCall's Software Quality Criteria are used to demonstrate how aspects of the design and implementation ensure the development of quality software.

Section 6: Setting Up the Project

6.1 Initial Decisions

6.1.1 Learning React

Having narrowed down some potential chart types through the literature review, some decisions followed around the best technology to use to develop an interactive version of these designs most effectively. The starting point was that Tumelo use React for their user dashboard so it was essential to use this library in order to ensure 'interoperability', one of McCall's Quality Criteria, defined as reducing 'Effort required to couple one system with another' (Cavano & McCall 1977, p.137). This was a learning point as I had not used React prior to beginning this project. Part of the reason for wanting to do an industry-based dissertation was to push myself and expand my skillset and React was something I was particularly interested in learning. This project was therefore ideal as it offered the opportunity to develop these skills, as well as to learn about development practices within a professional environment.

My learning strategy was to undertake an introductory course in React via Udemy before the start of the project, to familiarise myself with this library. This gave me a basic knowledge of React and enabled me to deploy an initial application based on a project on the course, which I drew on to develop an early prototype for the project (Schwarzmüller 2021). To develop more advanced skills, I decided to adopt a 'just in time' approach, which 'in contrast to traditional …approaches to training, is more closely associated with informal,

learner-driven knowledge acquisition and use' (Brandenburg and Ellinger 2003). This enabled me to focus on learning the more advanced React skills that were relevant to this project, and learning through applying these, rather trying to build a comprehensive knowledge of the whole library. I have therefore used the more advanced sections of the Udemy course on React as a reference point, accessing sections as and when I need to apply them within the project. This enabled me to move forwards with developing something relevant to the project and achieving early delivery of a usable product, rather than waiting to develop a more expansive knowledge of React first.

6.1.2 React libraries

In order to draw charts and visualisations in React, I explored a number of React libraries that would offer this functionality. At the beginning of the project, I had a conversation with members of the tech team at Tumelo about which libraries they would allow in deployment. They stated that they are happy to use external libraries providing they were well-maintained and there was sufficient community around them (Slingsby and Pierce 2021). I therefore identified a few potential libraries and checked whether they were acceptable with a member of Tumelo's tech team. Initially, I identified chart.js as a library that would be useable for building a TreeMap and react-bubble-chart as a possible one for drawing Bubble Plots. However, react-bubble-chart did not meet Tumelo's standards for external libraries 'based on the amount of traction it has and when it was last updated' (Pierce 2021, 23 July) and although initially chart.js seemed like a good option as it was sufficiently well-maintained, it became clear after using it to create a TreeMap that it didn't offer much flexibility as it was difficult to customise the chart.

I also considered using D3 as this would give me more control over the design of the visualisation. However, I felt this would also add another significant learning component into the project and I felt I needed to prioritise timescales, particularly as combining D3 and React is somewhat complicated. I then tried a library called react-vis and discovered that not only was this well-maintained, but it also offered all three of the chart styles that I had identified as my options (Bubble Plot, TreeMap and Doughnut Chart). This library also offers many more customisations than the previous ones I had tried, as well as the ability to add CSS styling to aspects of the chart, so this seemed like a much more suitable option for the

project. The tech team at Tumelo were happy to deploy using react-vis (Pierce 2021, 26 July), so I made the decision to go ahead with this library for the project.

Each library trialled required different data formats, so I then reformatted my sample data to a form that would be compatible with react-vis. As this library offers all three of my selected chart formats, it became far easier to change between the three layouts as the data structure could remain the same for each. This added to the 'flexibility' of the system, which relates to the effort required 'to modify an operational program' (Cavano & McCall 1977, p.136-7), as it is therefore far easier to change the visualisation type in future without having to change the structure of the data.

This change to using react-vis also had an impact upon Project Management and in particular the timeline for this project. As discussed in Section 10.1, one issue that arose was that the human research element of this project would fall at a reasonably late stage in the project. The flexibility that react-vis gave through the ability to switch between the three styles relatively easily, using the same data structure, was key to addressing this timeline issue as it became far easier to change the style of the chart at a later stage and meant that a good amount of development could be done without being dependent on the decision around which particular style would end up being used.

6.1.3 Typescript Decision

Tumelo also use Typescript in their dashboard, which is again new to me, so I had to make a decision around the project management triangulation of time, scope/quality and cost (or resources) (ILX group 2019). For quality and maintainability, I would have liked to develop my product using Typescript, however I was also conscious of the inability to change the timeline or resources for the project as I am the only human resource and the university deadline is fixed. This is similar to the approach taken in the 'Scrum' approach to Agile delivery as Sprints are 'fixed length events' (Schwaber and Sutherland 2020, p.7) and part of Sprint planning involves assessing 'how much can be completed within a Sprint' (Schwaber and Sutherland 2020, p.8). This means therefore that the work is planned according to a fixed time period and fixed amount of human resource, and the amount of work undertaken is adapted accordingly. In a similar way, one of the challenges of this work was assessing what could be done within the timeframe and I felt that learning Typescript could take up

too much of the delivery time. I therefore decided to begin by using React with Javascript, which I am familiar with. If time allows on the project, I may convert the code into Typescript at a later point, or this may be something that is done after completion of the dissertation.

6.2 Scoping Requirements

The core requirements for this project were ascertained through initial meetings with Tumelo's Solutions Architect, who acted as the Product Owner for this project. This shaped the aims and objectives set out in Section 2, to develop an interactive platform for users to explore the structure of their pension. In particular, the project objectives that relate directly to the requirements for this product are:

- To demonstrate the structure of investments within a given pension fund, including nested funds, in a visual way
- To offer interactivity, allowing the user to explore the data
- Drawing upon the results of research and information about the available data, to develop a system that presents the relevant data in a style that users find engaging

To further scope requirements for this project, I consulted with a range of team members from Tumelo via a number of meetings and presentations. In particular, when I had narrowed down three potential visualisation styles and made mock-ups of these designs, I showed these to a wide range of team members, to gauge their perspective on the design options but also to give a general sense of what I was hoping to develop and to generate discussion around the possibilities within this project. This led to some very valuable feedback around how they saw this feature being used, various possible use cases and specific functionalities they envisaged being included.

In terms of additional functionality, beyond the core aims and objectives of the project, suggestions included:

- Offering the ability for the user to toggle between different chart styles (eg TreeMap / Bubble Plot) or different categorisations, such as grouping companies by geographical location rather than industry (Slingsby et al, 2021).

- A search function for users to find certain companies within their pension. One team member suggested that if a pension holder was going to dig into their pension in this way, they were most likely looking for something. For example they may have seen a specific company in the news and want to know whether they are investing in them (Slingsby et al, 2021).
- Offering more context to the industry-standard categorisations, by giving further explanation or more details about a company's specific products, as users may not understand the Industry Classification Benchmark titles (FTSE Russell 2021) that are currently used (Slingsby et al, 2021).
- Adapting the chart more specifically to the needs of pension trustees and fund managers, to present data about votes at particular companies, or to group companies by geography rather than industry (Goodwin et al, 2021).

In terms of compatibility:

- Bringing in data via the API, or using sample data in the format the API uses, in order to transpose this starting data format into one that could be used for the chart.
- Using Typescript in order to be able to utilise pre-existing Tumelo components within my React project.

These suggested functionalities were then narrowed down, in consultation with the Product Owner, into the User Stories and Acceptance Criteria given in Section 6.3.

6.3 Requirements

In order to clarify the specifications for this project, I decided to use User Stories as this project is particularly focused on the end-user's experience, so I wanted to adopt a user-focused approach to requirements. 'A user story describes functionality that will be valuable to either a user or purchaser of a system or software' (Cohn 2004, Chapter 1) and this approach therefore helps to maintain a focus on user's needs. In addition, Tumelo's two dashboards ('Member' and 'Stewardship') have two very different user groups so writing two different User Stories is a helpful way to highlight the distinctions between these two and the ways they might use the platform. I consulted with the Tumelo team to draw up User Stories for this feature, to scope requirements and to narrow down acceptance criteria.

User Stories

Having made the decision to use User Stories to express the purpose of this product, I also chose to adopt the format used by Tumelo for User Stories, to be in line with their working practices. Their User Stories take the form "In order to…as a….I want….". They use this approach as it focuses first on the business purpose (the "in order to…") before focusing on the specific kind of feature that might be required. I have therefore written a User Story, in this style, for the users of the Stewardship Dashboard (Fund Managers and Pension Trustees) and the users of the Member Dashboard (pension holders).

Stewardship Dashboard User (Fund Manager / Pension Trustee):

"In order to

- find out more about the structure of the investments within the funds that I oversee

As a Fund Manager / Pension Trustee,

I want…

- an interactive way to explore the structure of a specific pension fund"

Member Dashboard User (Pension Holder):

"In order to

- find out more about exactly how my pension is invested
- make decisions about, or changes to, my pension investments

As a dashboard user,

I want…

- an interactive way to explore the structure of my pension(s)"

Acceptance Criteria

Drawing on the scoping work described in Section 6.2, and in consultation with the Product Owner, I narrowed down the requirements into the core functionality that was necessary for a Minimum Viable Product and those additional suggested requirements that might be addressed if time allows. These are shown below.

Minimum Viable Product:

User will be able to….

1. View the top level of their pension investments in a visual form
2. Explore the structure in an interactive way, viewing contents of nested funds and the companies invested in at any particular layer
3. Understand the current context of the chart they are viewing within the overall fund
4. Traverse through the structure to explore the structure of other layers / subfunds
5. View the specific companies within any groupings (eg. by industry) at any level of the fund

Other criteria:

6. A write-up of the project, with recommendations for further development to the feature to be presented to Tumelo

Additional Features if time allows:

User will be able to…

7. Search to locate specific companies within their pension and view where they appear within the structure
8. Toggle between different options eg. different layouts / different company attributes such as geographical location

The system will…

9. Import data in the format exported from Tumelo's internal APIs
10. Offer a suitable, and potentially different, chart style for both mobile and desktop use

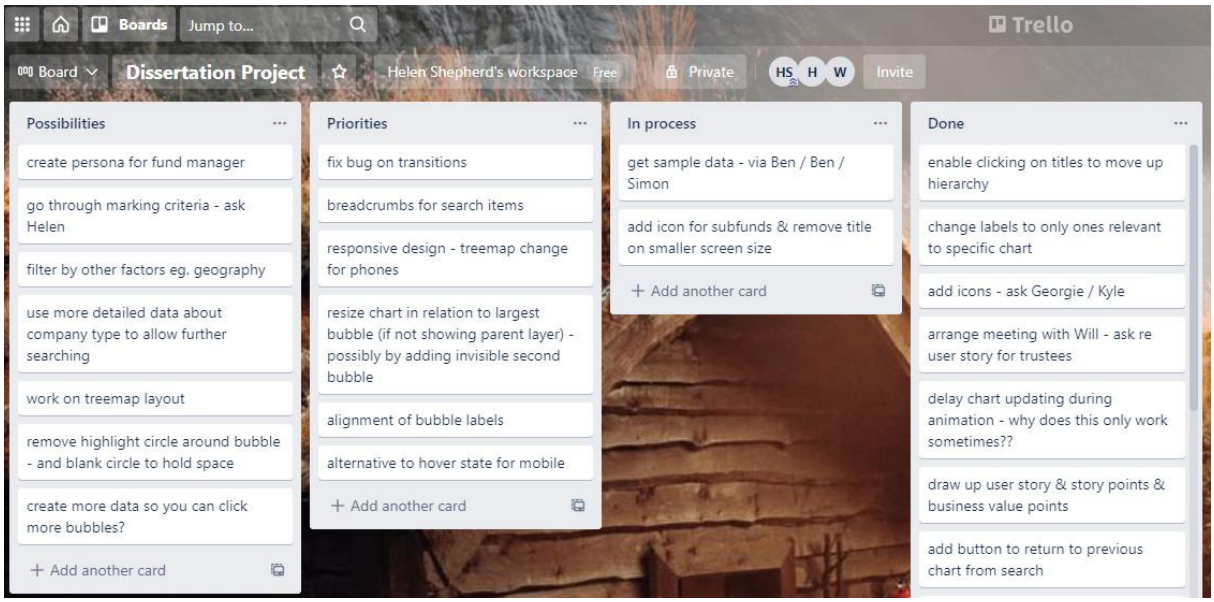
Setting out clear User Stories and Acceptance Criteria in this way facilitates two of McCall's quality criteria, namely 'correctness' and 'testability' as they enable us to judge the 'extent to which a program satisfies its specifications' ('correctness', Cavano & McCall 1977, p.136) and reduces the 'effort required to test a program to ensure it performs its intended function' ('testability', Cavano & McCall 1977, p.136) by providing a clear check list of functionality to test the program against.

6.4 Project Management

As set out in Section 5.2, I decided to use Agile Project Management methodologies for this project. One of the advantages to this approach was being able to work closely with the 'client', in this case representatives of the Tumelo team, in order to ensure the design and implementation were in line with their aspirations for the project. This was particularly useful in prioritising requirements for the project and setting the scope for the project. Having gathered a list of possible requirements from communications with the wider team, as set out in Section 6.2, I worked with the Product Owner for this project, to narrow down this list into the main priorities for a Minimum Viable Product and a list of secondary priorities to be achieved if possible within the timeline (Section 6.3).

