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APPLIED DESIGN THINKING FOR KIMBALL LIFECYCLE TO IMPROVE BUSINESS INTELLIGENCE DASHBOARD USABILITY

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Abstract. *BI (Business Intelligence), as a part of information technology, has been a unique medium for users to interact with data that were commonly used to make strategic business decisions; unfortunately, most business intelligence dashboards out there have a lack of usability for users that were not experts in the related field. Practical observation of this problem led to an exploration of how HCI (Human-Computer Interaction) practices could be used to solve the user experience and usability problems that existed within the business intelligence scope. There have been researches regarding the benefit of human-centered approaches used to solve multiple user experience problems in other fields; however, only a little research exists on how human-centered approaches could be used in the BI development process. This study shows how a human-centered approach, specifically design thinking, could be used to improve dashboard usability by embedding the five-stage process inside the "BI Application Track" of the Kimball lifecycle. This research has a valuable contribution that has been evaluated thoroughly to deliver better business intelligence dashboard usability; the results show a higher usability score measured with SUS (System Usability Scale); and lower time on task spent by the users while performing test prompts.*

Keywords: Design thinking, Human-computer interaction, Business intelligence, User experience, Usability

1. **Introduction.** BI (Business Intelligence) is a field in information technology that focuses on data representation used to make strategic business decisions. Organizations or companies that use the BI system for data analysis have been proven to have higher industry competitiveness [1]. BA (Business Analytics) and BI systems can help companies make strategic business processes decisions involving but not limited to productivity, operational costs, company development, company performance, and customer segmentation [2], but the most important thing is how far BA and BI systems can help companies determine effective decision-making for both marketing level and corporate level management. BI dashboard interfaces often influence the effectiveness level of the system; hence, an interactive dashboard is used as a popular approach to guide users of the dashboard. However, interactive dashboards were not fully ready to be implemented due to usability and utilization problems that were difficult to understand for beginners without the help of IT experts [3]. This shows the importance of usability design in creating interactive BI dashboards. One way to overcome the problem is to consider the aspect of UX (User Experience) and UI (User Interface).

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UX is everything related to reactions, behaviors, attitudes, and emotions that occurs when users interact directly with products, services, or other experiences in general, and can be measured with evaluation matrixes through user testing [4]. A common UX approach, "Human Centered Design", solves this particular experience problem. Recent studies and research also show the use of this approach in AI (Artificial Intelligence) and ML (Machine Learning). Shneiderman in his publication stated that HCAI (Human-Centered AI) is a promising new concept to be developed in designing AI by involving creativity and human factors as the focus [5]. From human-centered machine learning viewpoint, machine learning workflows are reframed based on contextual human working habits, and the co-adaptation of humans and intelligent systems is explored [6]. The human-centered approach utilizes a framework called "Design Thinking", which places humans or users as objects of behavioral observation when using a product. Design thinking was initially introduced as an approach used to identify and solve problems at the management level; however, recent research has shown that the implementation of design thinking can be applied to organizational-level and product-level, too [7]. Big companies like Google, Apple, and Amazon use design thinking side by side with UX Laws in designing products with good usability according to the needs and behavior of users. This shows how popular design thinking is in the industry, as mentioned by Lewrick et al. in their book, which stated that design thinking is the most popular innovation method used to innovate in solving various problems [8].

Following the usability issues found in many BI and BA implementations, the authors want to implement a human-centered approach, specifically design thinking, alongside traditional Kimball lifecycle methods used in BI development. This research will show how the implementation of a human-centered approach specifically design thinking can be done not only in product design, AI, and ML, but also in the BI process. The overall process will include the embedding of five stage iteration process of the design thinking into the "BI Application Track" of the Kimball lifecycle; the first two steps will explain how the empathize and define phase help us address numerous issues the users are facing. Based on the listed issue, a series of iteration is conducted to design the best possible solutions. The result of the new dashboard design was compared with the old dashboard with measurable metrics and KPI of system usability scale, time on task, and heuristic evaluation.

2. **Literature Review.**

Usability problems in business intelligence are often caused by poorly presented information from large amounts of data; This data is needed to be visualized and presented interactively as a contextual information delivery [9]. Nevertheless, it is important to always consider the aspect of usability and user experience in every technological product that will be used by the user. This importance has been shown in several research, including the study from Putra and Ogata which involved dedicated experiment steps to specifically assess the user experience of their eye gaze interface system navigation [10]. Research from Liu et al. has also shared common interest on how continuity maintenance is important to improve user experience of a product [11].

