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Progress Report

Decision support model mitigating scope variability in engineering R&D project

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Abstract

This paper presents a proposal of a Decision Support Model (DSM) in the Research and Development (R&D) of New Product Development (NPD) in Multinational Companies (MNC)'s. It is vital for Project Managers (PM) to be able to pick the right option to mitigate scope variability when they decide on project continuity. Hence, improvements need to be made to address challenges of on-the-shelf DSM's with modern solutions. The implementation of the proposed DSM is done idea management methodologies using a Balanced Scorecard (BSC) with SWOT analysis and Agile. New technologies are also implemented into the DSM using Progressive Web Applications (PWA)s to enhance traditional Project Management strategies and yield better results.

Index Terms – DSM, Engineering Management, R&D, BSC, SWOT, Agile, PWA.

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Nomenclature

AI	Artificial Intelligence
ANP	Analytic Network Process
API	Application Programming Interface
APP	Software Application
BSC	Balanced Scorecard
CSS	Cascading Style Sheets
CVCS	Centralized Version Control System
DSS	Decision Support System
DSM	Decision Support Model
DVCS	Distributed Version Control System
ERD	Entity Relationship Diagram
HTML	Hypertext Markup Language
IDE	Integrated Development Environment
JS	JavaScript
KPI	Key Performance Indicators
ML	Machine Learning
MNC	Multinational Company
MVP	Minimum Viable Product
NoSQL	Not Sequel
PI	Performance Indicators
PM	Project Managers
PWA	Progressive Web Application
QFD	Quality Function Deployment
R&D	Research and Development
RO	Research Objectives
SCM	Source Code Management
SDLC	System Development Life Cycle
SWOT	Strength Weakness Opportunity Threats
UI	User Interface
UML	Unified Modified Language
UX	User Experience
V&V	Verification and Validation
VOC	Voice of Customers
VSC	Visual Studio Code
WEBAPP	Web Application

1 Introduction

1.1 Research Background

Project management in engineering R&D for NPD's is known to be challenging due to its susceptibility towards contingencies through the long product development cycles [1]. This is due to the intensive researches and iterations on minimal viable products. In addition there are changes in regulations, new technologies, market stand, and competitors which needs to be considered by PMs that leads to complicated decision making. This consumes a lot of time and human resource. Hence, the proposed DSM needs to be flexible, current and adaptable to changes which will allow PM in making decisions when it comes to project continuity.

When PMs decide to use the DSM, there are many factors that affect its effectiveness. Hence, a study is conducted on current on-the-shelf DSM to create a more comprehensive and effective DSM that can better help in decision making. There is also a need to digitalize the DSM to overcome the challenges faced by on-the-shelf DSM's and shift towards Industrial Revolution 4.0.

In this paper, challenges of on-the-shelf DSM's are first studied and identified to create a more effective DSM in mitigating scope variability in R&D projects. The proposed DSM will be a combination of the advantages of on-the-shelf DSM's, solutions to the challenges faced by on-the-shelf DSM and the digitalization of the DSM.

1.2 Problem Statement

In an ever-changing R&D environment, the effectiveness of the DSM used will determine the quality of the NPD produced [1]. On-the-shelf DSM's are not adequate in mitigating scope variability in R&D projects and this is due to the various challenges affecting its effectiveness.

On-the-shelf DSM's lacks in multiple areas such accessibility, implementation and relevance which reduces its effectives. In its implementation, there is minimal idea management methodologies and DSM implementation methodologies which this study examine and overcome. On-the-shelf DSM's also lack a digital implementation of it. It has to be more user friendly and accessible to PM's. APP's help bridge the gap between laptops and phones by being versatile and very responsive while maintaining a reduce cost and effort [2].

With that, the aim of this research is to address the challenges faced by on-the-shelf DSM's in order to create the most effective DSM possible in the market.

1.3 Research Objective

1. Identifying the various characteristics on-the-shelf DSM's in engineering R&D processes in NPD which can reduce its effectiveness in guiding PM's on how to mitigate NPD scope variability.

2. Implementing solutions for the proposed DSM to address the common challenges of on-the-shelf DSM's.

3. V&V testing of the proposed DSM to gauge its relative effectiveness to on-the-shelf DSM's and areas for improvement.

2 Literature Review

A DSM is used to support decision making across various issues in an organization. It helps deliver insights and possible solutions to problems that allows decision makers to evaluate the consequences of their actions [3]. For the purpose of this study, a DSM is used to help PM's in an NPD to mitigate scope variability in R&D projects. It provides a guide to PM on what should be the future course of action and how it will affect project continuity of the NPD.

2.1 Challenges of On-the-Self DSM

In order to construct the proposed DSM model that can better help PM's in NPD, on-the-shelf DSM's are studied. The fundamentals, methodology, advantages and disadvantages are identified to determine its challenges. The study is then used to create a more effective DSM for PMs to use .

Decision Support Model	DSM [1]	BSC [4]	QFD [5]	ANP [6]	SWOT
Key Motivations for using the DSM	Relevant to industry practices and PM's	Ensures that company objectives are followed and personalized to each employee	Values engineering where quality assurance and quality control points are derived from the VOC	Deals with dependence and the feedback decision making	Shows managers how to achieve a competitive advantage in an ever-changing environment
Fundamentals	An adaptation of BSC, QFD, and ANP	Measures the four main aspects of a business.	Prioritization of the VOC and Seven Management and Quality Planning tools	Captures feedback and interdependent relationships among different levels of components.	Identifies strengths, weaknesses, opportunities and threats to a certain business or project.
Methodology	1. BSC 2. QFD 3. ANP 4. PI's	Four main aspects of a business: 1. Learning & Growth 2. Business Processes 3. Customers 4. Finance And strategy mapping	1. Seven Management Quality Planning tools used to identify and prioritize the VOC	1. Principle of decomposition 2. Pairwise comparison 3. Priority vector generation and synthesis 4. Saaty's 1-9 scale 5. Analytic Hierarchy Process	1. Internal factors 2. External factors
Advantages	1. Industry tested 2. Comprehensive and broad based PI's 3. Simple and Intuitive	1. Structure to company strategy 2. Improved communication 3. Better organizational alignment	1. Graphical information 2. Improved communication 3. VOC are prioritized	1. Handles multiple criteria 2. Flexible 3. Allows for complex relationships	1. Versatile, cheap and fast 2. Comprehensive 3. Neutral application

		4. Connects an individual to company strategy			
Disadvantages	1. No consideration of the quality of information.	1. Complicated 2. Requires a lot of data 3. Top down approach 4. Organization specific	1. Complex and time consuming 2. Difficult to meet all customer requirements 3. Multiple confusing and conflicting parameters	1. Complex and time consuming 2. Multiple calculations 3. Objectively graded comparisons	1. No weightage factors 2. Conflicting segments 3. Subjective analysis

Table 1: Comparison to Existing Decision Support System

Based on Table 1 above where a few of the most popular on-the-shelf DSM's are studied, a few common challenges were identified and summarized which are the accessibility, implementation and relevance of the DSM.

The first issue is accessibility. Time and flexibility are key to cost-effective and efficient R&D programmes. The proposed DSM must be easily accessed and used. Hence it is to be adapted into an APP and in this case a PWA. It will be using React.js library for its front-end and Cloud Firestore for its back-end.

The second issue is implementation. Most DSM's asks users to directly rank priorities based relative importance which leaves it open to influences that may affect its effectiveness. Managers are not given a way to organize their thoughts and carefully pick the right choices. The choices may be biased due to human emotions [7] and various other factors. Hence, there needs to be an idea sorting methodology to circumvent this.

The third issue is the relevance. The decision making process proposed by the DSM needs to be updated to keep with an ever-changing R&D environment and to ensure its continued relevance especially in an unstable world which was quite adequately demonstrated by the Covid-19 pandemic. New solutions for the continued implementation of the DSM's by PI's needs to be proposed to ensure its relevance.

2.2 Proposed Decision Support Model Study

Based on the challenges identified for on-the-shelf DSM's, a study is conducted to address the issues. Three questions were asked before proposing a DSM [3],

1. What is the model's purpose?
2. How is the model organized?
3. Is there evidence the model works?

Question 1 is addressed by creating a DSM model that can better help PM's in NPD scope variability in MNC's.

Question 2 is addressed by taking on-the-shelf DSM's and examining the advantages and challenges of current on-the-shelf DSM's which are related to the model's purpose. Then a study is done to overcome those challenges create a more effective DSM. The three main challenges area as below.

Firstly, on-the-shelf DSM's models are all offline and not accessible. It needs to include as data management and AI technologies that can further improve and automate processes significantly [8]. Hence, the first step is to implement the PWA and have a central database collecting DSM models created by project managers over time as the NPD R&D process goes on. PMs from various engineering sectors can help provide feedback and recommendations about how to improve the DSM.

The second issue the DSM faces is the implementation problems due to human factors. Human emotions affect judgment and decision making [7]. Hence there must be a methodology to regulate emotions to produce better results when it comes to decision making

The third issue is the need for regular updates to overall decision making process. Different methodologies need to be studied to identify which is suitable for the application of the DSM. In addition, cutting edge technology from science-based partnerships allows MNC's to within disruptions in the market [9]. A good system development lifecycle must also be identified to constantly update the PWA being used and the DSM in it to keep it up-to-date.

Question 3 is addressed by doing compatibility, functionality and usability testing with PM's who are in MNC's doing NPD. This would give a feedback of a higher quality as the target market for this DSM will be the ones who are reviewing it and examining its effectiveness.