In order to facilitate clear communication on which features were prioritised and which were being worked on at any particular time, I created an online Kanban board and added the Product Owner to the board, so that they could easily see items in the pipeline and which were being prioritised (see Figure 6A). This proved really helpful for regular communication around the workflow for the project and fed into our weekly meetings. The Product Owner was therefore able to suggest changes to what was being prioritised and, as this was a project for the company, I was able to focus on what they wanted as the 'client', and to change my priorities accordingly. For example, the Product Owner suggested at one point that I focus on consolidating what had been built so far by prioritising preventing user errors before adding any additional functionality, so I was able to move these issues up the pipeline so that they were completed sooner (Slingsby 2021, 17 August).

Figure 6A: Kanban board sample



Tumelo use a 'Scrum' approach to Agile development, using fixed two-week Sprints, with a planning meeting at the beginning and a demo and retrospective at the end. This is in line with the Scrum Guide which suggests Sprints 'are fixed length events of one month or less to create consistency… ensuring inspection and adaptation of progress toward a Product Goal at least every calendar month' (Schwaber and Sutherland 2020, p.7). However, as I was largely working independently on this project, there was no need to stick strictly to this pattern. I therefore adopted the more continuous approach of Kanban which focuses on visualisation of workflow through use of a Kanban board and 'the concept of flow. Flow is the movement of value throughout the product development system' (Scrum.org et al. 2021 p.3). To enable this flow, I applied some key principles of Kanban: 'Visualization of the Workflow' through use of my Kanban board, and 'Limiting Work in Progress (WIP)' through keeping less than three items on the 'In process' list at any time, as seen in the screenshot. I also focused on 'Active management of work items in progress' by seeking to ensure items weren't on the 'In process' list for too long and by identifying areas of blockage to seek help on so that these items could continue to flow.

Section 7 Research Results and Design Decisions

7.1 Design Decisions

7.1.1 Visualisation Structure Decisions

7.1.1.1 “Drill-down” vs “network” models

Drawing upon my literature review, I initially sought to narrow down visualisation options, to offer the team at Tumelo some potentials styles to consider, and to also determine what might be presented to participants in the survey as part of user research. The distinction raised in Figure 4C (‘“Drill-down” and “network” models’) between ‘network’ charts that demonstrate the overall structure of the data, and ‘drill-down’ models that highlight a particular route through the data, that might be selected by a user for example, was a key consideration (Rodriguez 2016, pp.29-31). To demonstrate the structure of a pension fund, either of these options might be possible. For example, a ‘network’ model might portray the overall structure of a pension using nodes and links to represent the various nested funds within a pension scheme. Alternatively, a ‘drill-down’ example, might involve displaying an initial chart to demonstrate the funds within the top layer of the pension, with the ability to click to explore a specific nested fund and its contents.

In order to make this decision, I made enquiries within the Tumelo team about the general structure of pension data to ascertain how many layers of depth there could be as well as how broad the data might be – ie. how many nested funds might exist within a particular layer of the data. I was advised that three layers of depth would cover the vast majority of cases but that breadth could vary widely and that there could be “a fund of funds … split across 10-20 funds within it” (Goodwin 2021, 5 July). It seemed that portraying the overall structure of a fund in a way that would work well for all possible structures might be difficult. Another advantage to the ‘drill-down’ approach is the ability to show more data as less nodes are being displayed. This is seen clearly in Figure 4C (‘“Drill-down” and “network” models’) where the ‘drill-down’ option includes bar charts showing the breakdown of data in the different layers.

I therefore felt that a ‘drill-down’ approach would be most suitable to this project, which I explained to team members at Tumelo to ensure they were happy with this decision. In

Section 4.2.6 I set out three chart styles that were perceived as being suitable to the kind of hierarchical, financial data that is dealt with in this project. Each of these could be used in an interactive way to demonstrate a path through the data and also to show the makeup of data at the various levels, so could each be applied to the selected 'drill-down' approach.

7.1.1.2 Categorising the data

Another key decision in deciding on potential visualisation styles was how to categorise the data. As each layer of a pension could contain investments in dozens of companies, it seemed that these needed grouping somehow to present something more meaningful and engaging to the user. The existing Tumelo platform offers two formats: a list of individual companies contained in a pension, and a list where companies are grouped according to their industry. In conversation with the Product Manager for the dashboard, it was confirmed that the page with companies grouped by industry is by far the most popular layout based on the usage of current clients (Sage 2021). It therefore seemed that using these industry groupings for this project's visualisation would be an appropriate format. At each level of a pension, therefore, the visualisation developed will show any nested funds and also the industries invested in at that level. Users will be able to click on specific industries to see a list of companies within that industry invested in at that layer of the pension structure. As mentioned earlier, the visualisation styles selected are from each of the models that Yau proposes are particularly relevant to data that is categorised in this way (2013, p.146).

7.1.2 Detailed Design Decisions

Once I had drafted an initial mock-up of the three visualisation types I had narrowed down as the options for this feature (Bubble Plot, TreeMap and DoughnutChart – see Figure 4K), I began canvassing opinions from amongst the Tumelo team, to determine which chart design they preferred but also to give a starting point for further design decisions.

7.1.2.1 Use of Colour

One more detailed design decision was around the use of colour. My initial mock-up used different colours for each of the company industry categories, mainly due to the colour options in the software I used to make the mock-up designs. However, reflecting on my

literature review and the section on 'Use Colour Wisely' (Section 4.2.3), I decided that it would be important to use saturation or luminance, either instead of or as well as colour hue to demonstrate the different categories, in order to make the design accessible to those with colour blindness. Offering greater accessibility in this way also increases the 'usability' of the product, by enabling a wider range of users to easily 'interpret output of a program' (Cavano & McCall 1977, p.136).

This direction was confirmed through a conversation with the Product Manager for the dashboard, who highlighted the challenge of making a design fit the branding of Tumelo's clients (Sage 2021). Tumelo provide their software to pension providers who then make the systems available to their customers. So the design elements of the software are adapted to each pension provider's branding. I therefore suggested that it would be better to use two key colours, one for the 'Direct Investments' (investments in companies) and one for the 'Nested Funds' within each layer of the pension. Colour grades of these two hues could then be used to show the different industries within the Direct Investments, or the specific funds within the Nested Funds category. This approach would mean that the feature could be adapted to individual clients by utilising two key hues from their branding for these two categories.

One of the challenges of this approach would be generating shades from two colour hues (probably given as hex codes). In building my system, therefore, I utilised a formula that took in a hex code and generated shades from it. These shades are then applied to the bubbles according to the size of the bubble, which relates to the percentage they represent. Higher percentages generate larger bubbles with darker shades. This enables users to more easily identify the varying categories the bubbles represent, and their respective proportions, whilst also allowing the design to be easily adapted to a client's branding requirements. The solution to this issue is described in further detail as part of the Implementation section (Section 8.4.2).

7.1.2.2 Responsive Design

Another design decision was around responsive design. Mobile has recently become the main way that people access the Member Dashboard, though this has only just overtaken desktop usage, meaning there's currently a reasonably even split between the two.

However, Tumelo believe usage will continue moving in this direction and that mobile will be the main mode for the Member Dashboard in future. This is also in line with the aims of the company for the platform as they want users to be accessing it frequently for short interactions, as is common with mobile apps (Sage 2021). However, the Stewardship dashboard, which is used by Pension Fund Managers and Pension Trustees, has '100% desktop' usage (Goodwin 2021, 1 Sept). This means that it was important to design for both mobile and desktop usage, to ensure the feature is accessible on both platforms. This might mean one design that works well on both screen sizes, or two layouts for each context. I therefore decided to ensure layout for both mobile and desktop were suitably designed and developed.

7.2 Research Results

I was able to gain ethical approval from the university and go through the set-up process with People for Research. I then accessed the results of this research, from 31 respondents, about seven weeks into the project. As mentioned, working with People for Research enabled me to access feedback from people across a range of demographics. In particular, I requested participants who met the following criteria:

1. They must have a workplace pension through the auto-enrolment scheme
2. They shouldn't have taken place in any previous research with Tumelo
3. Mix of Male and Female users
4. Mix of age between 20-60 years - weighted slightly more towards the 25-45 bracket
5. Mix of salary/household income
6. Mix of social grades ABC1C2 (these relate to grades based on income, used by People for Research)
7. Mix of pension literacy from some to moderate (mostly a, b and c, but also a few who selected d or e on the list below).

   Choose a statement that best describes your understanding of pensions and investments.

   a. I have an awareness of pensions and investments (basic level of knowledge).
   b. I would consider myself a novice when it comes to pensions and investments (limited experience).

c. I have an intermediate level of knowledge around pensions and investments. I could apply that knowledge in a practical application.
d. I have an advanced level of knowledge around pensions and investments (applied theory).
e. I would consider myself to have an expert level of understanding of pensions and investments. I'm a recognised authority in this area.

This meant that I was able to gather results from participants who form part of Tumelo's target market, with a good amount of diversity amongst the group. For example, criteria one relates to the fact that Tumelo's business model is to work with workplace pension auto-enrolment scheme providers, who then offer Tumelo's dashboards to their members. Criteria two is used often by Tumelo's user research team to ensure they recruit participants who have no prior knowledge of Tumelo's dashboard as they want to get a fresh perspective to see how new users would respond.

I asked the same set of questions about each chart design and then asked some more general questions about the kind of information users would like to see about their pension holdings. The first questions that related to the charts were posed using a Likert scale, shown in Figure 7A.

Figure 7A: Likert scale questions asked about each chart

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The Bubble Chart is visually engaging	○	○	○	○	○
It is easy to read/interpret the data on this chart	○	○	○	○	○
This chart makes it easy to understand how this pension is invested	○	○	○	○	○
This chart makes it easy to understand the structure of this pension (how funds are nested within others)	○	○	○	○	○

Written response questions on the same topics were also asked, to draw out the reasons behind the responses to the Likert scale. These were:

What are your thoughts on how visually engaging the chart is?

How did you find interpreting the data in the chart?

Were you able to easily understand how the pension was invested?

Please give any other comments you have about the chart & its effectiveness

Questions and responses for the broader questions around what pension data users would be interested in viewing are shown in Figure 7F.

The results fit into three main categories: feedback on the three designs and how visually engaging participants found them, feedback on how easy participants found interpreting the data on the charts, and more general feedback on the information they would like to know about their pension investments. I collated the feedback from all three of these categories into a presentation to share with the team at Tumelo and have included some screenshots from that to show the data below.

7.2.1 Feedback on the designs

The main purpose of the questionnaire was to answer two research questions, the second of which is 'What visualisation would be most engaging to the widest range of users?'. In order to answer this, I presented research participants with three possible chart styles, a Bubble Plot, a TreeMap and a Doughnut Chart, as set out in Section 4.2.6. One of the statements on the Likert scale (Figure 7A) was 'The chart is visually engaging' for each design and I also asked for a written response to 'What are your thoughts on how visually engaging the chart is?'. When isolating results to these questions on design, the Bubble Plot scored the highest, with 61.3% of participants responding 'Agree' or 'Strongly Agree' that this chart is visually engaging, compared to 51.6% for the TreeMap and 54.9% for the Doughnut Chart. The written responses also showed a much more positive reaction to the Bubble Plot in general, I have collected representative comments regarding each chart style on the next page.

Figure 7B: Bubble Plot

I would say this is very engaging as **it makes me want to study the chart and look at how it works and the structure of the pension**.

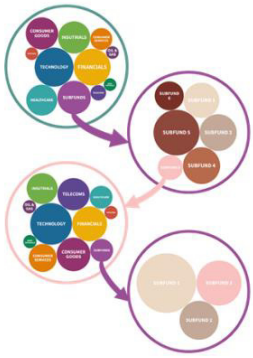
It's a **very good way to engage people.**

I think it could work but **the colours will need to change** and I would cascade down the info to make it clear you are looking at the details of a particular fund

I think such charts are **important, as the majority of the public is not informed about complex financial products**. Such charts are a good starting point

I do like its **simplicity...**
It seems intuitive to click on each bubble to unlock further layers of content.

Visually appealing and informative.



It is visually engaging and is quite easy to follow. **It is not too overwhelming and I think that I could follow it as a novice**.

Makes it look a little **gimmicky** and not entirely professional

It **would make me more likely to use and read this information** in comparison to just text

Grabs your attention

"very clear, colours are helpful and not over powering ...
A brief description of what is meant by ""consumer goods"" etc could prove useful if shown when a cursor is hovered over it"

Each bubble coloured separately so easier to distinguish, **looks like the size of the bubble is comparable to the 'area' it includes?** Font is clear

Figure 7C: TreeMap

I find the smaller sections **harder to read**

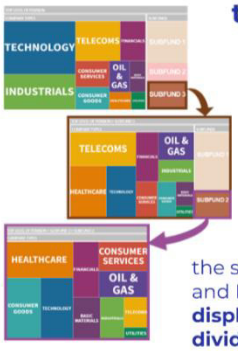
Looks **older school**

This isn't as clear to understand as the bubble chart, it's quite **stark and 'aggressive' to look at**

"Again, **it's fairly easy to see at a glance the split of investments across sectors**.
I find the boxy format of this one less immediate though - makes my brain have to think for half a second longer ... It's a bit busy. **Much prefer previous bubbles**."

Again I like that it's **attractive and different from just text**

Easy to assess investment opportunities and weighting of this in the block format



It works, but **less appealing than the circles**

They give away a **more serious look** to them, slightly less appealing to the eye but **better at highlighting the pots**.