2.1. **Related works.**

An effort to increase the effectiveness of business intelligence tools was done with amplified data knowledge by Zelenka and Podaras [12]. The publication contains steps taken to improve the data understanding process in the existing business intelligence architecture by adding a specific knowledge layer to the business model. The goal of this publication is to improve the BI-metamodel while still prioritizing functionality. Knowledge can be collected from several sources within an organization; one of the most common is feedback from business users. This feedback from the business user is

gathered through a survey with detailed questions to empathize with the user. User survey itself is one of many user research methods that are commonly found in the empathize phase of the design thinking process. Based on this survey and feedback, we will be able to align perceptions by empathizing and defining what issues or problems the users are facing. A similar approach will be used in this study as an attempt to understand more of the issues that existed within the BI dashboard.

A new business intelligence framework for associated text narration visualization is proposed by Wutthikhet et al. [13]. This research explains a visualization approach that utilizes text narrations to get better dashboard performance. The proposed UX model focuses on the interaction between narrative text and the corresponding graph. The proposed design uses horizontal and vertical splitters to distribute the narrative text section and the graph visualization section, as shown in Figure 1. While this method offers a way to give insight and information about the data, it does not really solve the bigger scope of the problem itself, which is the usability. The usability issues might persist in day-to-day usage knowing no actual understanding process of what issues the users are facing.

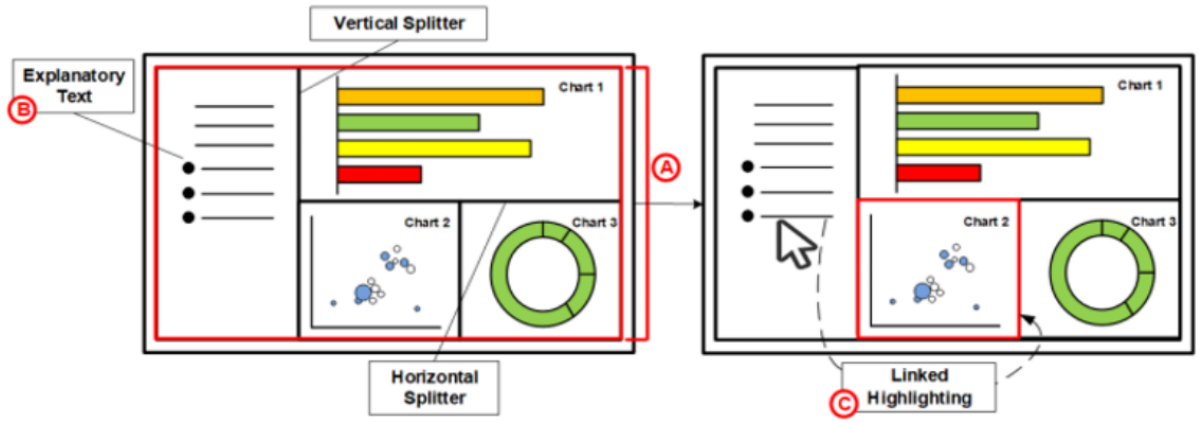

FIGURE 1. Concept proposed by Wutthikhet et al. utilizing text as narrative information

The term human-computer interaction in business analytics has also been used in the case of retail analytics platforms. The publication by Batziakoudi et al. is the result of UXR (User Experience Research) conducted on ten business analytics users on a retail analytics platform [14]. The authors explain how usability, UX, and aesthetic aspects play an important role in an information dashboard. The lack of research related to HCI elements in the BI & BA field is discussed as an open door for future research in concluding whether elements usage can influence and increase the use of BI & BA dashboards UX and usability. In other studies, UX laws are typically used as guidance to determine whether a layout or components is efficient for the users; unfortunately, this aspect is still missing from the Batziakoudi publication. This aspect should be taken into account in further study.

Another research on the improvement of business intelligence user experience was published by Chiasera et al. [15]. The authors explained that the first step to deliver data properly is to find critical data for each plan and goal in making a BI dashboard; the rest is to introduce how user experience is used in the development process so that the BI dashboard design is easy to operate intuitively. This study includes the modification of the traditional Kimball lifecycle process by embedding a method called Lean-BSC-CM (Lean, Balanced Scorecard and Change Management) and user test, as shown in Figure 2. The modified Kimball lifecycle shows an additional track that will require a new learning phase before implementing into the traditional Kimball lifecycle. As a consideration,