2.3 Software Application
2.3.1 Background of the System Architecture

The system architecture for PWA's is divided into two parts. The part that the user sees is called the front-end or client side. The part where the data for the PWA is stored is called the back-end or server side. The Front-End is connected to the Back-End via an API. The API is the computing interface which connects the relays orders from the Front-End programming languages to the back-end server to retrieve or deposit information.

The front-end is the UI. It is powered by HTML, CSS and React.js and hosted on Firebase's domain hosting. Any actions that the user does on the front-end is relayed to the back-end via the API's. The back-end is supported by Cloud Firebase Database Hosting.
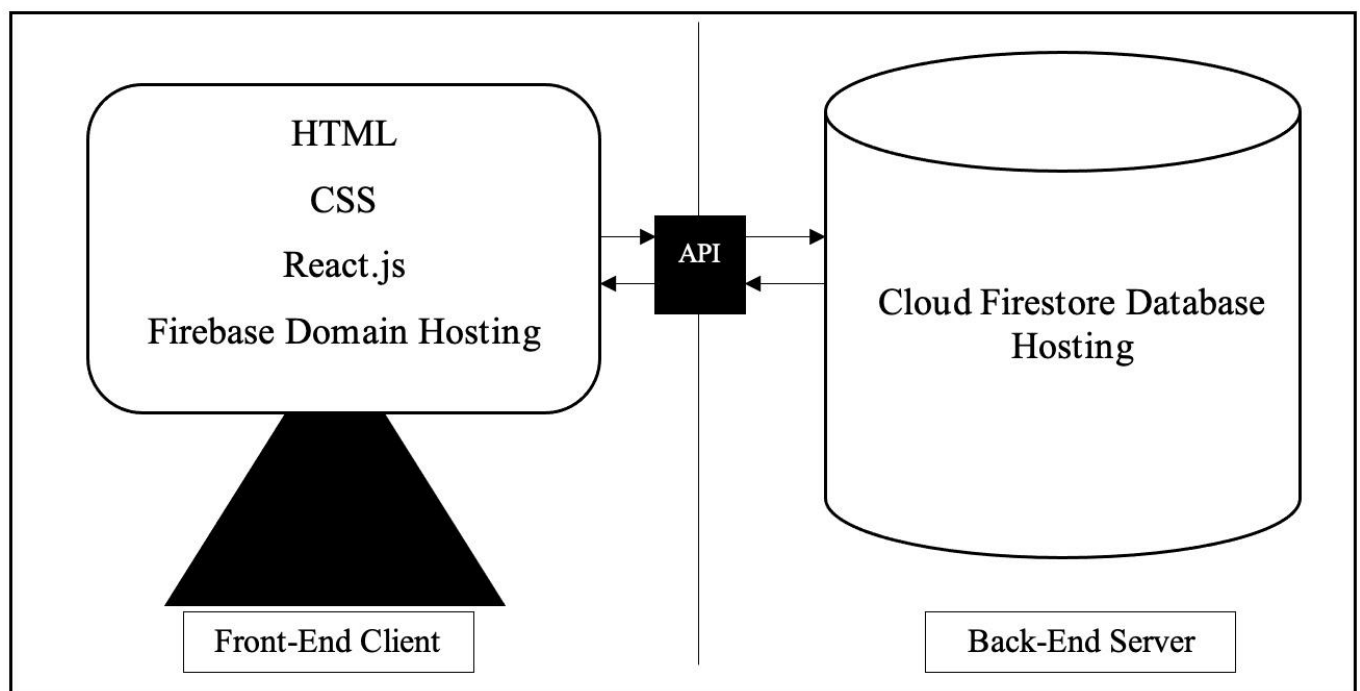
Figure 1: System Architecture for PWA

2.3.2 Selection of the Software Application

Based on literature, PWA is a software application that can be accessed via web browsers. At the end of this study, a PWA will be created with a Uniform Resource Locators that can run on most major browsers and is serviced and stored in web servers PWA's are built with modern API's to deliver enhanced capabilities, reliability and installability. This has enabled it to do what Native APP's couldn't do before, which is reaching all segments of society regardless of internet connection anywhere and on any device simply using one code base.

React.js is used to program the front-end client side of the PWA. It is an open-source, front end, JS library for building user interfaces or UI components. The reason for choosing React.js would be due to its popularity and community support in developing this library as shown in the Google Trends below. A framework allows for more structured, simple and uniform program script writing which leads to easier software maintenance [10]. This would reduce the cost in the long run if the DSM were to have expanded capabilities on the PWA.
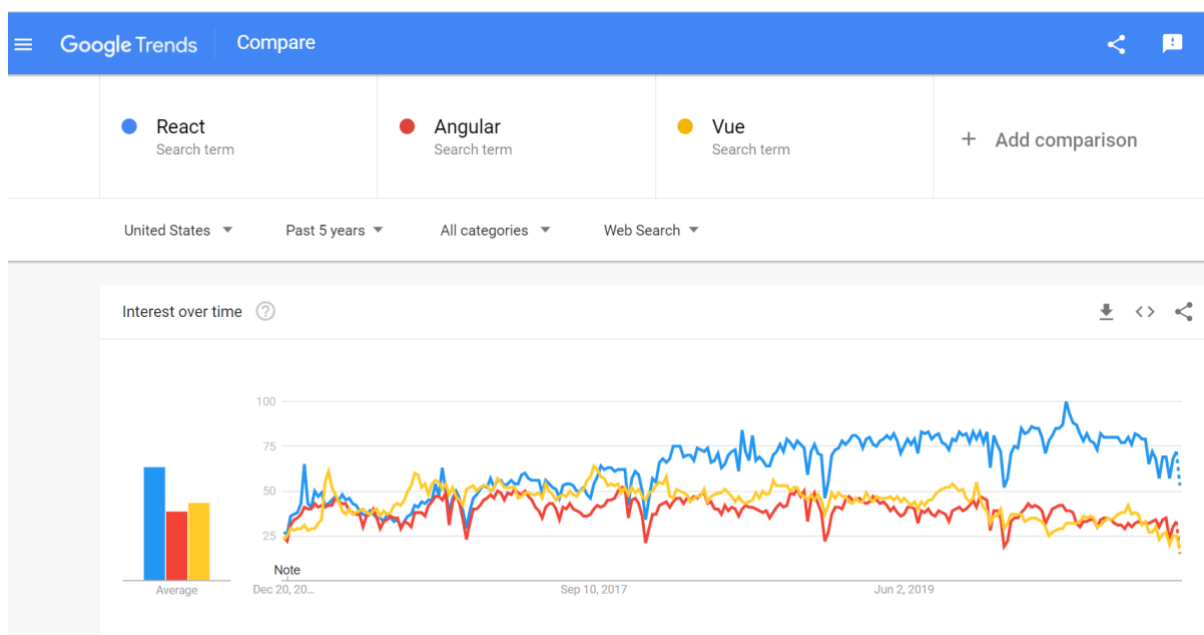
Figure 2: Google Trends for the past 5 years for the three biggest frameworks/libraries [11]

HTML is used to annotate a document that describes the structure of the web page semantically and can support other programming languages like CSS and JS which help improve the functionality of it. Hence, HTML5 will be used in the software application being developed [12][13]. CSS is a style sheet language used for describing the presentation in a mark-up language like HTML. It is the language that gives colour, flair and certain functionalities within the WEBAPP's [12][13]. JS is a high-level lightweight, interpreted or another words a just-in-time compiled programming language. JS enables WEBAPP's to become more interactive which is key to the UI.

Cloud Firestore by Firebase is used as the back-end server side. It is a NoSQL Database that efficient, has strong security due to its authentication mechanism, horizontally scalable, provides access control and is optimized for the user. Cloud Firestore's database works on small documents which are smaller than 1 Megabyte. These are placed in collections. The data within this database is segregated and repeated in multiple locations. NoSQL's style of database arrangement allows client-side interaction to be faster as data is all clumped together.

GitHub is used for the SCM as it keeps a record of the files version history file and note. GitHub is chosen for the SCM because it is a DVCS and compatible with VSC. It is easy to maintain, and the UI is easy to track and use. A DVCS is better than a CVCS because there are more than one machine storing the source code. This increases the risk as if only one machine/server is storing the data it and anything happens to it, all data is lost [14].

GitHub and Stock Overflow are open-source codes websites that will be used. As of today, GitHub has over 28 million public repositories which makes it perfect for source code referencing. Stack Overflow provides good technical solutions fast to help solve technical problems via the Question and Answer mechanism [15].

VSC is chosen for that IDE because it provides tools and plugins to do development and maintenance. Plugins can debug lines of code, version control, SCM, code completion and has various other functionalities such as live APP monitoring with React.js, database management with Cloud Firestore and Source Code Management with GitHub [16].

To sum up, based on literature reviewed PWA will be used for the WEBAPP. For the front-end, React.js, JS and HTML will be used interchangeably depending on the application. The back-end will be using Cloud Firestore Database. The IDE used will be VSC. GitHub will be used as the SCM system. Finally, GitHub and Stack Overflow will be used as sources of community technical expertise, open-source code and framework usage.

2.4 Software Development Lifecycle

The SDLC is the process of dividing software development work into distinct phases to improve the design and project management. The seven stages are planning, requirement analysis, prototyping, development, testing, implementation and maintenance.