It's ok a **bit easier to follow** compared to the bubbles

the same idea is conveyed as per the bubbles, and I guess it makes sense in terms of **displaying how 100% of your pension is divided x number of ways** with it being in a square. The angular nature of it is less appealing to my eyes though and looks more crammed. ..**doesn't encourage me to click around on it so much** as the bubbles did. **the bubbles do appear more "fun"**

Figure 7D: Doughnut Chart

I don't think this is very engaging, I don't like the design, I think it looks clumsy and it is unclear as **you can't read the text very well at all**.

Think this chart may not be the most visually engaging but is **a bit easier to read**.

I like the **circular layout** of the chart

Visually looks good although perhaps more difficult to navigate as you **might have to turn your head to read each area**

Writing is small and difficult to compare each investment compared to previous ideas.

They look clean and **the right touch of serious**

Reasonably well, the colours split and it's **easier to see how 'big' an area** is (although some headings are more difficult to read)

this is a visual i'm familiar with already from other pension providers - **bit of a head turner (literally) and an eye squinter** - don't think donut to donut is the way to visualise subfunds

"Yep I like this one too. **Easy to see different proportions of investments.** I like the fact this illustrates the split on one continuum.

I don't think it's the clearest way of doing it when a user is going to want to click through on lots of them. I think this kind of chart would be better to just give an overall visual sense of the way something is portioned out, but is less effective when there are subsequent layers

In general, the comments in terms of design were more positive about the Bubble Plot, with people finding it visually engaging and feeling that it drew them in to want to interact with it. Some of the more negative comments were that a minority felt it looked less serious and perhaps gimmicky. For the TreeMap, some people felt it more clearly demonstrated that the sections together made up the whole amount, as the rectangles fill the whole of the space. However, in general people found this less engaging and more stark. The reactions to the doughnut chart were interesting as for some this was their favourite design and they felt the proportions were clearer via the angles as opposed to area in the previous two designs. However, for others this was their least favourite design, and they found the labels harder to read with some segments ending up very small. Overall, if looking for the most engaging layout that would encourage people to explore and interact with the chart, it seemed that the Bubble Plot was the preferred option.

7.2.2 Feedback on Interpreting the Data

I asked for Likert scale responses to three statements regarding data interpretation: 'it is easy to read/interpret the data on this chart', 'this chart makes it easy to understand how this pension is invested', and 'this chart makes it easy to understand the structure of this pension'. In general, the feedback to these was less positive than the feedback regarding how visually engaging the designs were, across all of the options. There was also a much higher proportion of 'neutral' responses to these questions. As the three questions mentioned all related to interpretation of data, I have averaged the scores here for simplicity. For the Bubble Plot, the average percentage of 'Agree' or 'Strongly Agree' responses was 34.8% compared to 28.8% for the TreeMap and 39.2% for the Doughnut Chart.

There were also two written response questions, 'How did you find interpreting the data in the chart?' and 'Were you able to easily understand how the pension was invested?'. Overall, reading the responses to these questions, it's clear that, as is to be expected, presenting what is intended to be an interactive, online system in a picture has its limitations. In addition, although some paragraphs of context were given, there was also a loss of context compared to a chart appearing within Tumelo's platform where the user already understands they are exploring their pension investments. There were some really

useful comments around specific elements of each chart that made interpreting the data easier or harder, so I was able to draw on these in developing a final design. In particular, I drew out some of the comments about what was difficult to interpret to ensure I could address these in the next phase of development.

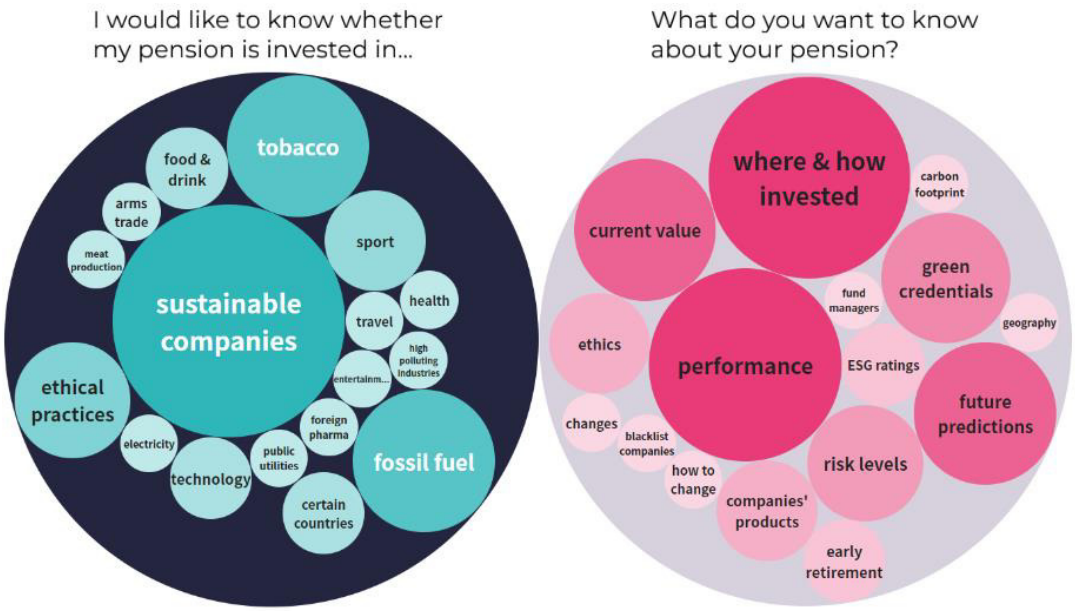
Figure 7E: Addressing Data Interpretation Comments

Comment	**How this will be addressed**
“without any numbers to show, I don't understand the cut”	Percentages will be added to the sections to show the different weightings (this was already planned but wasn’t possible in the mock-up software)
“I would prefer a more simple chart with %s illustrating the investments”	
“the second bubbles were actually small and hard to read”	On smaller sections, the title will not be displayed as the text would be too small. Instead, an icon and the percentage will be used. The text will then appear below the chart when each section is hovered over.
“I find the smaller sections harder to read”	
“I've no idea what INDUSTRIALS are? Not apparent either what BASIC MATERIALS consists of?”	An additional component will be used to display further information below the chart when each section is hovered over. This can be used to give a short description of each industry type. (The current titles use the Industry Classification Benchmark so it is not possible to change these in the chart.)
“additional info on what is meant by various sector names could be useful to those less aware”	
“it isn't completely clear about there being more subfunds within subfunds”	A recommendation will be made that, if this chart is integrated, a brief introduction to pension structures will be needed in accompaniment.

7.2.3 Feedback on Pension Data Preferences

The final questions on the survey were aimed at answering the first research question, 'What data would users like to see displayed about their pension holdings?'. These questions therefore asked the participants what they would like to know about their pension and the companies it is invested in. The responses therefore relate less directly to the design of the chart but give Tumelo some further data about what their users are looking for. I know that the Tumelo team feel that this kind of interactive chart could be used to show other aspects of pension data, so this was useful feedback to receive also for the future recommendations I will be presenting to them. There were some common themes amongst these responses, so I have grouped these and presented them in two Bubble Plots. These show the particular industries people want to be able to identify within their pension as well as the kind of data they would like to access. The sizes of the bubbles relate to the number of times each theme was mentioned.

Figure 7F: Feedback regarding pension data interests



7.2.4 Conclusions from Research Findings

Reflecting on the research results, it seems that each style of chart had particular strengths and weaknesses. The TreeMap seemed to perhaps be a good demonstration of how sub-sections make up the whole of their parent section, but in general this was seen as a less engaging design and it also scored the weakest in terms of data interpretation. The

doughnut charts were seen by some as clearer as they found the segment sizes easier to interpret and this design scored highest in terms of ease of understanding the pension data. This is potentially aided by the fact that this is a chart style people are more familiar with. The Bubble Plot scored lower in terms of data comprehension than the Doughnut Chart but was the clear leader in terms of visual engagement, particularly evident in the written responses.

I therefore considered what it was I had been most wanting to know from this research and that seemed reflected in the research question 'What visualisation would be most engaging to the widest range of users?'. I had particularly wanted to know which design people engaged with the most, which seemed to be the Bubble Plot. I was particularly struck by the comments that people felt drawn to interact with or explore this design, which is also part of the purpose. I therefore felt that using the Bubble Plot and addressing some of the issues around data interpretation, as suggested in Figure 7E, would give the best option and would reflect the preferences and comments of the research participants. This is therefore the design I decided to move forwards with, having presented these findings to the Tumelo team and gained their approval of this direction.

Section 8 Product & Implementation

Drawing on the results of the research, the agreed requirements, and the decisions made in consultation with the Tumelo team, I developed a React application that displayed the contents of a pension fund in an interactive Bubble Plot chart. The chart offers users the ability to explore their pension structure by clicking on specific bubbles to view the contents of specific parts of their pension. This is a React application using the library react-vis to build the chart component. The initial design, shown in the next section, uses Tumelo's brand colours, to demonstrate how the chart can easily be adapted to company branding.

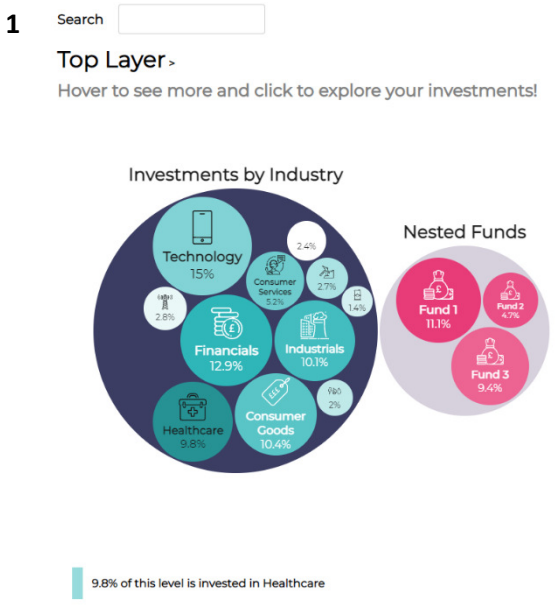
8.1 Screenshots of Final Product

8.1.1 Desktop Layout

The application created shows an initial chart that displays the top-level data for the relevant pension. This shows any investments in companies at this level, grouped by industry, as well as any funds nested within this level. This is shown in the first image in Figure 8A. All bubbles are then clickable and, if industry categories are clicked, a list view will appear showing the companies within that industry (as seen in the last image). If one of the nested funds is clicked, the chart transitions into a new chart (the first chart slides out of view to the left and the new one slides in from the right). An example of this is shown in the second and third images, where a new chart is loaded with the data for the contents of Fund 1 and then for Subfund 1. The 'breadcrumbs', or the route taken by the user, are shown in the titles at the top which show the user which level of the pension fund they are currently within, increasing the 'usability' of the feature (Cavano & McCall 1977, p.136). The images below show the progression as the user takes one particular route through the data, namely clicking first on Fund 1, then on Subfund 1, then on 'Technology', which then displays a list of the companies within that industry in that level of the pension.

Figure 8A: Screenshots of Dashboard View

1



2

3

4

8.1.2 Mobile Layout

The mobile version of the chart works in a similar way to the desktop version but the component below the chart has been adapted so that it appears on the first click of a bubble, as there is no hover state on a mobile. The transition to a new chart is also adapted to happen if the bubble is clicked a second time. To avoid bubbles being too small to view on the mobile screen used in portrait mode, this version loads two separate charts, stacked vertically, for the 'Investments by Industry' and the 'Nested Funds' at each level, as shown below.

Figure 8B: Screenshots of Mobile View (Showing the user clicking on Fund 1, then Subfund 1)