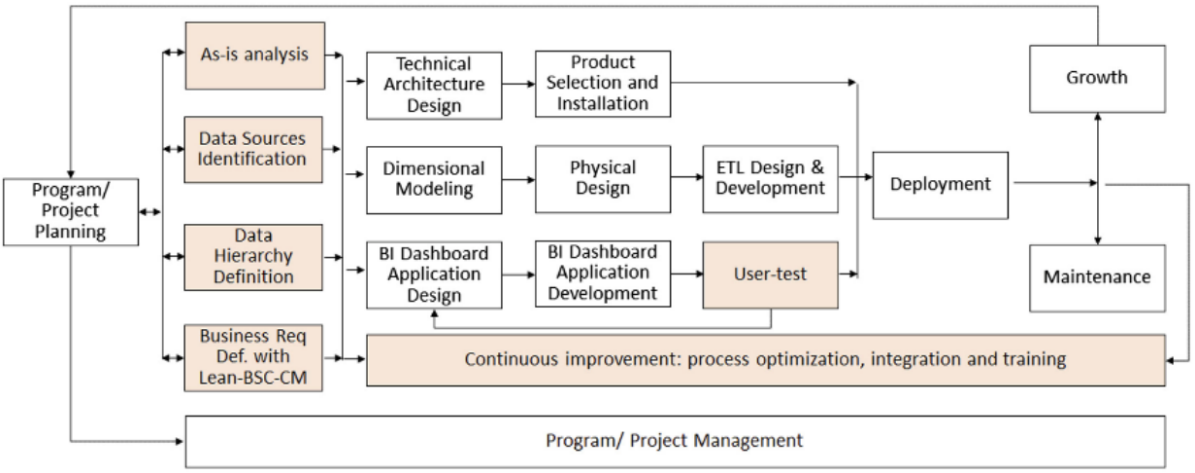

FIGURE 2. Concept used by Chiasera et al. adapting Lean-BSC-CM for Kimball development cycle

a simpler approach should be explored in further study which only utilizes one familiar design framework focused on human-centered approach.

Chongwatpol has also published an article that contains the implementation of the design thinking process for BI & BA learning within the scope of information systems in the classroom [16]. The process focuses on discussions and interviews between students involved in the project as the core stages of the empathize and define phases of the design thinking process. The results indicated that the design thinking process applied in classroom learning helps students become more creative in solving problems and has a higher contribution value compared to classes that do not use the design thinking process. Nonetheless, this study only shows an implementation of design thinking and BI within the scope of information systems learning in the classroom. This study is a strong foundation on how we might expect the implementation of design thinking performs in real BI cases.

Düştegör et al. in their publication mentioned how the implementation of design thinking process has help participance to work on a problem or a project, where empathizing fosters emotional intelligence, prototyping enables flexibility, exploration, and investigation [17]. Further discussion of the study also exposes the possibility of design thinking adoption in digital course, but instead of teaching the principles as stand-alone lessons, the authors decide and suggest direct integration of the design thinking principles. It is shows that direct integration of the method shows a significance result of improvement on how participance would collaborate to achieve goals.

The studies above have shown methods used to improve the user experience and usability of a BI dashboard. However, there is still no form of implementation of the design thinking framework in traditional methods such as the Kimball lifecycle in designing BI dashboards.

2.2. **Kimball lifecycle.** One of the frameworks and product life cycles commonly used within the scope of business intelligence is the Kimball lifecycle. Kimball lifecycle recognizes the term dimensional design, which consists of 4 main stages: project planning, business requirement definition, dimensional modeling, and ETL design. The four stages of the Kimball lifecycle are specifically designed to assist us in designing infrastructure systems that remain focused on business needs [18]. The schematic diagram of the entire process contained in the Kimball lifecycle can be seen in Figure 3.