Traditionally, methods like Waterfall are used to implement SLDC. However, new popular SLDC methodologies like the Agile Methodology [17] is adopted with the SCRUM implementation as it is reactive and allows for improvements. It accounts for customer input which is good for feedback and improvement of the PWA especially in an environment is competitive and every advantage matters.

Agile Methodology allows manoeuvrability, speed and cost savings [18] as projects always rescope and change requirements within a project's lifespan. A customer feedback loop is created for technical decisions, customer requirements and management constraints to do feature planning and dynamic prioritization in short bursts of time. Successful implementation allows for a more responsive to a change in requirements effectively reducing cost by eliminating change at a later stage. Scrum is a popular implementation of Agile and its key feature would be the short sprint aimed at creating different features, backlog which explains the product requirements, Sprint Backlog which explains work that needs to be done during the next sprint and the Burndown Chart showing the remaining work in the sprint backlog [19].

Hence, for the creation and implementation of the PWA, Scrum with Agile methodology is adopted for the SDLC to ensure that the PWA created meets the initial expectations of overcoming the challenges of on-the-shelf DSM's.

3 Methodology

To methodologically create a DSM that meets the ROs, a step-by-step process guide is done to identify and execute actions at different stages along the process.
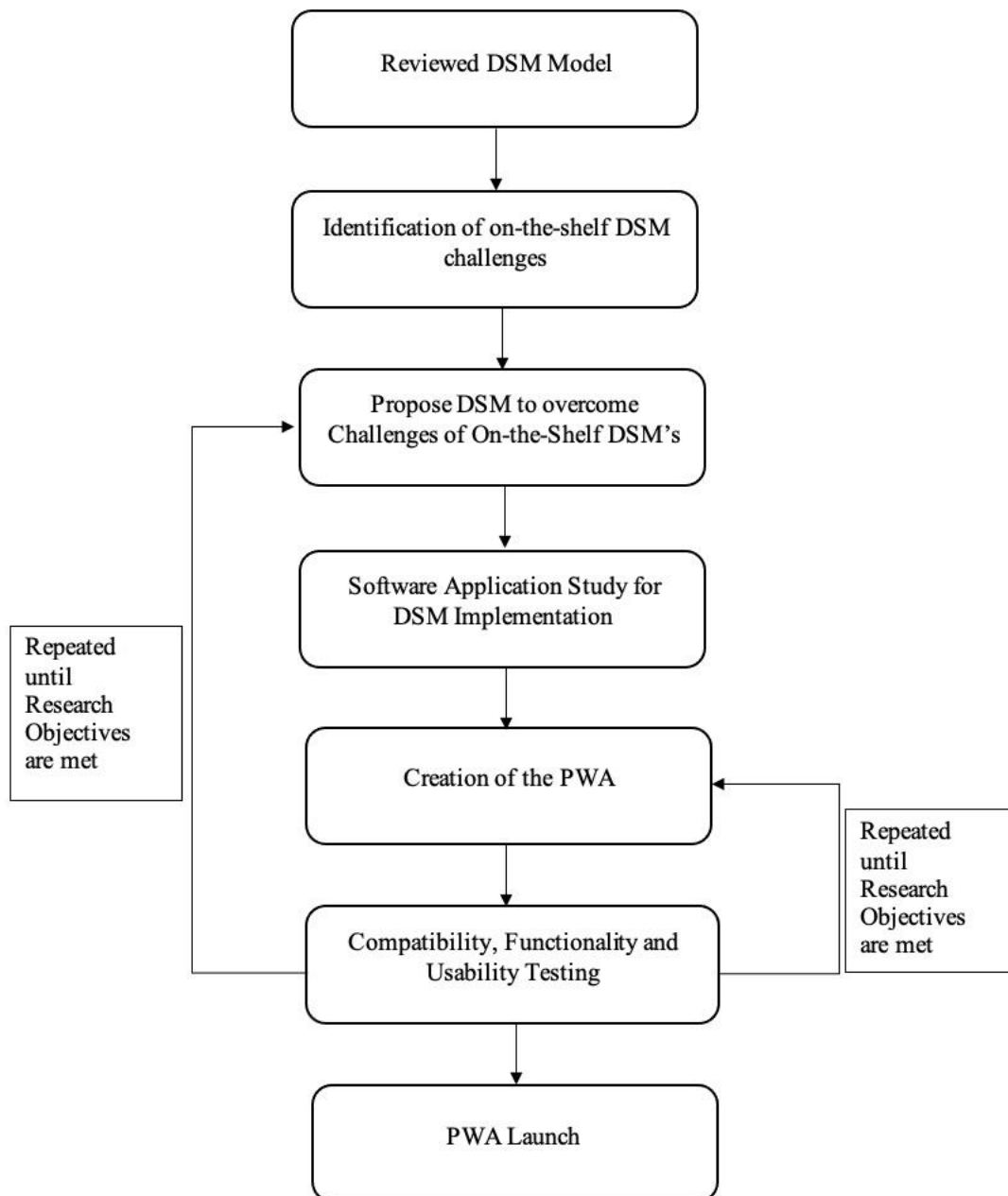
Figure 3: Flowchart for Proposed DSM

3.1 Decision Support Model

An on-the-shelf DSM [1] as shown in the 7.1 Reference DSM is taken as a base template for the proposed DSM. The challenges faced in the effective implementation of it and other on-the-shelf DSM's which are accessibility, implementation and relevance are then addressed and implemented into the proposed DSM.

The first problem to address is accessibility and this will be done via the creation of a software which is a PWA is to enable accessibility, time and flexibility of the DSM. The implementation of Information Technology will make traditional processes more efficient and information aggregation can be used for a wide variety of information views that will allow for better inter-relationships between different attributes [20]. It also provides the option for integration with existing technologies that can provide simulation and analysis.

The DSM needs data management and AI technologies to improve the DSS [8]. This is done by having a central database collecting DSM models created by project managers over time as the NPD R&D process goes on. ML and AI algorithms will be able to aggerate this data to form comprehensive trends. Henceforth, PMs from various engineering fields will consequently have a more comprehensive picture of how the DSM can be better shaped and give more suitable recommendations about NPD project continuity.

The second problem to address is implementation and this is done by addressing the human factor. Before doing the DSM, all inputs must be sorted using a methodology as human emotions can affect cognition and decision making [7]. It will give an objective, comprehensive and unbiased view of the project before PM's select the PI's.

The framework used is based on "Sun Tzu's The Art of Business Management Strategies" on QFD methodology' [21] as shown below. It is used to sort out ideas and problems by listing them and giving them a rating. Here, QFD, SWOT and Sun Tzu's Art of War is merged into a comprehensive framework that covers all the "What's" and "How's" to create a more holistic strategic management system. This framework should be used by PM's prior to using the proposed DSM to provide a clear sound mindset and make rational decisions because this methodology forces PM's to think about a variety of factors and rationalize each part of the NPD.

Table I

The SWOT matrix of Hong Kong with attributes of the balanced scorecard

	Strengths	Weaknesses
	S1 – Good legal system S2 – Good tele-communication/ infrastructure S3 – Huge reserve S4 – Quality/efficient civil servant S5 – Stable currency S6 – Hard working quality people	W1 – Inexperienced executive council W2 – Weakening English standard W3 – Lack of natural resource W4 – US $ Peg W5 – Weakening manufacture base W6 – High operating costs
Opportunities O1 – Spring board to China O2 – Unstable Asian politic O3 – Support from China O4 – Birth of EURO O5 – 50th anniversary of China	Maxi-maxi (strengths/opportunities) (F) S1S2O1 – Promote commerce activity (F) S1S2O2 – Attract foreign/ Chinese investment/tourism (F) S1S2S3O4 – Asian joint currency (F) S1S2O3 – Intensify financial service (currency window) (C) S1O1 – Advisory role to China (C) S3O1O3 – Co-operation with China to develop hi-technology (C) S1S2O5 – Promote tourism. (L) S4O1O3 – Cross-training with Chinese government	Mini-maxi (weaknesses/ opportunities) (F) W3W5O2 – Financial/service focus (F) W4O4 – Diversify governmental investment (I) W1O1 – Restructure executive council (L) W2O3 – Multiple languages policy
Threats T1 – Inrush of immigrant T2 – From neighbouring countries T3 – Millennium bugs (Y2K) T4 – Pollution of water from China T5 – China opening up to the world Market T6 – Declining world economy	Maxi-mini (strengths/threats) (C) S3T4 – Promote environmental protection concept to China. (C) S1S2T6 – Media businesses. (I) S1T1 – Review immigration law/ co-operation with related Chinese authorities (I) S3S4T2 – Improve quality image of Hong Kong. (I) S3S4T3 – Y2k promotion campaign (L) S3T1 – Build new schools for immigrants (L) S3S6T5 – Bilingual education	Mini-mini (weaknesses/threats) (C) W3T5 – Develop a natural resource link between Hong Kong and China (C) W5T1T5 – Develop Chinese medicine research centre (I) W3T1 – Review tax policy and social welfare policy (L) W2T5T6 – Improve English education standard

Notes: F = Financial perspective, C = Customer perspective, I = Internal process perspective, L = Learning and growth perspective

Figure 4: Part 1 of Balanced Scorecard with SWOT analysis, and implementing "Sun Tzu's The Art of Business Management Strategies" on QFD methodology [21]