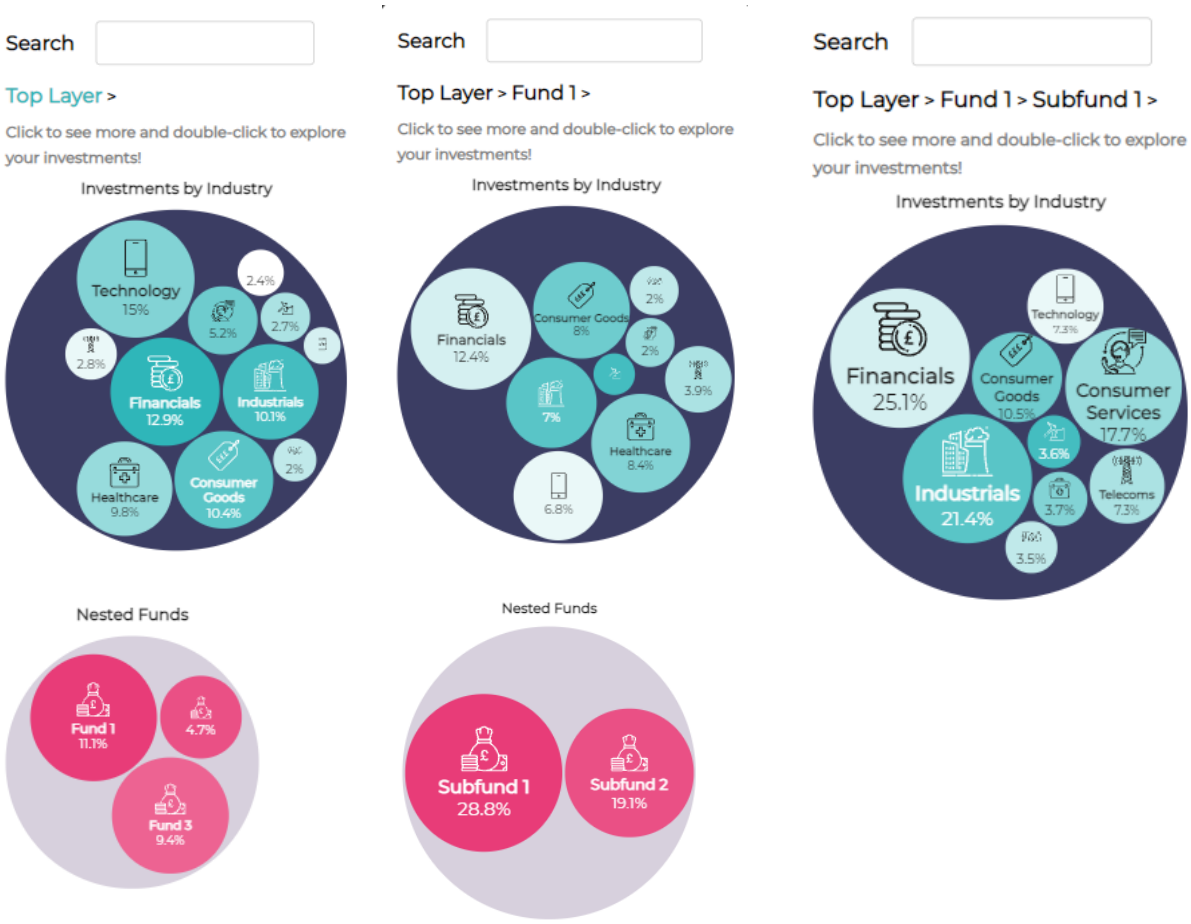
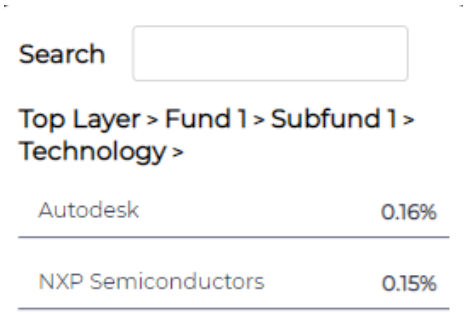


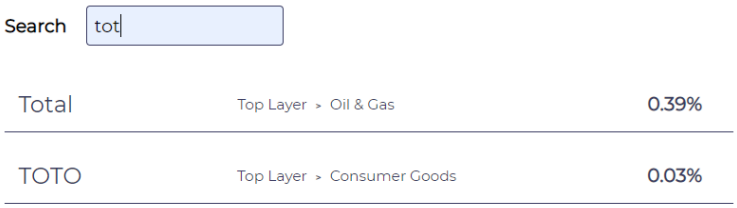
Figure 8C: Screenshot of List View on Mobile



8.2 Search Function

The chart also offers a search function for users to locate specific company within their pension. The search updates dynamically as the user types and displays a list of the companies whose names include their input. This is beyond the agreed core functionality of a Minimum Viable Product but is an important additional feature that came out of requirements scoping. An additional feature is that the search results include 'breadcrumbs' for each item, as a company may appear in several funds within the pension. This allows users to see where each occurrence of a company is situated and to navigate to those layers of the fund easily.

Figure 8D: Screenshot of Search Results



8.3 Data Structure & Data Conversion

8.3.1 Initial phase, self-constructed data

To create the chart, I initially used a sample data set that I wrote, to enable me to build a prototype. This data set took the form of objects for each company included in the pension fund. A sample of this data is shown below.

Figure 8E: Sample data created by the author

```
const RVdata = [
    {
      id: 'aa',
      title: 'Top Layer',
      amount: 0,
      parent: '',
      type: 'Direct Investments'
    },
    {
      id: 'a1',
      title: 'Financials',
      amount: 21.2,
      parent: 'aa',
      type: 'Direct Investments'
    },
    {
      id: 'a2',
      title: 'Industrials',
      amount: 16.8,
      parent: 'aa',
      type: 'Direct Investments'
    },
```

I then had to draw in this data and convert it into a format that could be used by the react-vis library. This was done via one specific React component, the TreeMapChart component whose purpose is to pull in the data in the original format shown above and to convert it into the format needed for the react-vis library. It does this by iterating through the investments in specific companies and pulling out the relevant information such as title and amount (ie. the percentage invested in a particular company). It then converts these into the relevant format using the 'InvestmentData' formula. As part of this formula, data is passed to an additional React component, 'BubbleContent', which generates the labels for the bubbles (with an icon, title and percentage in).

The code for the 'InvestmentData' formula, which converts the data, and its usage, is shown below. This section of code is also a demonstration of some of McCall's Software Quality Criteria, as using a formula to extract the functionality of creating the necessary data for each investment, creates a reusable piece of code that is then called multiple times within the code shown in Figure 8F, as the data is iterated over using the formula 'fontSizeCheck'. 'Reusability', defined as 'will I be able to resuse some of the software?' along with

‘maintainability’, which relates to the effort required to ‘locate and fix an error’ (Cavano & McCall 1977, p.136-7), are both improved by code being made more readable code through extracting code into a reusable function.

Figure 8F: Investment Data formula and data array generation

```
export const InvestmentData = (width, investment, withTitle, withPercent, industry, style) => {
    let InvestmentDataReturn = {
        "title":
        <BubbleContent
            withTitle={withTitle}
            withPercent={withPercent}
            industry={industry}
            title={investment.title}
            width={`${(Math.sqrt(investment.amount))*(calculateFontSizeMultiplier(width))*2.5}px`}
            height={`${(Math.sqrt(investment.amount))*(calculateFontSizeMultiplier(width))*2.5}px`}
            percentage={investment.amount}
            />,
        "size":`${investment.amount}`,
        "id":`${investment.id}`,
        "breadcrumb":`${investment.title}`,
        "style": style,
        "type": `${investment.type}`,
        "color": `gjdfghdkfghaldkf`
    }
    return InvestmentDataReturn;
}

export const fontSizeCheck = (width, investment) => {
    delete investment.color;
    let fontSize = (Math.sqrt(investment.amount))*(calculateFontSizeMultiplier(width));
    let returnItem;
    if(investment.type === 'Direct Investments'){
        if(fontSize>10){
            returnItem = InvestmentData(width, investment, true, true, investment.title, {"fontSize": `${fontSize}px`});
        }
        else if (fontSize<5){
            returnItem = InvestmentData(width, investment, false, false, investment.title, {});
        }
        else{
            returnItem = InvestmentData(width, investment, false, true, investment.title, {});
        }
    }
    else if(investment.type === 'Subfunds'){
        if(fontSize>10){
            returnItem = InvestmentData(width, investment, true, true, 'subfund', {"fontSize": `${fontSize}px`});
        }
        else if(fontSize<5){
            returnItem = InvestmentData(width, investment, false, false, 'subfund', {});
        }
        else{
            returnItem = InvestmentData(width, investment, false, true, 'subfund', {});
        }
    }
    return returnItem;
}
```

Once an array of data items in the current format has been created for both the ‘Direct Investments’ and ‘Subfunds’ groupings, the TreeMapChart component then adds these two arrays into a data structure that matches that required by the react-vis library. This can be seen in Figure 8G.

Figure 8G: Converting the data into the format for the react-vis library

```
const DataPoints = {
    "title": "Top Layer",
    "color":"white",
    "style": {'alignItems': "flex-start", "gap": "-20px", "boxShadow": "0 0 0 10px #888"},
    "children": [
        {
            'title': 'Investments by Industry',
            "style": dataStyle(DirectInvestments),
            "color": "#3a3c62",
            "children": [...DirectInvestments]
        },
        {
            "title": "Nested Funds",
            "color": "#d7d0dd",
            "style": dataStyle(Subfunds),
            "children": [...Subfunds]
        }
        ]
};
```

8.3.2 Second phase, importing data from Tumelo's API

Having created my own sample data in order to build a working prototype, I then wanted to import data from the format used by Tumelo's API, in order to ensure greater compatibility. I was given a set of sample data, which is the data used for Tumelo's demo Member Dashboard. Currently, Tumelo's APIs do not have endpoints that produce hierarchical data showing the funds nested within a pension, so the sample data I was given is aggregated data showing the overall percentages invested in each company within the sample pension. This meant that I needed to combine this data with some of my own sample data to provide examples of nested funds. As shown in Section 8.6, a recommendation for Tumelo resulting from this project is that an additional endpoint would need to be created to provide the hierarchical data needed to show the structure of a pension fund.

As I needed to combine the sample data from the API with some of my own sample data, I decided to convert the sample data into the format used in my data, shown in Figure 8E, so that these data sets could be combined. I used the API data to populate the investments within the Top Level of the pension for my prototype. Once the data conversion was done, the results were exported into my sample data file and combined into that data set.

In processing the data from Tumelo, I needed to generate for each company:

- a unique 'id'
- a 'title'
- an 'amount' (percentage they represent)
- a 'parent', this contains the id of the part of the pension they sit within. In this case, this id for the industry grouping the company falls within, within the Top Level of the pension.
- a 'type', which in my data is either 'Direct Investments' or 'Nested Funds' to show which of these categories this data sits within. As all of the sample data related to investments in companies, and not funds, the value for this property was 'Direct Investments' in all cases.

The most complex aspect of this data conversion was determining the 'parent', which here related to the industry grouping for each company. This is because the industry is not given in the title form used by Tumelo (eg. Industrials / Consumer Goods), but is rather determined from an industry code. These codes are also not part of the initial data set and have to be accessed via a call to one of Tumelo's APIs, using the unique IDs for the companies. As I don't have access to this, one of the Tumelo team made a call to the API and provided me with another data set that included the ID and industry code for each company. I then used this data set to map the codes as a new property into the object for each company within the dataset. I was also given access to Tumelo's Git repository for their Member Dashboard, which includes a component that converts industry codes into the currently used industry titles. This code is written in Typescript but, drawing on knowledge of Javascript and Java (which helped with the object-oriented approach and 'typed' nature of Typescript), I was able to read through this code, determine the relevant conversions and draw on this code to create a switch statement that converted industry codes into titles. Some IDs did not seem to be found within the dataset that mapped IDs to codes, which led me to create an 'Other' category for companies that could not be assigned an industry grouping due to incomplete data. The data import and conversion were successful, and the chart updated to include this data without issue.

Figure 8H: Sample of Tumelo's demo data


```
  },
  {
    "organization": {
      "bio": {
        "description": "Alphabet Inc. is an American multinational conglomerate headquartered in Mountain View, California. It w
        "source": "wikipedia",
        "sourceUrl": "https://en.wikipedia.org/wiki/Alphabet_Inc."
      },
      "displayName": "Alphabet",
      "externalIdentifiers": ["LEI_5493006MHB84DD0ZWV18"],
      "headquarters": {
        "isoCountryCode2": "US"
      },
      "id": "650e0af5-19d6-4e50-a7e5-53bea79bfa99",
      "industry": {
        "naics2017": {
          "code": "541511",
          "title": "Custom Computer Programming Services"
        }
      },
      "issuedIsins": [
        "US02079K1079",
        "US02079K3059",
        "US02079KAB35",
        "US02079KAC18",
        "US02079KAD90",
        "US02079KAE73",
        "US02079KAF49",
        "US02079KAG22",
        "US02079KAH05",
        "US02079KAJ60"
      ],
      "legalName": "Alphabet Inc",
      "logoUrl": "https://res.cloudinary.com/tumelo/image/upload/w_128,h_128,c_fit/v1580300100/x5h9s3or3gndffue1ovd.png",
      "websiteUrl": "https://abc.xyz/"
    },
    "weight": 0.024863929
  },
```


Figure 8I: Sample of code that converts Tumelo's data into the required format

```
const getProperties = (item) => {
    return {
        "id": item.organization.id,
        "title": item.organization.displayName,
        "amount": (item.weight)*100,
        "parent": '',
        "type": 'Direct Investments',
        "country": item.organization.headquarters.isoCountryCode2,
    }
}



const checkCode = (id) => {
    if(codes.codes.find(obj => {return obj.organizationId === id})){
        return codes.codes.find(obj => {return obj.organizationId === id}).icbV2Code.trim();
    }
    else{
        return "";
    }
}

var newData = data.components.organizations.map(getProperties);
newData.forEach((company)=> {
    company.industryCode = checkCode(company.id);
})
newData.forEach((company)=> {
    if(company.industryCode !== ""){
        company.parent = createIndustryTitle(parseInt(company.industryCode.slice(0,1)));
    }
    else{
        company.parent = "a11";
    }
})

module.exports = newData;
```

8.4 Areas of Complexity

The TreeMapChart component, used to do the data conversion shown in Section 8.3.1, is also where the code for a number of the more complex design features of the chart exists. This is because this component is where individual investments are iterated over and turned into the current data format, and certain aspects of styling relate to the size of each individual bubble, such as the font size, the colour shade of the bubble and the text colour – which is black or white depending on the colour shade of the bubble (code adapted from Paliath 2011). These design aspects therefore need to be calculated based on the data for each bubble as this is generated. The font size for each bubble, for example, in generated in response to the diameter of the bubble. This depends also upon the screen width as the bubbles change in size in response to the screen size, except that the chart's container has a maximum width so above a certain screen size it remains the same size.

8.4.1 Font Size

In order to make the font size change dynamically with the screen size, a formula is used to calculate a number based on the screen width, which is then multiplied by the square root of the percentage the bubble represents (as this is directly proportional to the area of the bubble, making the square root directly proportional to the diameter). The formulas for calculating this are shown in Figure 8J.