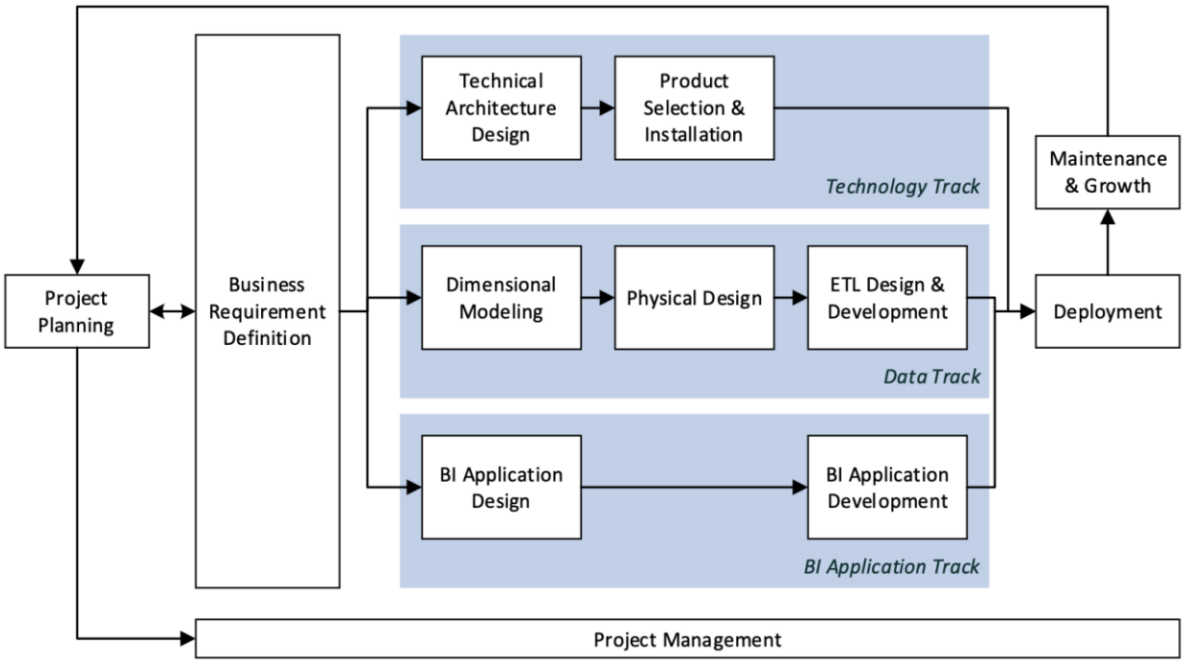

FIGURE 3. Kimball lifecycle process

2.3. **Design thinking.** This method is a process commonly used by designers to find solutions to complex problems in an uncertain environment using elements of empathy, reflection, creation, and experimentation to collaborate [19]. Based on this statement, the authors hope that the use of design thinking in the design of the BI dashboard can help understand the complex needs of users in an uncertain environment. Interaction Design Foundation Organization explained design thinking as a non-linear process, that runs iteratively to understand users and solve problems with creative innovative solutions through prototyping and testing [20]. The whole process can be seen in Figure 4, where the dotted line show processes that can be repeated in two or more iterations.

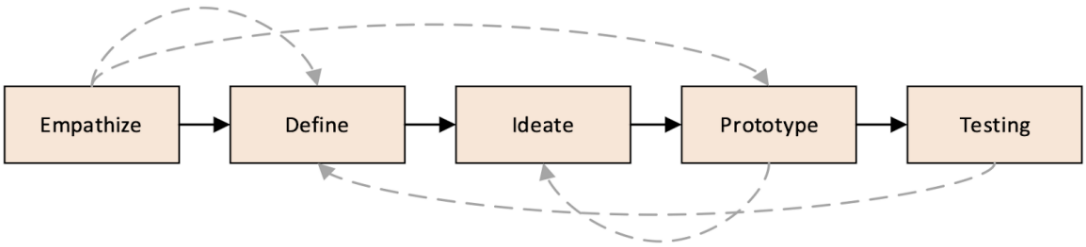

FIGURE 4. Design thinking process

3. **Methodology.** The research methodology will be explained into three sub-chapters. The first one is an overview of the proposed method which embeds design thinking into the "BI Application Track" inside the Kimball process. The two following sub-chapters will explain how the proposed method should be executed and how the dashboard usability will be evaluated.

3.1. **Proposed method.** The proposed method combines the two frameworks explained in the previous chapter for the development process. Design thinking process will be implemented in the "BI Application Track" of the traditional Kimball lifecycle to help