		Sun Tzu's The Art of Business Management Strategies																
		1	2	3	4	5	6	7	8	9	10	11	12	13			
	Hows / **Whats**	Planning of Strategies, Estimation & Leadership	Resources & Competitive Actions	Competitive Strategy & Wisdom	Positioning & Targeting, Strengths & Weaknesses Estimation	Opportunity, Timing & Management Structure	Control of Market Situations & Climate	Management of Conflict & Avoid Confrontation	Flexibility & Adaptability	Observing & Manoeuvring	Competitive Situations & Causes of Failure	Competitive Conditions and Offensive Strategy, Alliance & Vision	Destroying & Decision	Intelligence and Information	Score	Percentage %	Sub-total
F = Financial Perspective																	
(F) S1S2O1	Promote Commerce activity.	3	9	9	1	3	9	0	1	1	0	0	0	0	36	2.8%	
(F) S1S2O2	Attract foreign / Chinese Investment / Tourism.	9	9	9	1	9	3	0	9	3	1	3	0	0	56	4.3%	
(F) S1S2S3O4	Asian Joint Currency.	9	0	1	0	9	0	0	9	9	1	9	0	9	56	4.3%	
(F) S1S2O3	Intensify Financial Service (Currency Window).	9	9	9	3	1	9	0	3	3	1	9	1	1	58	4.4%	
(F) W3W5O2	Financial / Service Focus.	9	9	9	3	3	3	0	9	9	0	9	3	0	66	5.1%	
(F) W4O4	Diversify Governmental Investment	9	9	9	1	9	9	0	9	3	1	3	1	0	63	4.8%	26%
C = Customer Perspective																	
(C) S1O1	Advisory role to China.	9	9	9	9	9	9	0	9	9	3	9	1	0	85	6.5%	
(C) S3O1O3	Co-operation with China to Develop Hi-Technology.	9	9	9	9	9	9	0	3	3	1	9	0	0	70	5.4%	
(C) S1S2O5	Promote Tourism.	9	9	9	9	3	9	0	9	1	3	9	1	0	71	5.4%	
(C) S3T4	Promote Environmental Protection Concept to China.	9	3	3	0	9	3	0	9	9	1	3	0	0	49	3.8%	
(C) S1S2T6	Media Businesses.	9	9	9	3	9	9	0	3	1	1	9	0	0	62	4.8%	
(C) W3T5	Develop a natural resource link between Hong Kong and China.	9	9	3	3	1	9	0	9	9	1	9	0	0	62	4.8%	
(C) W5T1T5	Develop Chinese medicine research centre.	9	9	9	9	1	9	0	3	3	0	9	0	0	61	4.7%	35%
I = Internal Process Perspective																	
(I) W1O1	Restructure Executive Council.	3	1	1	9	9	0	3	3	0	9	1	0	0	45	3.4%	
(I) S1T1	Review Immigration Law / Co-operation with related Chinese Authorities.	3	1	3	3	9	9	9	1	0	1	9	0	9	57	4.4%	
(I) S3S4T2	Improve Quality Image of Hong Kong.	9	9	9	1	1	1	0	3	0	0	0	0	0	33	2.5%	
(I) S3S4T3	Y2k Promotion Campaign.	0	0	0	9	0	9	0	9	9	9	0	0	0	45	3.4%	
(I) W3T1	Review tax policy and social welfare policy.	9	0	0	9	9	0	9	9	9	9	0	0	0	63	4.8%	19%
L = Learning and Growth Perspective																	
(L) W2O3	Multiple Languages Policy.	9	9	9	3	1	1	9	9	1	1	1	0	1	54	4.1%	
(L) S3T1	Build new schools for Immigrants.	3	9	3	3	9	9	3	9	9	3	3	0	0	63	4.8%	
(L) S3S6T5	Bilingual Education.	1	9	9	9	1	1	0	9	3	3	3	0	9	57	4.4%	
(L) S4O1O3	Cross-Training with Chinese Government.	9	9	9	9	9	9	9	9	9	0	9	0	3	93	7.1%	20%
	Note: Predictive quality of Performance Measure:	157	149	140	106	123	129	42	152	103	49	116	7	32	1305		
	Strong - 9, Medium - 3, Weak - 1, None - 0	12.0%	11.4%	10.7%	8.1%	9.4%	9.9%	3.2%	11.6%	7.9%	3.8%	8.9%	0.5%	2.5%			
	Priority	1	3	4	8	6	5	11	2	9	10	7	13	12			

Table 2) Use of Quality Function Deployment (QFD) Methodology in Balanced Scorecard and Sun Tzu The Art of Business Management in Strategic Planning

Figure 5: Part 2 of Balanced Scorecard with SWOT analysis, and implementing "Sun Tzu's The Art of Business Management Strategies" on QFD methodology [21]

The third problem is relevance, and this is addressed by using the proposed DSM to encourage MNC's be more open towards innovation as them undergo NPD. The Agile methodology would make them more responsive to changes in technology, market etc [18] as explained in the 2.4 SDLC. It is relevant and applicable to project management theories. Under this system, companies would be required to focus on tasks and customer feedback for their NPD as they make prototypes every 2-6 weeks rather than focusing on a prefect product with good documentation at the end of the process. Science-based partnerships are also helps MNC's to be up to date with technologies [9]. This fits in the Agile methodologies as new input of technology and industry is the core fundamentals of Agile.

The parameters of the proposed DSM together with the advantages and disadvantages is shown in the table below.

Parameters	Proposed DSM
Key Motivations for using the DSM	To create the most effective DSM on the market by focusing on challenges of on-the-shelf DSM's
Fundamentals	Proposed DSM should be able to address challenges of current on-the-shelf DSM
Methodology	1. On-the-shelf DSM 2. SWOT, BSC and Sun Tzu: The Art of War for Executives 3. Software Deployment using PWA 4. Agile
Features	1. A BSC and SWOT Campus to identify relative priorities 2. A Prioritization Matrix to select key PI's 3. A Pairwise Function to select and rank the relative importance of PI's
Advantages	1. Agile 2. Accessible 3. Comprehensive 4. Considers the quality and the variety of information
Disadvantages	1. Time consuming 2. Requires a lot of information

Table 2: Proposed DSM table of parameters

3.2 Software Application
3.2.1 System Development Lifecycle

Based on literature, a SDLC is necessary because it plays an important role in software development of the PWA. The Agile Methodology with Scrum implementation will be used while creating the PWA.

Hence, the first step is to create a bare bones prototype of the PWA then constantly approaching PM's to get feedback before improving on the PWA. This would enable the PWA to be built according to consumer feedback, making it more relevant to PMs..

3.2.2 UML Diagram

UML is used to model and document systems using specific notation [22]. It is used to represent how different functions and designs relate to each other in a visual way.

3.2.2.1 ER Diagram

ERD's shows the relationships of data sets in a database. This shows how different entities are defined and how they are linked to each other in order to design the logical structure of the database. Cardinality arrows are used to describe how distinct values in an entities relate to each other.
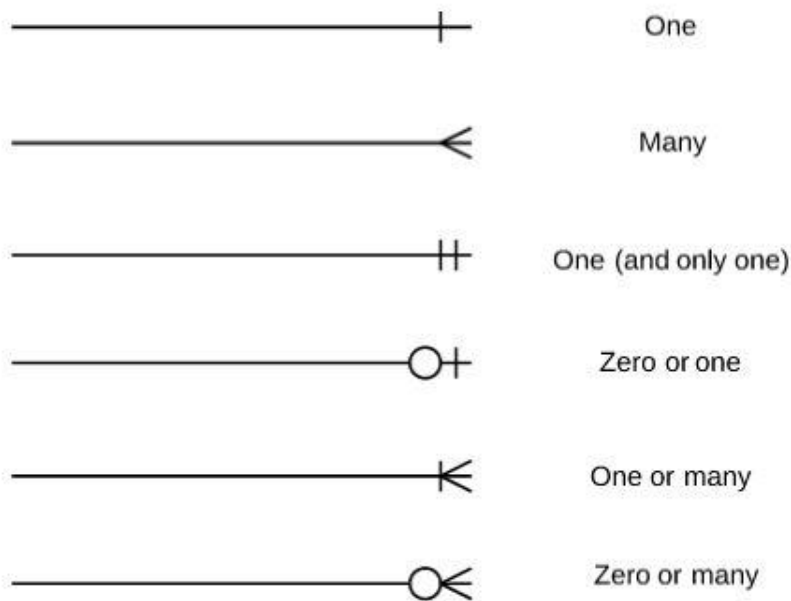
Figure 6: Cardinality Arrow Representation [22]