Figure 8J: Calculating font size

```
const [width, setWindowWidth] = useState(0);

useEffect(() => {

  updateDimensions();
  window.addEventListener('resize', updateDimensions);
  return () =>
    window.removeEventListener('resize',updateDimensions);
 }, [])

 const updateDimensions = () => {
    const width = window.innerWidth
    setWindowWidth(width)
  }

const calculateFontSizeMultiplier = () => {
    if (width>842){
        return 6;
    }
    else{
        return width*0.007
    }
}
```

8.4.2 Colour Shades

As explained in Section 7.1.2.1, I decided to use colour shades rather than different hues to distinguish the bubbles and it was also decided that these should be able to be based on the branding colours of individual client companies. These shades are therefore generated using a formula that takes in a hex code and a decimal and generates a lighter shade (depending on the decimal) of the original colour (Trizkit 2019). Two arrays of shades are generated from this formula, one to be used for the colours of the 'Direct Investments' bubbles and one for the 'Nested Funds' bubbles. These are stored within the context file for the application so that this array of shades can be accessed here in the TreeMapChart component, as shown below (the arrays are called using ctx.directInvestmentBubbles and ctx.subfundsBubbles respectively).

The colours for the bubbles and their fonts are also generated here, as these relate to the size of each investment. Once the data for each investment is converted into the correct format and added to the data arrays, these are ordered by percentage size and then colour grades are added in order, meaning that shades get progressively lighter as the percentages get lower (and the bubbles get smaller). This provides another pointer to the respective proportions that each bubble represents, making the data easier to interpret on the chart, and addressing some of the points highlighted in the user research. This also draws on some of the literature-based research that suggested use of colour shades as opposed to hues offers greater accessibility for those with colour blindness (see Section 4.2.3). The formula that assigns colours to bubbles is shown below and provides another example of using formulas to avoid code repetition and to increase 'reusability' within the software (Cavano & McCall 1977, p.137).

Figure 8K: Adding colours to bubbles

```
const addColors = (investmentsArray, colorGrades) => {
    investmentsArray.sort((a,b) => parseFloat(b.amount) - parseFloat(a.size));
    investmentsArray.forEach((element, index) => {
        element.color = colorGrades[index];
        element.style.color = idealTextColor(colorGrades[index]);
        element.style.fill = idealTextColor(colorGrades[index]);
    });
};

addColors(DirectInvestments, ctx.directInvestmentsBubbles);
addColors(Subfunds, ctx.subfundsBubbles);
```

8.4.3 Other complex design features

As well as calculating the font size and colour shades, the TreeMapChart component also loads a label for each bubble which generates the relevant icon, title and percentage for each bubble. The label is a separate component called BubbleContent and the icon itself is another component, Icon, which checks the title of the industry and loads the relevant image. The BubbleContent component also performs a check on the font size and, if this is below a certain size, loads only the icon and percentage to prevent loading small, illegible titles.

These design features added complexity to the software design but also ensured higher quality in terms of end result. Specifically, these features were aimed at increasing the 'usability' (Cavano & McCall 1977, p.136) of the final product by making the titles more readable and by using icons as a visual aid to make the industry groupings easier to interpret. The need for these 'usability' features which reduce the 'effort required to … operate … and interpret output of a program' was highlighted through the human research element of this project where participants found smaller text hard to read and found industry titles hard to interpret in isolation (see Section 7.2.2).

8.5 React features

8.5.1 Extracting Components

Using React involves creating components that can be used to build other elements within a page. One of the strengths and purposes of this model is that it creates a 'palette of reusable components' (ReactJS, 2021). This means that when building components, it's important to consider modularity and whether aspects of a component can be extracted into smaller components that might be able to be re-used. 'A good rule of thumb is that if a part of your UI is used several times … or is complex enough on its own … it is a good candidate to be extracted to a separate component' (ReactJS, 2021). Separating functionality into components increases 'reusability' by increasing the 'extent to which a program can be used in other applications' as simpler components can be used again within the existing system and imported into others. This also aids maintainability as it makes each component's functionality clearer, making it easier for future users to 'locate and fix an error' within the system (Cavano & McCall 1977, p.136).

One example of this within this project was that initially I had created the content for the bubbles within the TreeMapChart component shown above. However, this component already has a fairly complex function in re-ordering the data for the chart. I therefore extracted the functionality for creating the labels for individual bubbles into a separate component called BubbleContent and then again extracted the specific functionality for loading the correct icon for each bubble into another component called Icon.

I have included the BubbleContent code below as an example of how extracting components can create simpler, reusable components. This component simply loads the relevant icon, a title if needed (this depends on the size of the bubble) and a percentage into a label for the bubble.

Figure 8L: BubbleContent component

```
import Icon from "./Icon";

const BubbleContent = (props) => {
    return(
        <div>
            <Icon
            industry={props.industry}
            fill="inherit"
            style={{
                "width": props.width,
                "height":props.height}}
                />
            {props.withTitle?
            (<p style={{fontSize:'inherit'}}><br></br>
            {props.title}</p> ) : null}
            <br></br>
            {Math.round(props.percentage)}%
        </div>)
        };

export default BubbleContent;
```

8.5.2 Hooks

The purpose of React hooks is 'to let you use state and other React features without writing a class' (ReactJS, 2021), offering functionality that previously required the use of classes. Three main React hooks are used within this project to enable the use of these advanced functionalities, these are useState, useContext and useEffect. Each is described in more detail below with an example of their usage within this application.

useState

useState is used in a number of places within the application and provides a means of updating certain components based on, for example, user interaction with the platform. For example, State is used to record the previous colour of a bubble during its hover state and to reset this when the bubble is no longer hovered over.

A State is created to record and update the previous colour, as seen in Figure 8M.

Figure 8M: Use of useState

```
const [previousColor, setPreviousColor] = useState([''']);
```

This is then used in the onLeafMouseOver and onLeafMouseOut functions to record the colour of the bubble when the hover state begins and then to reset it to this once the hover state ends.

Figure 8N: Use of State within functions

```
onLeafMouseOver = {(leaf, event) => {
  showChart();

  if(leaf.data.title!=="Investments by Industry" && leaf.data.title!=="Nested Funds"){
    setPreviousColor(leaf.data.color)
    setCurrentBubbleData({'industry':leaf.data.breadcrumb, 'percentage':leaf.data.size})
    if (leaf.parent.data.title===="Nested Funds"){
      leaf.data.color=ctx.subfundsHighlight;
    }
    else if (leaf.parent.data.title===="Investments by Industry"){
      leaf.data.color=ctx.directInvestmentsHighlight;
    }
  }
}}
onLeafMouseOut = {(leaf, event) => {
  if(leaf.data.title!=="Investments by Industry" && leaf.data.title!=="Nested Funds"){
    leaf.data.color=previousColor;
  }
}}
```

useContext

useContext provides a way of updating certain variables and making them available to as many components as needed within the application, without having to pass these as props between individual components. In this application, the context holds variables such as the colour shades for the bubbles and the breadcrumbs to show which bubbles have been clicked on. These variables can then be updated and accessed by various components, as the overarching App component is wrapped in a context "Provider". Using context in this way also allows functions to be defined and passed to the context via the Provider, allowing these to then be accessed and called in various components within the application.

For example, a function is created to handle clicks to individual bubbles:

Figure 8O: bubbleClickHandler function

```
const bubbleClickHandler = (bubbleID) => {
  let previous = ctx.selectedBubbles;
  previous.push(bubbleID);
  setSelectedBubbles([...previous]);
};
```

which is passed to the context via the Provider:

Figure 8P: Context Provider

```
return (
  <ParentContext.Provider value={{
    parent: filteredParent,
    listParent: selectedIndustry,
    directInvestmentsBubbles: ctx.directInvestmentsBubbles,
    subfundsBubbles: ctx.subfundsBubbles,
    selectedBubbles: selectedBubbles,
    selectedIndustry: selectedIndustry,
    subfundsHighlight: ctx.subfundsHighlight,
    directInvestmentsHighlight: ctx.directInvestmentsHighlight,
    searchInput: enteredText,
    onItemClick: filterChangeHandler,
    onTitleClick: titleClickHandler,
    onBubbleClick: bubbleClickHandler,
    onIndustryClick: industryClickHandler,
    onSearchInput: inputChangeHandler,
    onSearchSubmit: searchSubmissionHandler,
    onSearchEnter: searchEnterHandler
  }}>
```

This function is then callable in other components, such as in the component that creates the Bubble Plot, where it is called within a function 'onLeafClick' that is called when individual bubbles are clicked on.

Figure 8Q: onLeafClick function

```
onLeafClick={(leaf, event) => {
  ctx.onBubbleClick(leaf.data.id)
  if(leaf.parent.data.title=== "Nested Funds"){
    hideChart();
    setTimeout(function(){ctx.onItemClick({title: leaf.data.title, id: leaf.data.id, breadcrumb: leaf.data.breadcrumb})}, 700);
  };
  if(leaf.parent.data.title=="Investments by Industry"){
    ctx.onIndustryClick(leaf.data.id);
    ctx.onItemClick({title: leaf.data.title, id: leaf.data.id, breadcrumb: leaf.data.breadcrumb});
  }
}}
```

useEffect

The useEffect hook allows you to 'tell React that your component needs to do something after render. React will remember the function you passed (we'll refer to it as our "effect"), and call it later after performing the DOM updates' (ReactJS 2021). In this application useEffect is used to record the screen width (using State) each time the screen is resized (Keohan 2019). This allows this width to be used to calculate font size using the calculateFontSizeMultiplier function seen below.

Figure 8R: Use of useEffect

```
const TreeMapChart = (props) => {

    const [width, setWindowWidth] = useState(0);

    useEffect(() => {

      updateDimensions();
      window.addEventListener('resize', updateDimensions);
      return () =>
        window.removeEventListener('resize',updateDimensions);
    }, [])

    const updateDimensions = () => {
        const width = window.innerWidth
        setWindowWidth(width)
    }

    const calculateFontSizeMultiplier = () => {
        if (width>842){
            return 6;
        }
        else{
            return width*0.007
        }
    }
```

8.6 Recommendations for Future Development

One of the expected benefits from this project was 'A set of recommendations for further development of this project' (see Section 3). This expectation was set in recognition that there would be requirements that were scoped, and suggestions from the user research, that could not be fully addressed within the timescale of this project.

Future Development Recommendations:

1. When the chart is integrated, it will need an introduction or instructions so that users understand what is being displayed and how to use the feature, as highlighted in the user research (see Section 7.2.2).
2. In order to access hierarchical data that shows the nesting of funds within a pension, Tumelo's API will need extending to include endpoint to for retrieving this format of data.
3. Descriptions for the industry groupings should be included in the on-hover descriptor, and the possibility of offering more detailed data about the companies' specific area of industry / products should be explored – so that users could search for some of the things they said were important to them eg. tobacco.
4. The chart could be adapted to offer additional data such as geographical location of companies, or voting data that would be of relevance to Fund Managers and Pension Trustees

Section 9: Analysis

9.1 Success of the project

The final product meets all of the specified requirements for a Minimum Viable Product (as set out in Section 6.3). It also offers many of the additional features that were identified as being lower priorities but to be added if time allowed (Section 6.3). Specifically, the system offers a search function for users to locate specific companies within their pension (point 7, Section 6.3), it imports data from the format exported by Tumelo's APIs (point 9, Section 6.3) and it offers two different suitable layouts for desktop and mobile use (point 10, Section 6.3). The main requirement that hasn't been addressed here, therefore, is the functionality to toggle between different layouts or data attributes, such as updating the chart to show companies by geographical location rather than industry (point 8, Section 6.3). There are a few reasons why this requirement hasn't been prioritised.

Firstly, it was felt by the Product Owner that toggling between different chart styles was not of particularly high value but that toggling between different aspects of data might be valuable, particularly to Fund Managers and Pension Trustees. Secondly, whilst toggling between charts might have been relatively simple to include, toggling between different data aspects was less so and time constraints meant that this was not able to be addressed within the project timeframe. Lastly, the Tumelo team are still scoping what functionality might be most useful for Fund Managers and Pension Trustees accessing the Stewardship Dashboard so adapting this chart to present different data will be more relevant once this feedback has been collected.

As well as meeting these requirements, the system also offers some additional functionality. In particular, one take home from the user research, as well as conversations with the Tumelo team, was that the industry grouping titles currently used (eg. Industrials / Consumer Goods) are not necessarily easy to understand. As these are the Industry Classification Benchmark groupings and are not easy to change, I felt that some further description might be the best way to mitigate this issue. Therefore, I added a component that appears below the chart which displays the percentage and industry title (or nested fund title) when the bubbles are hovered over, on desktop view, or clicked on, on mobile view. This could offer further description of these categories and provides a way of

displaying the titles for smaller bubbles, as below a certain font size only icons and percentages show in the bubbles. I did not add the industry descriptors myself, as this would require further work by those more familiar with these groupings to determine how to describe them. The added component, however, provides a means of providing such information.

9.2 Testing

9.2.1 Unit Testing

The modular nature of React makes unit testing relatively easy as it allows you to create a number of components, each with reasonably limited functionality. It then becomes simple to check whether each performs its expected functionality, as Agarwal states, 'When only one function is addressed by a component, the number of test cases is reduced and errors can be more easily predicted and uncovered' (Agarwal 2010, p.167). This unit testing was performed as each component was developed, in line with Agile practices, rather than at the end of the development process, and was undertaken by myself, through verifying that each component once built performed its expected function.