The ER diagram below is for the database of the PWA. The White Entities indicates Collections which can hold more than 1 document. The Green Entities indicates documents which show specific data values. This is where data will be added, altered and called.
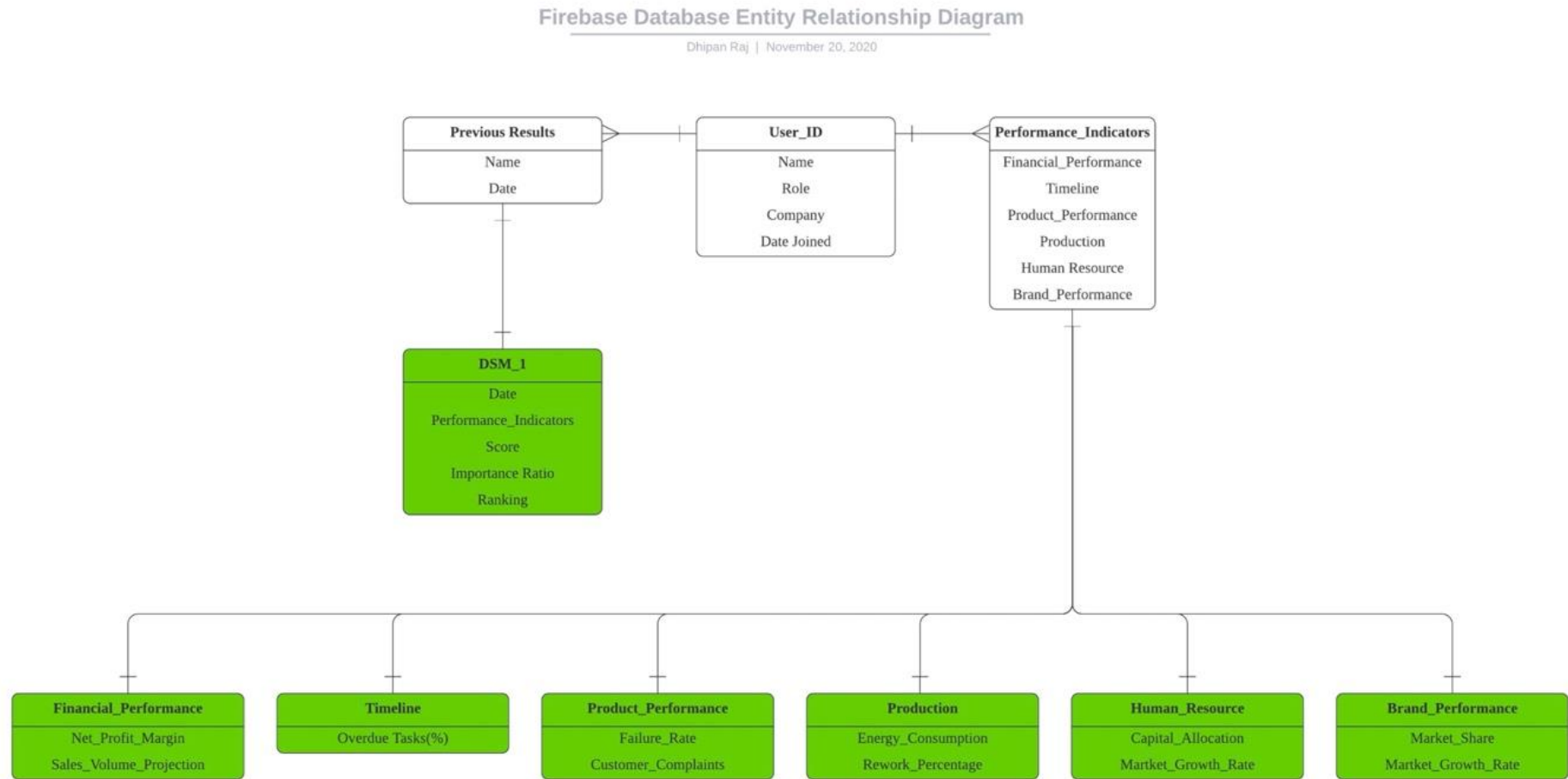
Figure 7: Cloud Firestore Database ER Diagram

3.2.2.2 Use Case Diagram

A Use Case Diagram is a visual representation of the relationship between the system and the environment. It helps identify actors, use-cases and the relationship between entities in order to extract the requirements needed to build the PWA.
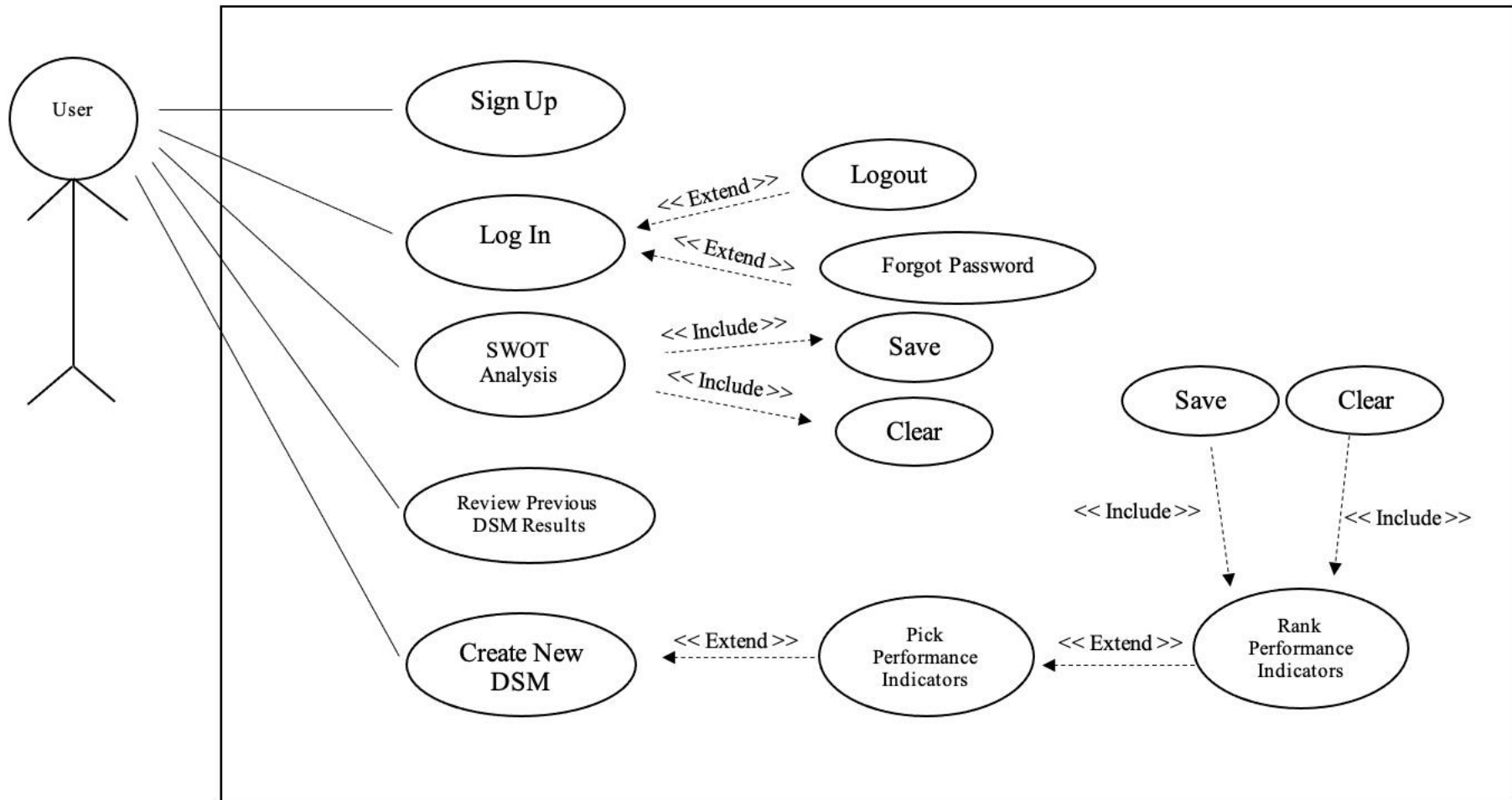
Figure 8: Use Case Diagram

3.2.2.3 Activity Diagram

The Activity Diagram is like a data flow diagram. It shows the series of actions in a system and it describes the steps in the Use Case Diagram. The Activity Diagram gives a better view on how the prototype for the PWA should be constructed.
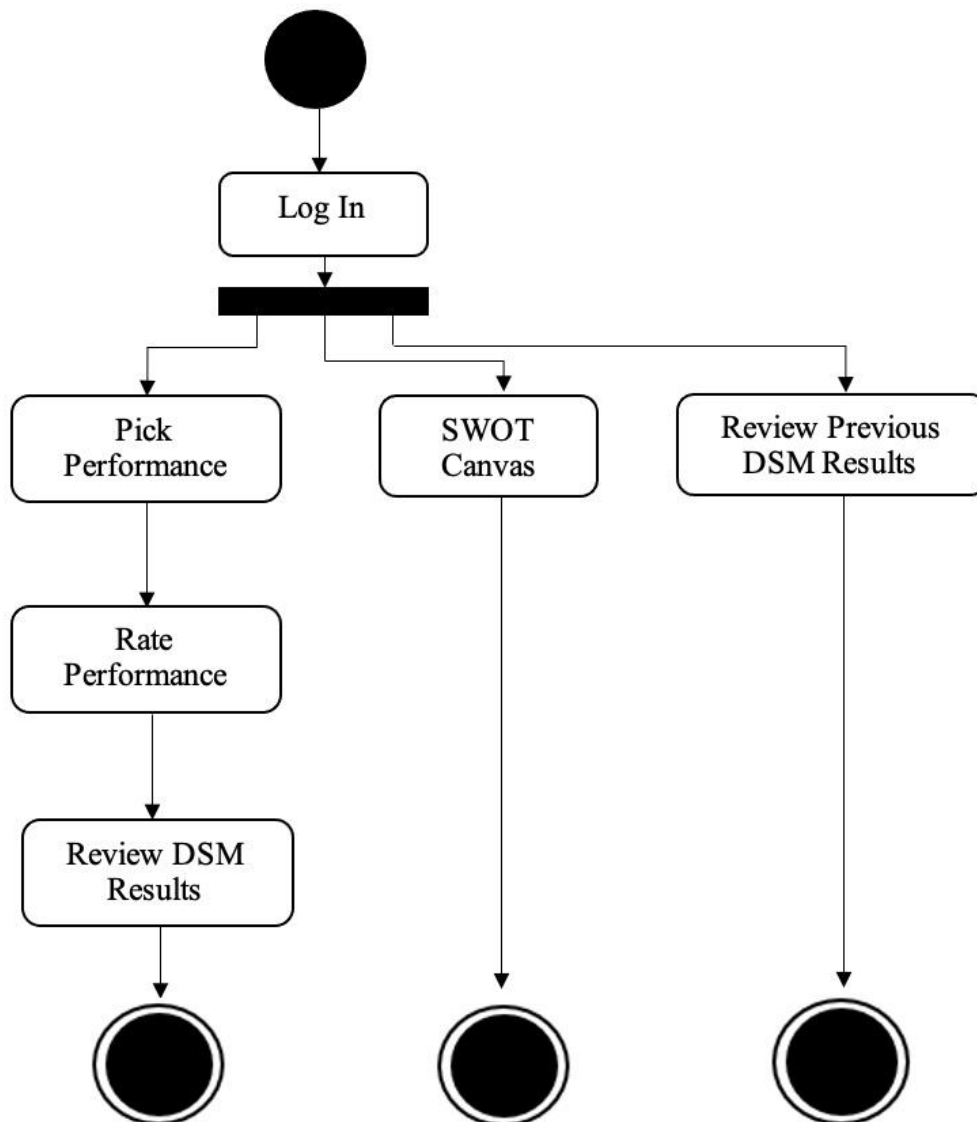
Figure 9: Activity Diagram

3.3.3 UI Design

Wireframing is used to design a website service by prototyping and expressing design ideas. A hand-sketched is called a low fidelity model. Then these are converted in mid-fidelity models like mock-ups and finally high-fidelity which are the APPs themselves.

Design is extremely important in any PWA as it affects its success by making it efficient, practical, easy to use, increasing brand loyalty, increasing downloads, reducing user complaints and retaining users. User experience can also be enhanced using keywords, patterns and cross-referencing different data sets to better predict the users future responses [23]. This will be implemented in the PWA for the auto-suggestion of the KPI's and the SWOT analysis.

To think of the methodology of designing the PWA, the 'Bull's-Eye' methodology [24] is used. It provides a clear step-by-step framework on how to design a PWA. This methodology moves from inside out starting from the Components and ending at the Overarching Features and Principles.
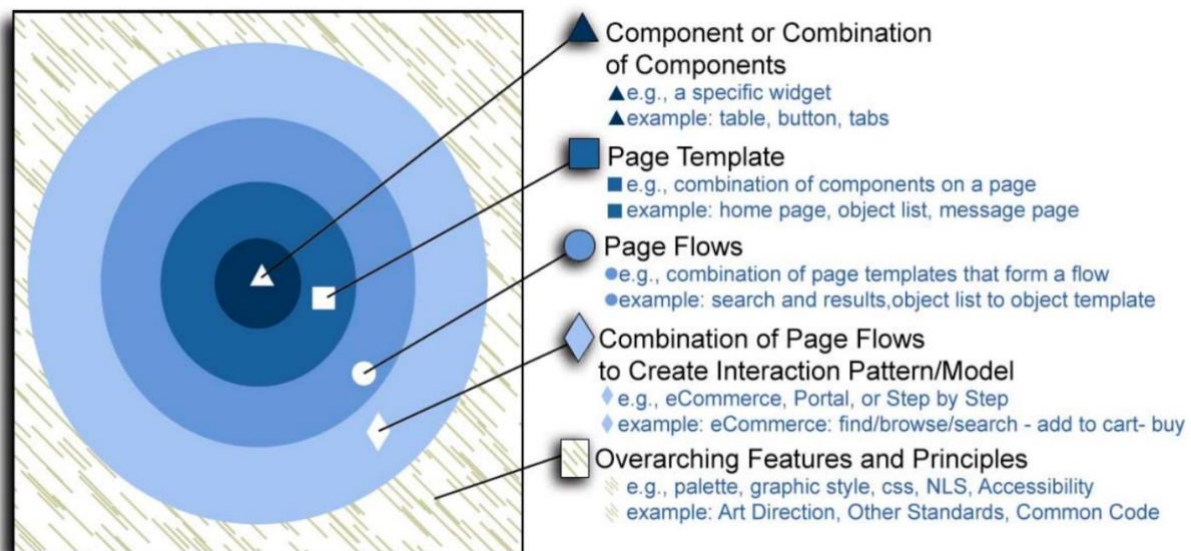
Figure 10: The Bull's-Eye: A Framework for Web Application UI Design Guidelines [24]

Based on the Activity Diagram, a Low Fidelity Wireframe is constructed to show the application will visually look. The Low Fidelity Wireframe is needed to ensure that at the very base, all the requirements set out for the PWA and in the Use Case Diagram are met.
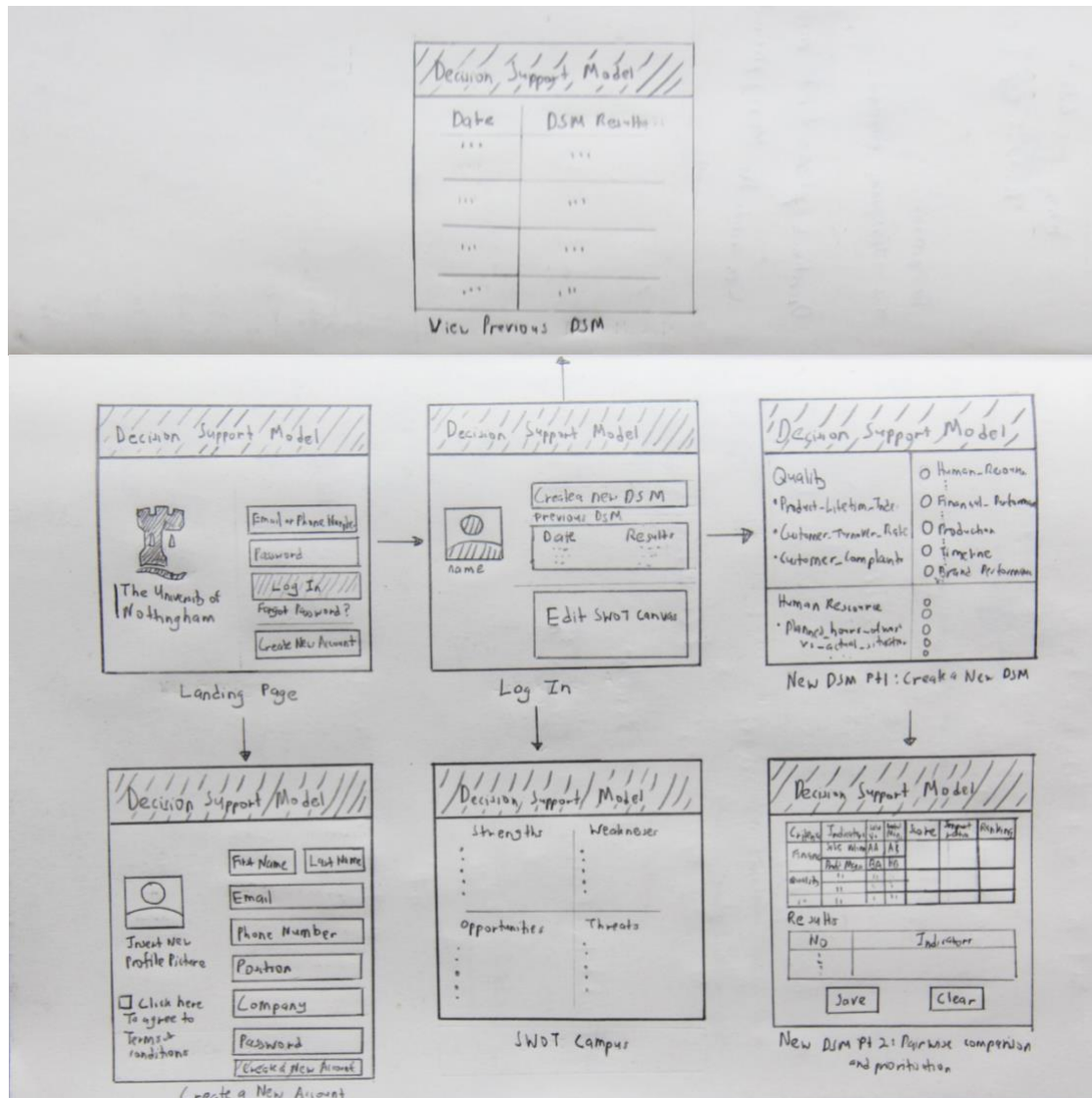
Figure 11: Low Fidelity Wireframe

3.3.4 Code Descriptor

The PWA created will use certain key scripts that will ensure its usability and functionality. These scripts are specific to the software application selected.

Software Application	Key Scripts	Explanation
React.js [25]	ReactDOM.render()	A single root DOM is used to only update parts of the webpage that have need only

Cloud Firestore [26]	```db.collection("users").add({
	    first: "Ada",
	    last: "Lovelace",
	    born: 1815
	})
	.then(function(docRef) {
	    console.log("Document written with ID: ",
	docRef.id);
	})
	.catch(function(error) {
	    console.error("Error adding document: ", error);
	});```
		Data is stored in Collections which are branched out into documents.