To assist with this, I developed some automated tests using react-testing-library, which I used to create 'snapshots' of what the expected output HTML of components was. If changes are made to the code that cause the rendered HTML to no longer match this snapshot, the test will fail. This provides a means of identifying whether updates to the code have caused components to stop performing as expected, and the snapshot can then be updated if it is decided that this newer version of HTML output is now the expected rendering. An example of a test file for the 'Icon' component is shown in Figure 9A.

Figure 9A: Test file for 'Icon' component'

```
import React from 'react';
import renderer from 'react-test-renderer';
import Icon from './Icon';

it('renders correctly', () => {
  const tree = renderer
    .create(<Icon industry='Industrials'fill="inherit" style={{
        "width": 30,
        "height": 30}}/>)
    .toJSON();
  expect(tree).toMatchSnapshot();
});
```

9.2.2 Integration Testing

'The primary objective of integration testing is to test the module interfaces in order to ensure that there are no errors in the parameter passing, when one module invokes another module.' (Agarwal 2010, p.167). Within my React application, there are groupings of components that are used together to create certain parts of the system. For example, the InvestmentsList component which creates the list of companies returned when the search bar is used, or an industry grouping is clicked, invokes an InvestmentItem component, which in turn calls a ListBreadcrumbs component. These groupings of components required integration testing to ensure no errors occurred during the interface between individual components. Taking the InvestmentsList example, this meant ensuring that the list loaded and correctly displayed all InvestmentItems, and that these in turn displayed the correct ListBreadcrumbs. In a similar way to unit testing, this was performed by myself throughout the development process by verifying that these smaller systems performed their functionality, and was assisted through the use of automated tests which verified that these composite components loaded as expected. An example is shown in Figure 9B, where the test checks a 'snapshot' of a component that calls another component, testing this integration.

Figure 9B: Test file for 'BubbleContent' component, which calls the 'Icon' component

```
import React from 'react';
import {render} from '@testing-library/react';
import renderer from 'react-test-renderer';
import BubbleContent from './BubbleContent';

it('renders correctly', () => {
  const tree = renderer
    .create(<BubbleContent
        industry='Industrials'
        width={30}
        height={30}
        title="Industrials"
        withPercent={true}
        percentage={10}
        withTitle ={true}/>)
    .toJSON();
  expect(tree).toMatchSnapshot();
});
```

9.2.3 System Testing

As importing data from Tumelo's API happened towards the end of the project, this provided a means of testing the system. The data I was provided with is that used for a demo Member Dashboard platform Tumelo have developed, so once I had imported this data I was able to compare the results in my chart to the demo platform. This enabled me to verify that companies were appearing within the correct industry groupings, and that companies were not being missed out.

In addition, I tested some key aspects of the system using automated testing. For example, one key output on the display is the percentages, which also determines the size and colour of the associated bubbles. I therefore selected the formula that calculates this percentage as an important aspect to test and created a test file to verify its output (see Figure 9C). I created a set of test data that contained a smaller sample of the data from the API to enable me to check expected outputs more easily. In addition, I created a continuous integration pipeline that automatically ran these tests on every push to Gitlab to ensure that any changes to the system were checked against these tests. A screenshot of the .yml file for this pipeline is shown in Figure 9D.

Figure 9C: Test file for calculateTotal formula

```
import {calculateTotal} from './myOriginalData';
const testingData = require('./testingDataConvert');
const sampleData = require('./dataConvert');

test('check sampleData percentage for Financials grouping', () => {
    const calculatedTotal = calculateTotal(sampleData, 'a1');
    expect(calculatedTotal).toBe(17.230143124399987);
});

test('check test data percentage for Financials grouping - one company', () => {
    const calculatedTotal = calculateTotal(testingData, 'a1');
    expect(calculatedTotal).toBe(0.8994477000000001);
});

test('check test data percentage for Tehcnology grouping - multiple companies', () => {
    const calculatedTotal = calculateTotal(testingData, 'a5');
    expect(calculatedTotal).toBe(10.643106470000001);
});

test('check test data percentage for Industrials grouping - 0 companies', () => {
    const calculatedTotal = calculateTotal(testingData, 'a2');
    expect(calculatedTotal).toBe(0);
});
```

Figure 9D: CI pipeline created using a .yml file

```
image: node:12.18.3

stages:
  - build
  - test

build-code-job:
  stage: build
  script:
    - echo "Running npm build:"
    - npm install
    - CI=false npm run build
  tags:
    - comsc-ci


test-code-job1:
  stage: test
  script:
    - echo "If the files are built successfully, test some files with one command:"
    - npm install
    - npm run test
  tags:
    - comsc-ci
```

As well as ensuring the application worked effectively, I also checked aspects of the design as a central theme for this project was to produce something engaging and user-friendly. For example, I demonstrated the system to one of Tumelo's designers who gave some feedback on aspects of the design, which led, for example, to changing titles on the bubbles to bold font and using a suitable icon for nested funds. I also sought to ensure the use of colour was working effectively on different machines, as use of colour was a key aspect of the design. I loaded the chart application on my university laptop, my Tumelo macbook and a personal laptop and also viewed in on two different monitor screens, to ensure the colours and colour grades appeared correctly on all of these screens. Results were positive and colour did not seem to be affected by use on different machines.

Tumelo testing - User acceptance

As this project is particularly focused on the user and their experience, I decided to use User Acceptance Testing to verify that the user experience was as expected. As Cohn summarises, 'Acceptance testing is the process of verifying that stories were developed such that each works exactly the way the customer team expected it to work' (Cohn 2004, Chapter 1). This also provided a means to ensure the product met the initial requirements and that the Tumelo team were happy with the results. I therefore created a list of tests for the system, which correlated to the completed requirements, and asked a member of the team to carry them out.

These were:

Figure 9E: Tests mapped against Requirements

Requirement	**Test(s)**
1. View the top level of their pension investments in a visual form	Test 1: Load application, this should display a Bubble Plot chart showing the data for the Top Level of a sample pension.
2. Explore the structure in an interactive way, viewing contents of nested funds and the companies invested in at any particular layer	Test 2: Click on 'Fund 1' – this should load a new chart with the data for the contents of Fund 1.

	Test 3: Click on 'Subfund 1' – this should load a new chart with the contents of Subfund 1.
3. Understand the current context of the chart they are viewing within the overall fund	Test 4: Above the chart should be 'breadcrumbs', titles showing the layers you have traversed through so far. Within Subfund 1, this should display "Top Layer > Fund 1 > Subfund 1"
4. Traverse through the structure to explore the structure of other layers / subfunds	Test 5: Using the 'breadcrumbs' in the titles above the chart, click on 'Top Layer'. This should return you to the initial chart showing the Top Layer of the pension.
5. View the specific companies within any groupings (eg. by industry) at any level of the fund	Test 6: Within the Top Layer of the pension, click on the bubble titled 'Industrials', this should load a list view showing the companies within this industry contained in the Top Layer of the pension (starting with Sony, Keyence, Relx).
6. A write-up of the project, with recommendations for further development to the feature to be presented to Tumelo	Not included – this will be tested via submission of recommendations to the Product Owner.
7. Search to locate specific companies within their pension and view where they appear within the structure	Test 7: Use the search bar at the top of the page to type "Tot", this should load a list of companies whose names include this text, namely "Total", which appears twice within the pension, so is listed twice, and "TOTO".
8. Import data in the format exported from Tumelo's internal APIs	Test 8: Delete search text to return to 'Industrials'. Load Tumelo's demo dashboard. Compare list of companies within chart to those in the 'Industrials' list on the demo

	platform to check these are matching company listings.
9. Offer a suitable, and potentially different, chart style for both mobile and desktop use	Test 9: Click on 'Top Layer' within the breadcrumbs to return to this layer. Load the chart in mobile format using the relevant browser tool. This should show two charts, stacked vertically, one showing the Direct Investments and one showing the nested funds.

Each of these tests were turned into test cases that could then be used to verify that the system met its requirements. These tests were carried out by the Product Owner for this project, Tumelo's Solutions Architect. The reports from this testing can be seen in Appendix 4, which show that the system passed all tests, showing that it meets the given requirements for a Minimum Viable Product and most of the additional requirements, as described in Section 9.1.

Tumelo Feedback

The team at Tumelo have been extremely pleased with the results of this project and a written report from the Product Owner is included in Appendix 5. A summary quote from that report is included below, demonstrating the positive reception this project has received at Tumelo and the way it has highlighted the potential of visually engaging, interactive, data visualisation to address some of their business needs.

"During the course of the project Helen communicated proactively and regularly with the Tumelo team and she presented her work several times to the whole team as part of our fortnightly sprint demo ceremonies. Without exception the feedback from the team on both her designs and implementation was hugely enthusiastic, with several team members suggesting news ways to incorporate her ideas into a range of product areas.

As it draws to its conclusion, Helen's project has been extremely successful from Tumelo's perspective, in no small part due to the technical, organisational and communication skills Helen has demonstrated. The prototype implementation uses real data wherever practical.

It works flawlessly and looks fantastic on both mobile and desktop clients. Helen's attention to detail and openness to push beyond her previous knowledge has delivered some really nice UX features such as animation, auto-scaling icons and the graceful handling of long text in a mobile environment.

The project has met all of the criteria we set out at the start, and yet presented something totally new and novel in its approach that we had not considered until Helen presented the ideas. As a result I fully expect our product team to incorporate the key concepts, and perhaps even elements of the prototype implementation into a future version of our product." (Slingsby 2021, 27th Sept).

Section 10: Conclusions

This project offers a number of key achievements, most notably:

- Through extensive review of relevant literature and projects, suitable chart styles that effectively portray hierarchical and categorical data have been identified, as well as key principles of effective Data Visualization.
- Through a survey with individuals from Tumelo's target user group, design options have been compared and feedback gained on the most engaging design and how to improve the readability of the chart.
- Drawing on this user feedback, a Bubble Plot chart has been designed and implemented as an interactive React application that presents a user's pension data in a visually-engaging way.
- The application offers the core functionality expected for a Minimum Viable Product as well as most additional requirements, as demonstrated in the User Acceptance Testing in Section 9.
- The application received positive feedback from the Tumelo team and gained User Acceptance, see Appendix 4 and Appendix 5.

What would I have done differently:

10.1 User Research Timeline

Alongside these successes, there are also aspects that could have been done differently that offer points of learning for future projects. In particular, there were some timing-related issues that could have made the project smoother. The first of these related to the human research element of the project and the need to comply with processes of the company as well as those of the university. The university has clear processes that govern research projects, which include gaining approval from the relevant ethics committee prior to beginning such a project. Tumelo also have clear procedures when it comes to user research and use an external agency, People for Research, to find participants and organise user testing.

The advantages to involving People for Research are that this removes the requirement to find participants and, more importantly, they are able to source participants according to

specific criteria (see Section 7.2). Another advantage is that using People for Research is in line with Tumelo's practice and therefore the results of the research are more likely to be seen as informative by the company's team. However, this meant that combining the length of time to get ethical approval from the university with the lead time for People for Research, the research element of the project ended up being projected to happen fairly late in the timeline.

The main issue this presented was whether there would be sufficient time to change the chart style according to the results of the research in the remaining period, and how much meaningful development could be done prior to receiving these results. In some ways there is little that could be done about this but perhaps knowing this in advance of the project might have meant different decisions could have been made around how to effectively make use of the user research element. To address this, I initially considered changing the scope of the research to perhaps focus on more specific elements of one of the chart styles, or to choose between two options rather than three. This would reduce the number of options and would mean I could focus on developing one or two styles prior to conducting the research.

However, as mentioned in Section 6.1.2, a deciding factor was the adoption of react-vis as the library for writing the chart. As this library offered the capability to draw all three possible designs, the work involved in changing between the three options, based on research results, was significantly reduced. On this basis, I decided to keep the original focus of the research, and to change the final design based on the results.

10.2 Importing Data

Another aspect that could have been smoother was around importing data. Initially, I created my own sample data to get a prototype available as soon as possible. I then drew in some sample data from Tumelo's API at a later stage. It might have been easier to use Tumelo's data format from the beginning as this would have meant my data conversions within the application were set up to use this format as a starting point. However, this would have meant more work during the early stages of development and would have delayed the release of a usable prototype. Another limitation to this was that Tumelo's API currently only has endpoints that produce flat pension data – ie. aggregated totals for each company

that do not show the tree structure of nested funds. This means that while I was able to use their sample data to populate the investments in the top level of the pension fund, I was not able to generate sample nested funds from it.

Rather than moving wholly to importing data from the format used by the API, therefore, I had to combine this with my own sample data for nested funds. I therefore imported Tumelo's sample data into the format of my sample data, to combine it with the nested funds data, prior to then adapting this into the format for the React library react-vis (used to generate the charts). I could have missed out this middle step if a sample data set with nested funds was available, as I could then have drawn straight from that format into the data structure needed for react-vis. If the system I have developed is used in future, an additional endpoint will need to be created for Tumelo's API, to import the hierarchical data that includes how funds are nested within the pension. This is covered in the recommendations made to Tumelo for future development of this feature (see Section 8.6).

10.3 Testing

Another timing aspect that I would change in future projects is that of automated testing. As writing automated tests in React was a new skill to me, this happened later in the project than might be ideal, as I was initially learning React and looking to create a prototype. Early testing was therefore done manually by verifying the outputs of components was as expected. I then decided to learn how to write unit tests for React components and created some automated tests. These were used in the later development stages to ensure that any changes to code did not impact on the results of these tests and were useful in ensuring quality at this stage. However, in future projects, it would be beneficial to build in some automated testing sooner to assist with earlier development stages.