Table 3: Code Descriptor

3.3 V&V Testing

V&V Testing is done to check if the software application created meets the requirements and specifications for it to be able to meet its purpose. Compatibility, functionality and usability testing are used [27].

Firstly, the PWA is tested to ensure compatibility on major web browsers like Google Chrome, Safari and Microsoft Edge using Operating Systems like Windows 10 and Apple OS. The Compatibility Testing will work on a Yes or No scale.

Web Browsers / Operating Systems	Google Chrome	Safari	Microsoft Edge
Windows 10	Yes/No	Yes/No	Yes/No
Apple OS	Yes/No	Yes/No	Yes/No

Table 4: Compatibility Testing

Secondly, the PWA will be tested to ensure that its functionality by meeting all the criteria for the DSM. The following are the criteria inspected using a

No	Questions	Yes/No
1	Does it meet the functionality and visuals of the Wireframe created?	Yes/No
2	Can fully support the DSM personalized to each user within the application?	Yes/No
3	Has a made the DSM fully digital and accessible?	Yes/No

Table 5: Functionality Testing

Finally, the PWA will be tested for its usability using a usability testing survey on 10 Project Managers. It will consider the different stages of human information processing and factors that are considered relevant to software testing. A 1-10 Likert scale is used to measure all these parameters. The ethical approval for this will be done next semester.

No	Question	Score
1	Is the overall colour scheme and design aesthetically pleasing?	1-10
2	Is the navigation for the PWA easy to use?	1-10
3	Does the PWA meet the aim of the user using the DSM?	1-10
4	Is the PWA user-friendly?	1-10
5	Does the PWA easily allow the input of information?	1-10
6	Does the PWA show an accurate and easy to interpret output?	1-10
7	Does the guide provided make it easier to use the PWA?	1-10
8	Is all the functionality that is expected from a digital DSM within the PWA?	1-10

Table 6: Usability Testing

The compatibility, functionality and usability tests done will to determine the effectiveness of the DSM in the PWA and find areas of improvement.

4 Conclusion

For the Autumn Semester, a detailed literature study is conducted to identify the challenges faced in the effective implementation of DSM's in R&D projects. On-the-shelf DSM's are studied in detail to propose a better DSM. A focus is placed on the accessibility, implementation and relevance of DSM's in an ever-changing environment. BSC with SWOT analysis, PWA's, Agile and Science-based partners are studied in detailed to propose a more effective DSM.

RO 1 and 2 functions to identify the study on-the-shelf DSMs and then propose a more effective DSM to be used by PMs. Based on the literature review and the systematic approach in creating the DSM, RO 1 and RO 2 has been met.

RO 3 is the implementation of the proposed DSM into a PWA. Improvisation will be done using V&V testing to create an effective DSM. The workflow for this has already begun this semester with the selection of the software for implementation and will end next semester once the PWA has been created to digitize the DSM and tested.

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6 Gantt Chart

The following are the Gantt Charts for Autumn 2020/2021 and Spring 2020/2021 using Microsoft Project. All milestones, tasks and completion rate are detailed below.
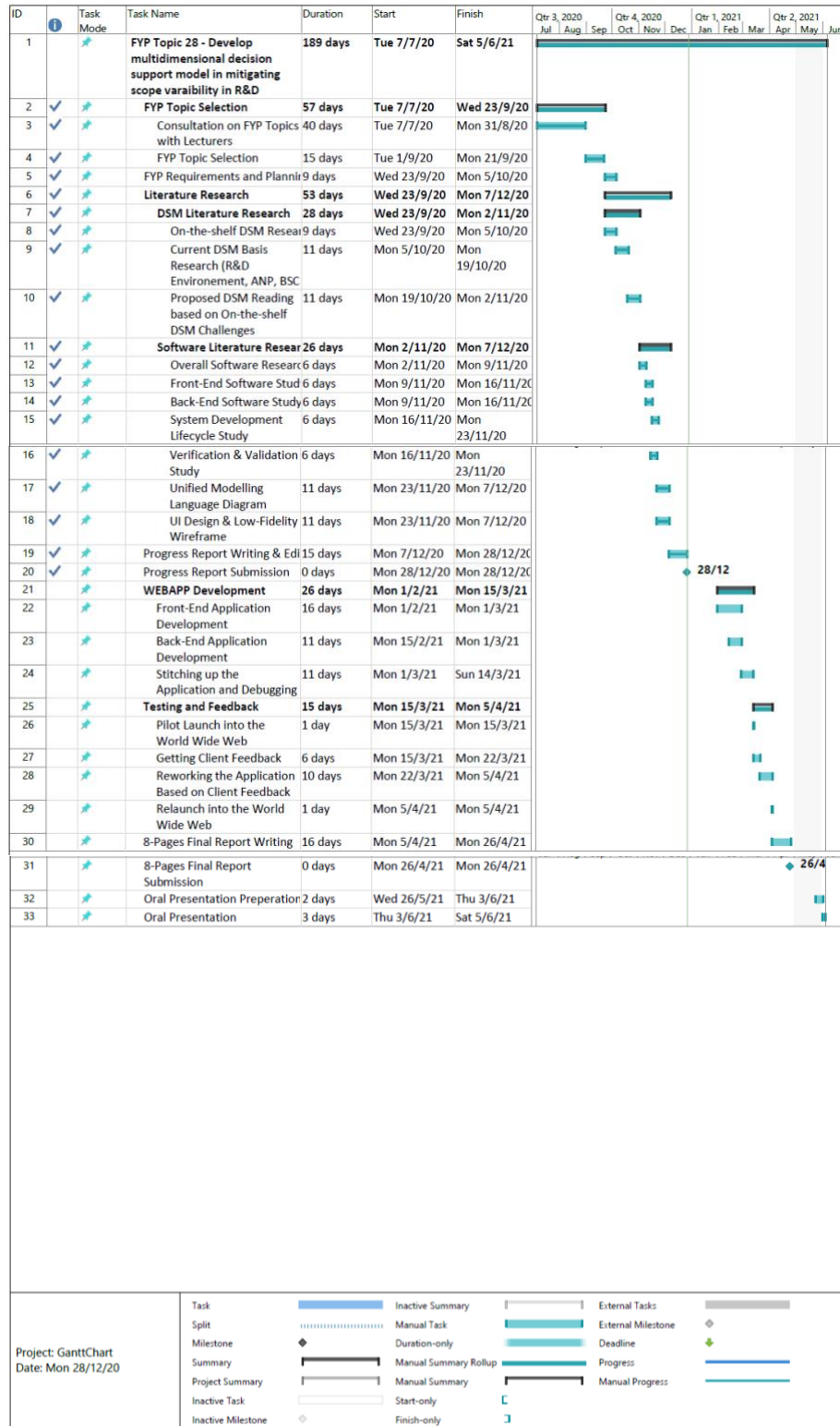
ID		Task Mode	Task Name	Duration	Start	Finish
1			FYP Topic 28 - Develop multidimensional decision support model in mitigating scope varaibility in R&D	189 days	Tue 7/7/20	Sat 5/6/21
2	✓		FYP Topic Selection	57 days	Tue 7/7/20	Wed 23/9/20
3	✓		Consultation on FYP Topics with Lecturers	40 days	Tue 7/7/20	Mon 31/8/20
4	✓		FYP Topic Selection	15 days	Tue 1/9/20	Mon 21/9/20
5	✓		FYP Requirements and Planning	9 days	Wed 23/9/20	Mon 5/10/20
6	✓		Literature Research	53 days	Wed 23/9/20	Mon 7/12/20
7	✓		DSM Literature Research	28 days	Wed 23/9/20	Mon 2/11/20
8	✓		On-the-shelf DSM Research	9 days	Wed 23/9/20	Mon 5/10/20
9	✓		Current DSM Basis Research (R&D Environoement, ANP, BSC	11 days	Mon 5/10/20	Mon 19/10/20
10	✓		Proposed DSM Reading based on On-the-shelf DSM Challenges	11 days	Mon 19/10/20	Mon 2/11/20
11	✓		Software Literature Research	26 days	Mon 2/11/20	Mon 7/12/20
12	✓		Overall Software Research	6 days	Mon 2/11/20	Mon 9/11/20
13	✓		Front-End Software Study	6 days	Mon 9/11/20	Mon 16/11/20
14	✓		Back-End Software Study	6 days	Mon 9/11/20	Mon 16/11/20
15	✓		System Development Lifecycle Study	6 days	Mon 16/11/20	Mon 23/11/20
16	✓		Verification & Validation Study	6 days	Mon 16/11/20	Mon 23/11/20
17	✓		Unified Modelling Language Diagram	11 days	Mon 23/11/20	Mon 7/12/20
18	✓		UI Design & Low-Fidelity Wireframe	11 days	Mon 23/11/20	Mon 7/12/20
19	✓		Progress Report Writing & Editing	15 days	Mon 7/12/20	Mon 28/12/20
20	✓		Progress Report Submission	0 days	Mon 28/12/20	Mon 28/12/20
21			WEBAPP Development	26 days	Mon 1/2/21	Mon 15/3/21
22			Front-End Application Development	16 days	Mon 1/2/21	Mon 1/3/21
23			Back-End Application Development	11 days	Mon 15/2/21	Mon 1/3/21
24			Stitching up the Application and Debugging	11 days	Mon 1/3/21	Sun 14/3/21
25			Testing and Feedback	15 days	Mon 15/3/21	Mon 5/4/21
26			Pilot Launch into the World Wide Web	1 day	Mon 15/3/21	Mon 15/3/21
27			Getting Client Feedback	6 days	Mon 15/3/21	Mon 22/3/21
28			Reworking the Application Based on Client Feedback	10 days	Mon 22/3/21	Mon 5/4/21
29			Relaunch into the World Wide Web	1 day	Mon 5/4/21	Mon 5/4/21
30			8-Pages Final Report Writing	16 days	Mon 5/4/21	Mon 26/4/21
31			8-Pages Final Report Submission	0 days	Mon 26/4/21	Mon 26/4/21
32			Oral Presentation Preperation	2 days	Wed 26/5/21	Thu 3/6/21
33			Oral Presentation	3 days	Thu 3/6/21	Sat 5/6/21

Project: GanttChart
Date: Mon 28/12/20

Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

Figure 12: Gantt Chart 2020/2021

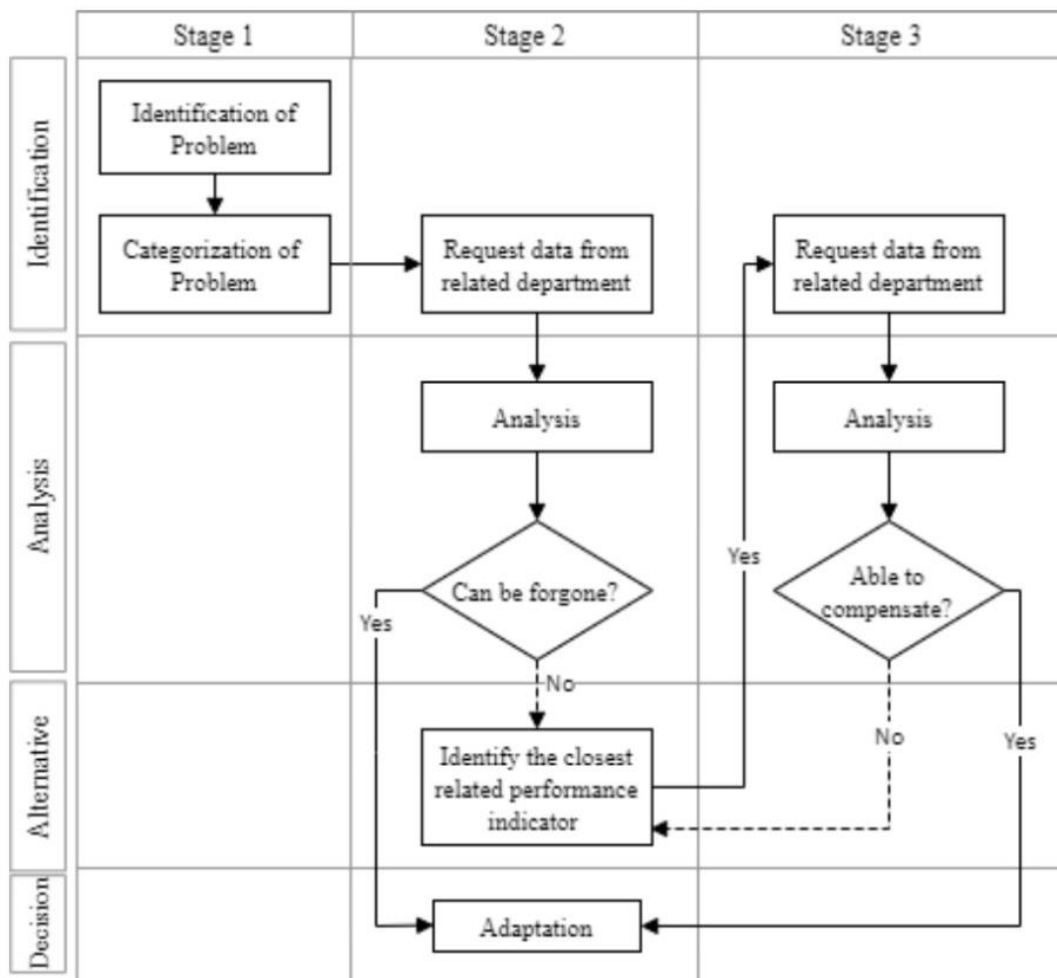# 7 Appendix
7.1 Reference DSM [1]

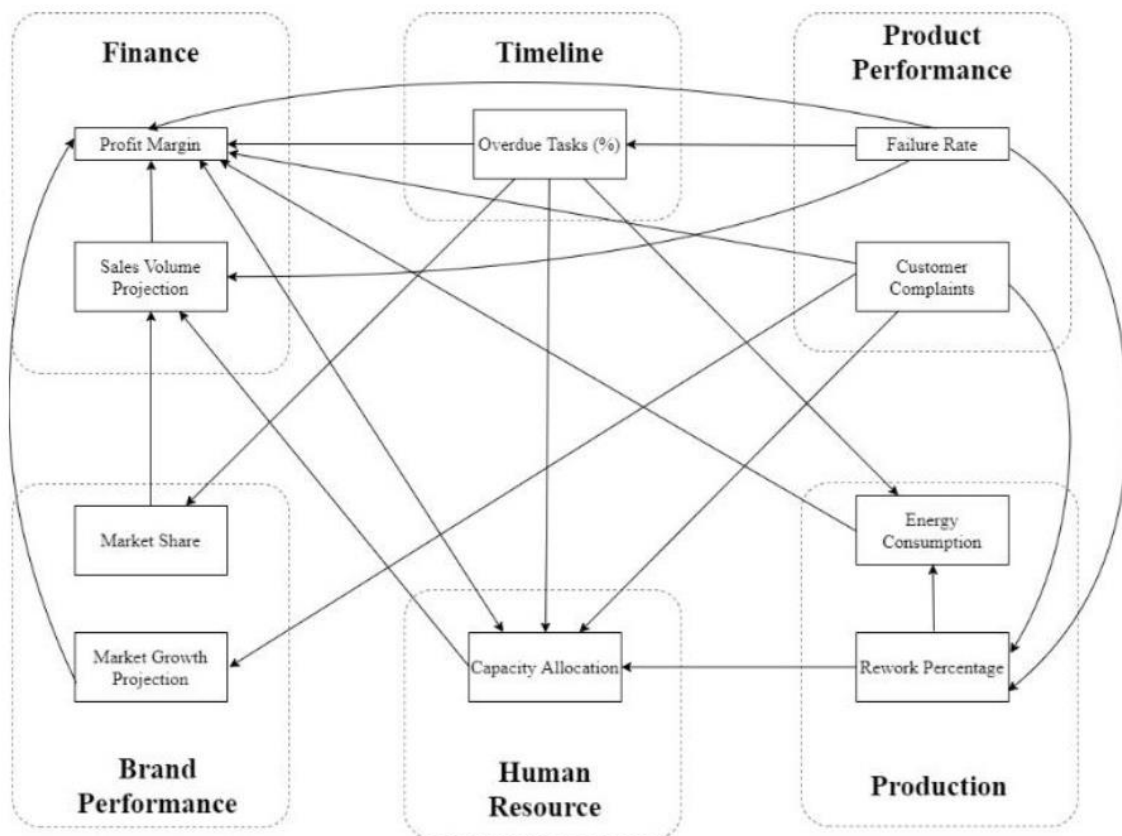**Figure 13: DSM Decision-making flow [1]**

Figure 14: Part 1 of the DSM: Key PI for R&D projects and the interrelationships, categorised in respective criteria [1]

Criteria	Indicators	Sales Volume Projection	Profit Margin	Failure Rate	Customer Complaints	Capacity Allocation	Score	Importance Ratio	Ranking
Finance	Sales Volume Projection (A)	AA	AB	AC	AD	AE			
	Profit Margin (B)	BA	BB	BC	BD	BE			
Quality	Failure Rate (C)	CA	CB	CC	CD	CE			
	Customer Complaints (D)	DA	DB	DC	DD	DE			
HR	Capacity Allocation (E)	EA	EB	EC	ED	EE			
						Total Score			

Table 7: Part 2 of the DSM: Sample calculation of pairwise comparison and prioritisation [1]

8 Risk and Mitigation Plan

Legend

H   = High

M   = Medium

L   = Low

Tasks	Risks	Likelihood	Consequences	Actions to be taken to mitigate risk
Creating a working DSM	Not a 100% certain that the DSM will be better than on-the-shelf DSMs	L	M	Comprehensive literature study will be conducted and cross-referenced with testing for improvement
Creating the PWA	Not a 100% certain that the PWA will meet the expectations in one go	L	M	Complete, launch and improvise the initial prototype before adding in more features and better UI
Getting Feedback on the DSM and PWA	Stakeholders might not be free or willing to try the DSM and PWA and give feedback	M	M	Contact stakeholders early to find availability

Table 8: Risk and Mitigation Plan

9 Budget Analysis

The creation of the proposed DSM will incur no cost as it is based on literature research and PM feedback.

The implementation of it into a PWA will incur costs like initial development costs, maintenance costs and software upgrades. The driving factor would be based on the number of users and the functionalities required within the PWA. The cost increases linearly due to the horizontal scaling of this database [28]. The minimum wage of RM22/hr [29] is a rough industry average for software developers. This project would take roughly 150 hours to develop based on industry estimates. In order to get the MVP, the PWA would cost at around RM 3,300.

Items	Cost
UI Design	RM 1,000
Custom Development	RM 1,000
Quality Assurance/Security	RM 500
Project Management	RM 300
Business Analysis	RM 500
Total Cost	RM 3,300

Table 9: Budget Analysis