10.4 Design Details

Some aspects of the final design could be improved with further time. For example, the titles that make up the 'breadcrumbs' at the top of the chart could be styled to look more in line with the overall design. The layout of the page overall could also be improved, such as the design and alignment of the search bar. However, these design elements were identified as lower priority as, if Tumelo incorporate this feature into their dashboard in future, it would sit within a different overall page so elements such as the search bar would need to sit

within that overall layout. It was therefore felt, by the Product Owner and myself, that these were the lowest priority items on the list of possible fixes to the system.

Contribution to academic/practical/business knowledge:

This project has contributed to business knowledge within Tumelo by highlighting the potential of data visualisations to make pensions data more engaging to their users and clients. The interactive nature of the chart has also shown how users can be drawn in to explore their pension, adding another way of engaging them with this data. This fits in well with the company vision of Tumelo, to give people awareness about using their investments as a way of influencing decisions on issues they are concerned about, such as climate change, creating a 'more sustainable investment system' (Tumelo 2018). On seeing the prototype for this project, the Tumelo team identified a number of possible use cases for such an interactive data visualisation, including adapting it to show other aspects of data that would be of interest to Fund Managers and Pension Trustees (explored in Section 4.2.1). This shows that the system developed in this project could offer real business value to the company.

As well as contributing to business knowledge for Tumelo, this project has also contributed to the wider field of financial data visualisation. As mentioned in Section 4.1, whilst there has been some work in the area of finance visualisations, little has been published in the specific areas of pensions, especially pertaining to presenting this data to pension holders themselves. This project therefore offers a model that can be applied within other pension contexts as well as within additional financial settings, particularly where hierarchical and categorical data is being interpreted.

Section 11: Reflection

Research Process

Some of the initial lessons learnt on this project were around research, through completion of review of relevant literature and projects. This demonstrated the importance of accessing reputable sources and the challenge of finding projects of direct relevance to this piece of work. In particular, it was useful to use university resources to ensure quality. Using the online library system enabled me to identify sources that were peer-reviewed or had been frequently cited by other authors. Lecturers also provided a valuable source of guidance, recommending relevant journals and publications, which enabled me to find previous projects to draw upon. I was also grateful for access to the Data Visualisation module for reading lists and teaching resources that were relevant to this project.

An additional skill required was to identify sources that would offer value to this project. This meant not only identifying reputable sources in relevant fields but also selecting amongst these for those that contained the kind of material that was useful. For example, sources were not necessarily more helpful if they were from a closer field of work as some sources within the field of financial visualisation offer a survey of styles or a model based on a specific finance context, but don't offer more general reflection on what makes a good visualisation. Therefore, more general texts on data visualisation sometimes proved more relevant, even if they weren't specific to the financial sector, as they provided valuable expertise such as on design and accessibility.

Project Management

Another area of learning was in project management and particularly the application of Agile processes. One of the great advantages of undertaking this particular project was the opportunity to work within a team based at a company and to learn from their particular application of Agile methodologies. In particular, the ability to work with a Product Owner and to have regular communication with someone representing the business case for the project was of real value. One area of learning was how this changes the decision-making for the project. In contrast to university projects, the focus for the development became far more focused on what was required by the company Tumelo and on the opinions of the team on various aspects. For example, Tumelo employ designers who helped with the look

and feel of the chart. The Product Owner also provided a valuable steer on the priorities for the development Sprints.

This did mean, however, that a learning point was to let go of some of what I might have focused on had it been a personal project. I tend to hold myself to high standards so, for example, I might have wanted to give more time to perfecting small aspects of the layout and design of the application. However, the priority for Tumelo was to develop a working prototype that showed the kind of functionality they had envisaged and features such as prevention of user errors were prioritised over design. This is also influenced by the fact that if the system I have developed is incorporated into their Member Dashboard, it would sit within a wider page so its layout would need to adapt to this context anyway. It was a really valuable learning experience to develop something focused on 'client' requirements and their decision-making, rather than on my own perspective on what would be most valuable.

Methodology Decisions

Reflecting upon the methodology chosen, there are a few areas of learning and ways these decisions might have been improved. One example is the use of the human research element and, whilst this generated useful results, there might have been a different approach that might have suited the style of application better. As the system developed in this project is an interactive feature, there were some limitations in presenting options for this in a survey, and interviews or focus groups where the interactive platform could have been shown may have been better. However, had I wanted to consult on different design options, this approach would have meant developing three different interactive applications, and this did not seem an appropriate use of time within the project.

Personal Development

Completing this project provided a valuable skills development opportunity, especially in learning React, which was core to the process. This also highlighted areas for continuing development, in terms of technical expertise and more broadly. On the technical side, this project identified Typescript as a valuable skill, and learning this language will be part of my personal development plan going forwards. There are also more advanced features of React, such as Redux, that I did not use for this project but would be good areas to develop for ongoing use of React.

The project also required a broader skillset beyond the technical, such as interpersonal skills for interacting with a range of Tumelo team members, and project management skills to ensure the project was delivered on time and to a sufficient quality, meeting Tumelo's requirements. In particular, this included development in my understanding and application of Agile principles and working with a Product Owner from a 'client' company, and using a Kanban approach and a Kanban board, were areas of learning for me. Having used the more continuous Kanban approach here, one area of development going forwards will be to gain experience in using a Scrum approach, with fixed-length Sprints. This approach is used by the team at Tumelo who, as a result of the success of this project, have offered me the opportunity to stay on as part of their development team. This demonstrates the effectiveness of this project, both in terms of delivery a well-received system, but also in terms of project management and interpersonal relationships, all of which have contributed to this job offer. This will provide an ideal context to continue the personal development plans described here.

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Appendices

Appendix 1: Archetypes: Trending Newcomer and Quietly Established

<u>The Trending Newcomer Archetype</u>

THE TRENDING NEWCOMER

Life Moment Mature young professional

tumelo

COMMUNICATIONS CHANNELS
- Instagram
- Facebook
- Twitter
- Pinterest
- Email
- Whatsapp
- Banking Apps (e.g. Natwest, Monzo)
- News Apps (e.g. BBC, Apple)

Mission

To be financially empowered. To have a future that feels stable, secure & in my control.

If I can do my bit for a better world then I want to.

Tumelo: to understand my place in the larger ecosystem.

Bio

I'm often described as millennial or tech native. I'm well educated, work full time and am lucky enough to have some disposable income.

I know I should be thinking about my financial future but planning isn't my strong point. I have a rough idea how much I contribute to my pension monthly but that's about all I do know.

I do my bit when I can for the environment. I tried Veganuary and get involved with some activist campaigns - more of a sheep than a leader.

I invest...

Because I know I should. But I focus more on the near-term.

In the hope to make money, improve my financial wellbeing & avoid losing money.

To try and think about long-term savings. I need help to do more of this.

Personality

Analytical	Creative
Loyal	Fickle
Active	Passive
Patient	Impatient
Financially Savvy	Clueless

I value...

My connection to something bigger e.g. social change, eco. I'm willing to financially contribute if returns are comparable to other investments. I don't mind loosing a little if it makes me look or feel good.

Working for a company that cares about its impact and positive contribution to society. But I also value job security - it's a balance.

My small role in influencing businesses to make positive changes. I just need some help to know what I can do and how I can do it.

How might we?

- help them save towards a future they care about?
- help them become financially empowered without adding another chore on their to-do list?
- help them understand their potential impact of their money?

THE TRENDING NEWCOMER

"I'm forgetful and when I retire I don't want to sift through 40 years of paperwork to track down my pension info."

tumelo

FINANCIAL KNOWLEDGE

I don't think much about my pension. Sometimes it feels invisible to me. I'm rather apathetic to it. Maybe I shouldn't be.

I don't really know much about my pension. Auto-enrollment means I've never had to think about it. Retirement is still a long way off. My pension is what it is and I'm stuck with what my employer has chosen.

Goals

- Have a holistic view of my finances and their impact on the world.
- Feel financially confident & in control.
- To start considering financial wellbeing like I do physical and mental wellbeing.
- To be financially flexible and resilient both now and in the future.
- Save for near / mid-term.
- Become more aware of the long-term.
- Understand where my money is, what it is doing & what impact it has.
- Be perceived as acting 'sustainably' by others.

Behaviour

- Heavily influenced by social media, recommendations and employer. Will join this conversation about core issues/brands.
- May return to the platform to see if they're invested in a company in the news.
- Unlikely to shop around for competitor products in this sector.
- May want to switch pension or fund if not aligned with their values. Only if an effortless experience.
- May opt for a sustainable pension.
- Motivated to save more if money was being used for positive impact.
- Regularly donate to charity or volunteer.

Need

- Financial flexibility to be prepared for unexpected events as I go through life.
- Advice & support to save more & wisely.
- To understand the impact of my financial (in)actions.
- Reassurance that my money is secure and not invested in 'bad' companies.
- Accessible & engaging education around pensions & investments.
- Fast, easy to use tools for total convenience.
- Hassle free fully integrated services.

Frustrations

- Lack of control, clarity & transparency.
- Information overload: what's important?
- Uncertainty and confusing nature of pensions and investments.
- Pensions are too abstract.
- Too much jargon.
- They don't know what to do for the best.
- Feel anxious about their finances: in particular savings, the future & the idea of loosing money by investing.
- Time poor.
- Is this really ethical / eco?
- Reliability & trust in tools and providers: for the here & now but also when I retire.

The Quietly Established Archetype

THE QUIETLY ESTABLISHED

Life Moment Settled

tumelo

COMMUNICATIONS CHANNELS

- Facebook
- Pinterest
- Email
- Whatsapp
- Banking Apps (e.g. Natwest)
- Mail (paper or paperless)

Mission

First and foremost I cannot lose money, not much.

I'd like to do my bit, without impacting my loved ones future.

Tumelo: to ensure my money is in the best place for security & growth.

Bio

I own a home, have a family and have risen to a senior level in a steady career. I'm well educated but not always through traditional means. Thanks to my long career I have a decent amount to invest (£25k+). But sometimes I contract so have to plan for sick days etc.

I have multiple pension pots and savings accounts. I check in on these throughout the year. I could invest more sustainably but I worry about risk.

I'm environmentally aware but are not fixated on it.

I invest...

Because I have responsibilities to consider (family, mortgage, health) & prepare for.

To make the most of my money & know that it is increasing in line with inflation.

To help give the next generation a better future.

Personality

Analytical	Creative
Loyal	Fickle
Active	Passive
Patient	Impatient
Financially Sav	Clueless

I value...

The needs of my family and my own circumstances. I need to be financially resilient to weather any storm. That means thinking about what we need & when at different life stages.

My role in influencing businesses to make positive changes. I just need some help to know what I can do and how I can do it. My priorities will always be closer to home, but I want my children to live in a better world.

I'm willing to financially contribute if returns are comparable to other investments. I don't mind loosing a little but it's a careful balance.

How might we?

- help them use their money effectively for the whole family?
- help them feel their money is secure but see growth potential?
- show them how to use their investments for positive impact and remain steady as a rock?

THE QUIETLY ESTABLISHED

"My greatest fear in life is running out of money."

tumelo

FINANCIAL KNOWLEDGE

I am relatively financially aware. I've had a few pensions and different types of savings over the years. I've also worked with an IFA before.

I'm aware of what a pension is and how the process of investing works.

I don't think of myself as a shareholder with the right to vote but I know that shareholders can influence company decisions.

Goals

- Make the most of my money.
- Minimise, preferably avoid, financial risk.
- To understand where my money is, what impact it could have & what the real financial risks of that are.
- To feel totally in control of my financial future (for me & my family).
- Long-term financial wellbeing.
- Give my children a head-start where possible.
- Deal with financial stresses.
- Make the right financial decisions.

Behaviour

- Warier & more cautious decision maker. Concerned around data security. Need trustworthy assurances.
- Consider competition before choosing a new service provider.
- Convenience is nice but I'm happy to spend time learning new tools etc.
- May opt for a sustainable investments or pensions if given option. Likely to consider ESG when investing for kids.
- Likely to believe returns must be sacrificed in order to invest ethically.
- Affected by employer pension attitude.
- Likely to discuss finances more.

Need

- Clarity on the big picture of their finances – a holistic approach.
- Long-term financial security & clarity.
- Knowledge & ability to invest in what is right for me & my circumstances.
- Time to determine & understand what's right for their future.
- Manage multiple pension pots, investments & savings.
- To understand how finances all interlink & effect of individual decisions (e.g. voting) on the bigger picture.
- Reassurance my money is doing 'good' (financially & in relation to ESG).

Frustrations

- Technical jargon.
- Anxiety & fear about making the right decision in my specific circumstances.
- What about the risk?
- How should I manage / track multiple pension pots, savings & investments?
- Fear of scamming or spamming.
- Time poor.
- Is this really ethical / eco?
- Reliability & trust: will they store my data safely? Can I rely on this now & in the future?

Appendix 2: Trending Newcomer Personas ('Holly' and 'Jack')

Trending Newcomer Persona: 'Holly'

Bio

- 21-35 years old
- NRS social grade: BC1C2
- UK based
- Predominantly a mobile user: would be highly engaged with an app
- Highly comfortable with technology: regularly uses a computer for work or study, spends a significant amount of time using mobile for tasks, social etc.
- Educated to Bachelor level

Occupation

- Relatively early in her career: junior or mid-level role
- May have changed careers or taken a career break
- But now settled in role and may have worked with current employer for 2-5 yrs
- Some responsibilities at work but comfortable in role & position within a team
- Average income for stage in life (e.g. junior with minimal family responsibilities)

Employer

Holly works for organisations such as:

- John Lewis
- Amazon
- Retail
- ...

The Employer

- Are pension engaged
- See pensions as a major employee benefit for both retention and acquisition
- Need some support in how best to communicate pension information to the variety of employees within their company
- Will match an employee's contribution at a minimum
- May be revamping their pension scheme
- May have a high turnover of staff due to training opportunities and corporate schemes
- Many pension members may be ex-staff alongside present staff

Personal Finances

- More recently has thought she should consider her pension more
  - A few members of her family are approaching retirement and have helped her see how important this is
- Contributing £100-£150 per month
- Little to some disposable income
- Has 1-3 pension pots
- Little pension literacy

Interests

- Beauty, wellness & lifestyle trends
- Shopping, entertainment & dining out
- Home, social, travel
- Arts, media & celebrity news

Trending Newcomer Persona: 'Jack'

Bio

- 25-44 year old
- Educated to Bachelor Degree level or higher
- UK office based
- Desktop-based: interact during working hours
- May consider using an app on mobile with push notifications as an alternative to email comms
- Changing life phase: education, family, home
- Very comfortable with technology: uses a computer daily for work, spends a lot of time on mobile and/or tablet for work and home life

Occupation

- Professional & skilled
- NRS Social Grade BC1
- Above-average earner (perhaps only just)
- 0-5 years spent with employer
- May work in a team or be quite independent

Employer

Jack works for organisations such as:

- NatWest
- Ernst & Young
- Accenture
- KPMG
- Deloitte
- ...

But is likely to have worked in a few different organisations across several roles including part-time work or internships.

Jack may now have multiple pension pots so he doesn't necessarily work for the employer who's pension scheme is accessible through Tumelo's platform.

The employer:

- Are highly pension engaged
- See a pension as a major employee benefit for both retention and acquisition
- Need some support in how best to communicate pension information
- Will match an employee's contribution at a minimum

Personal Finances

- Invests between £100 & £250 per month into pensions
- Has 1-3 pension pots
- Moderately pension & financially literate: due to role, employer culture & education/home
- Some disposable income
- Wants money to support positive climate goals

Interests

- Opening the door to pensions & getting a handle on their own finances
- Business & employment, technology, financial services, real estate, lifestyle & media, travel, sports, fitness
- The home: moving, decorating, DIY, gardening
- Social justice & sustainability

Appendix 3: Quietly Established Persona: 'John'

Bio

- 45-65
- Closer to retirement age
- UK based - greater spread of location. Likely to be located near larger cities or towns.
- Quite comfortable with technology: uses a computer daily for work, spends a lot of time on mobile at home

Occupation

- Professional, desk-based job: moderate skill required
  - More senior role
  - Likely longer-term employee who may have worked up to this role
  - May be a team lead or work closely across teams
- Average income
- Majority NRS Social Grade BC1

Employer

John works for organisations such as:

- Tesco
- Amazon
- ...

But will have worked elsewhere during his career.

The employer:

- Are not necessarily very pension engaged
- May have undergone a recent pension shift e.g. from DB to DC, to a new pension provider or to increasing contributions
- Understand pensions are beneficial to their employee's but are not overly vocal at communicating this to all levels of employees. Some employers are increasingly trying to change this.
- Need a high level of support to communicate pensions information to a variety of employees and roles
- May do the minimum in terms of financial contributions or offer great benefits (either way, not all employees are aware of this)
- May have a spread of employees across a variety of job role types incl. part-time, contract, hourly and of varying skill levels
- May have a high turnover of staff and many pension members may be ex-staff alongside present staff

Personal Finances

- Moderate financial literacy
- May have been on an old DB scheme & might now also have a DC scheme
  - Never thought about pensions much in the past but things are changing - this can be confusing
- May have multiple pension pots

Interests

- Sports, media and entertainment, lifestyle, home, DIY, gardening, food

Appendix 4: Test Case Reports

Test Case Id: 1	**Test Purpose:** Verify requirement 1: User will be able to view the top level of their pension investments in a visual form		
Environment: React application, Tumelo laptop, using Chrome			
Preconditions:			
Test Case Steps:			
Step No	Procedure	Expected Response	Pass/Fail
1	Load application by deploying locally	This should display a Bubble Plot chart showing the data for the Top Level of a sample pension.	Pass
Comments: [provide details of any failed steps] Bubbles, titles and percentages all visible. Nested funds also clear. Hovering on bubbles displays more information at the bottom of the screen.			
Related Tests:			
Author: Helen Shepherd		**Checker:** Wyc Slingsby	

Test Case Id: 2	**Test Purpose:** Verify requirement 2: Users are able to explore the structure in an interactive way, viewing contents of nested funds and the companies invested in at any particular layer		
Environment: React application, Tumelo laptop, using Chrome			
Preconditions: Application loaded to initial screen			
Test Case Steps:			
Step No	Procedure	Expected Response	Pass/Fail
1	Click on ‘Fund 1’	A new chart should load with the data for the contents of Fund 1.	Pass
2	Click on ‘Subfund 1’	This should load a new chart with the contents of Subfund 1.	Pass
Comments: [provide details of any failed steps] Really liked the transitions. Helped to give context to the structure.			
Related Tests:			
Author: Helen Shepherd		**Checker:** Wyc Slingsby	

Test Case Id: 3	**Test Purpose:** Verify requirement 3: User will be able to understand the current context of the chart they are viewing within the overall fund Verify requirement 4: Traverse through the structure to explore the structure of other layers / subfunds		
Environment: React application, Tumelo laptop, using Chrome			
Preconditions: Within chart for Subfund 1 (end of test case 2)			
Test Case Steps:			
Step No	Procedure	Expected Response	Pass/Fail
1	View 'breadcrumbs' above chart	Within Subfund 1, this should display "Top Layer > Fund 1 > Subfund 1"	Pass
2	Using the 'breadcrumbs' in the titles above the chart, click on 'Top Level'.	This should return you to the initial chart showing the Top Level of the pension.	Pass
Comments: [provide details of any failed steps] Breadcrumb gives clear information about current location within the pension fund.			
Related Tests:			
Author: Helen Shepherd		**Checker:** Wyc Slingsby	

Test Case Id: 4	**Test Purpose:** Verify requirement 5: User will be able to view the specific companies within any groupings (eg. by industry) at any level of the fund		
Environment: React application, Tumelo laptop, using Chrome			
Preconditions: Within Top Level of pension fund (end of test case 3)			
Test Case Steps:			
Step No	Procedure	Expected Response	Pass/Fail
1	Click on the bubble titled 'Industrials'	This should load a list view showing the companies within this industry contained in this level of the pension (starting with Sony, Keyence, Relx).	Pass
Comments: [provide details of any failed steps] Company list was visible, with highest percent at the top. A possible future enhancement would be to include the company logos in the list view			
Related Tests:			
Author: Helen Shepherd		**Checker:** Wyc Slingsby	

Test Case Id: 5		**Test Purpose:** Verify requirement 7: User will be able to search to locate specific companies within their pension and view where they appear within the structure	
Environment: React application, Tumelo laptop, using Chrome			
Preconditions: Within 'Industrials', within 'Top Layer' (end of test case 4)			
Test Case Steps:			
Step No	Procedure	Expected Response	Pass/Fail
1	Use the search bar at the top of the page to type "Tot".	This should load a list of companies whose names include this text, namely "Total" (which appears twice within the pension) and "TOTO"	Pass
Comments: [provide details of any failed steps] Having the clickable breadcrumb to the location within the pension that the matching company appear is a really nice and powerful touch.			
Related Tests:			
Author: Helen Shepherd		**Checker:** Wyc Slingsby	

Test Case Id: 6		**Test Purpose:** Verify requirement 8: Import data using format exported from Tumelo's internal APIs	
Environment: React application, Tumelo laptop, using Chrome			
Preconditions: Within search results (end of test case 5)			
Test Case Steps:			
Step No	Procedure	Expected Response	Pass/Fail
1	Delete search text to return to 'Industrials'.	Load Tumelo's demo dashboard. Compare list of companies within chart to those in the 'Industrials' list on the demo platform to check these companies appear on the demo dashboard list.	Pass
Comments: [provide details of any failed steps] The two lists matched.			
Related Tests:			
Author: Helen Shepherd		**Checker:** Wyc Slingsby	

Test Case Id: 7		**Test Purpose:** Verify requirement 9: Offer a suitable, and potentially different, chart style for both mobile and desktop use	
Environment: React application, Tumelo laptop, using Chrome			
Preconditions: Within 'Industrials' within 'Top Layer' (end of test case 6)			
Test Case Steps:			
Step No	Procedure	Expected Response	Pass/Fail
1	Click on 'Top Layer' breadcrumb to return to chart. Load the chart in mobile format using the relevant browser tool.	This should show two charts, stacked vertically, one showing the Direct Investments and one showing the nested funds.	Pass
Comments: [provide details of any failed steps] All bubbles nicely resized to fit the narrower screen. Hover behaviour in the wider web view has changed to a tap behaviour in the mobile view. Tapping again drilled in. This behaviour seemed intuitive.			
Related Tests:			
Author: Helen Shepherd		**Checker:** Wyc Slingsby	

Appendix 5: Feedback from Tumelo

One of Tumelo's key features is to help non-expert investors, typically people who are enrolled in a workplace pension scheme, to understand which companies their pension contributions are invested in. Many of these companies are household brand names, however pension schemes invariably don't invest directly in shares of individual companies, preferring instead to invest in one or more funds which are run by expert fund managers. Funds typically hold hundreds or even thousands of separate investments, or else invest in other funds. Whilst this is good in terms of diversifying risk for the pension member, it introduces complexity and it becomes difficult for the pension member to understand exactly where their money is invested. This is especially true when funds invest in other funds.

Tumelo works directly with fund managers to understand exactly how their funds are made up, and using that data, we can build up a detailed understanding of the companies represented in a user's pension or other equity-based investment product (e.g. an ISA). Tumelo's current product provides a simple flattened, aggregated list of all the companies whose shares are in some way invested in a person's pension or portfolio.

At the outset of Helen's project, our brief was very open, but with a number of constraints aimed at ensuring alignment with Tumelo's standard practices. The brief was to design, user test, and prototype a way to visualise the structure of a pension account or investment portfolio, taking into consideration the very broad range of structures that can and do occur. The aim was to be simple and intuitive to use for non-expert investors, whilst at the same time being engaging and providing genuine added value to the end user. We wanted any solution to work well in both mobile and desktop clients. Tumelo's existing product uses the React framework and Helen was keen to get experience in React, so the use of React became a project requirement. Additionally we asked that any 3rd party libraries that Helen used should conform to Tumelo's standard criteria. Finally, we were keen for any user testing carried out to not only conform to the University's requirements for ethical approval, but also to follow Tumelo's standard approach in which we engage a 3rd party company to recruit a diverse range of user testers. By following Tumelo's standard practices we aimed to minimise the difficulties that might otherwise arise in the event that we wanted to incorporate some or all of the project into a future iteration of the Tumelo product, but also to give Helen visibility of a typical set of constraints that she might encounter as a developer in industry. The wider Tumelo team was also available for Helen to talk to and work with to get feedback and advice throughout the project.

Helen very quickly grasped the intricacies of the challenge and after completing some research, presented at least three different design concepts for initial feedback. These designs went on to form the basis of the user research that she subsequently conducted though Tumelo's regular user testing recruitment partner. The use of our user test partner made the process of obtaining the University's ethical approval more complex than expected, but Helen navigated around the difficulties with patience, understanding and tenacity. She had a Plan B on the table in case problems arose that might threaten project timescales. In the meantime she started to identify candidate JavaScript libraries that could help

with rendering suitable React views, and to put together some initial prototypes based on her initial design concepts.

During the course of the project Helen communicated proactively and regularly with the Tumelo team and she presented her work several times to the whole team as part of our fortnightly sprint demo ceremonies. Without exception the feedback from the team on both her designs and implementation was hugely enthusiastic, with several team members suggesting news ways to incorporate her ideas into a range of product areas.

As it draws to its conclusion, Helen's project has been extremely successful from Tumelo's perspective, in no small part due to the technical, organisational and communication skills Helen has demonstrated. The prototype implementation uses real data wherever practical. It works flawlessly and looks fantastic on both mobile and desktop clients. Helen's attention to detail and openness to push beyond her previous knowledge has delivered some really nice UX features such as animation, auto-scaling icons and the graceful handling of long text in a mobile environment.

The project has met all of the criteria we set out at the start, and yet presented something totally new and novel in its approach that we had not considered until Helen presented the ideas. As a result I fully expect our product team to incorporate the key concepts, and perhaps even elements of the prototype implementation into a future version of our product.

We are grateful to both Helen for all her hard work during the project and to the University for giving us the opportunity to support the project. We viewed this as both a kind of very extended technical interview and in the reverse sense, an extended period of time for Helen to get to know the Tumelo team, our mission and values with a view to her potentially joining the team when the project concluded. Helen has been a joy to work with, and we're very pleased with the outcomes. I'm delighted to say that we are very excited that Helen has accepted our offer to join Tumelo as a permanent member of the development team and we're looking forward to her future contributions, both technical and non-technical.

(Slingsby 2021, 27 September)