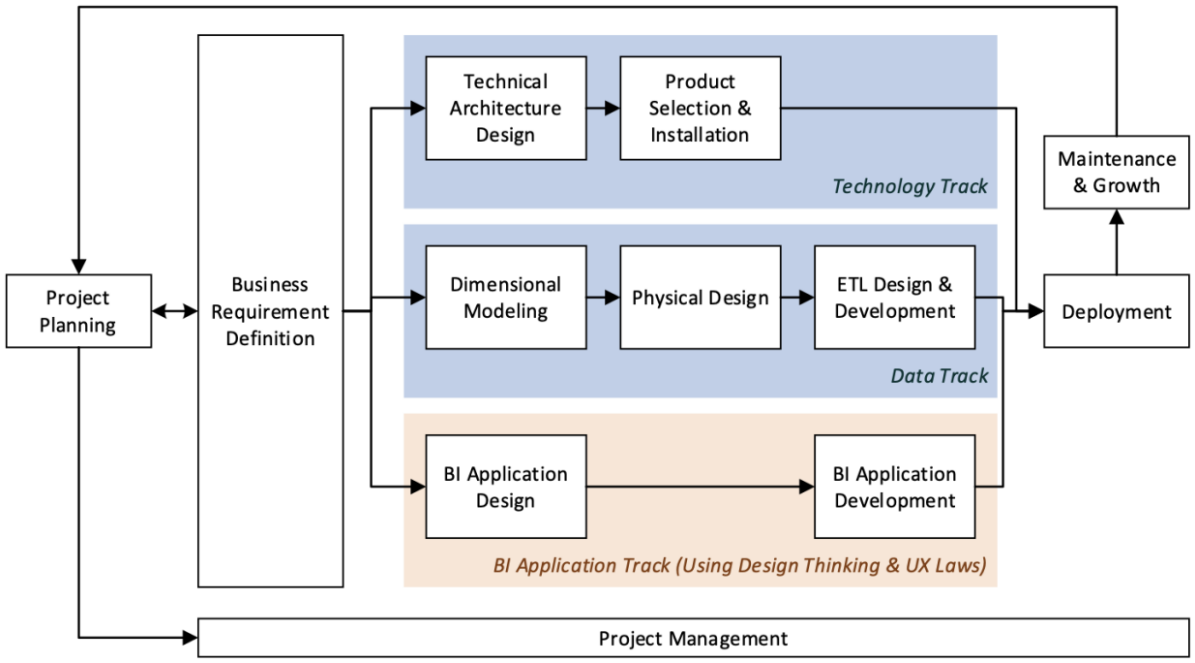

FIGURE 5. Proposed Kimball lifecycle with design thinking process

deliver a better user experience and usability dashboard for users. The proposed method can be seen in Figure 5. UX Laws will also be included as guidance in designing the dashboard user experience.

The dashboard that will be recreated is obtained from one of the thesis researches of Bina Nusantara University students and contains "Global COVID-19 Case" data. The corresponding dashboard can be accessed via the Public Tableau URL[1], and will be used as a comparison after the design of the new dashboard is completed. The authors have gained researcher permission regarding the use of dashboards, data sources, and the form of data warehouse schemas that have been made for evaluation materials.

3.2. **Execution steps.** The Kimball lifecycle process will be executed first according to what has been explained. The process of designing transformation diagrams will be carried out and will later be proceeded with the development process using ETL tools. The expected output from this process is a database with a schema similar to the schema in previous studies. Furthermore, the key processes in design thinking: "Empathize" and "Define", will be carried out through user research to understand the user experience when using a similar dashboard that already exists. Wasil in his book "*Petunjuk Memulai UX Dari NOL*" reminded the importance to minimize bias when conducting user research; one of them is avoiding the framing effect [21]. The framing effect is one of the mistakes commonly encountered when conducting user research, caused by the form of questions that indirectly isolate the answer options for the user. Following two key processes, the "Ideate", "Prototype", and "Testing" stages will be executed afterwards. The final form of the dashboard will be developed once the prototype is tested. Business Intelligence & Analytics Software such as Tableau will be used as the main tools to convert the prototype into a working dashboard; if there are features that cannot be developed following what was designed in the prototype, the use of web frameworks such as PHP Laravel and Ruby on Rails will be used as an alternative.

[1]https://public.tableau.com/app/profile/aditya.samagan/viz/CovidDashboard-Skripsi/Distribution

3.3. **Usability evaluation.** After completing the whole process, final product in the form of a dashboard system will be evaluated using metrics that can be measured through usability testing. Usability testing will be carried out using the unmoderated usability study method. Testing data will be gathered through interviews with 4 selected participants. This usability testing will measure "Time on Task" from the given prompt and scenario, followed by Jakob Nielsen heuristics evaluation questionnaire and system usability scale form. This follows the usability study method recommended by "Google Professional UX Program".

4. **Results and Discussion.** The following explanation covers both the dashboard system result and the usability testing result.

4.1. **Dashboard result.** The technology track and the data track of this Kimball lifecycle were designed to be identical to the old dashboard system. This allows us to focus on the design thinking process itself more than the overall BI process.

- **Technology Track and Data Track**
  After a brief study and observation of the old dashboard system, it is determined that Pentaho Data Integration, MySQL Database, Figma, Tableau, and Ruby on Rails will be used in the development process. An identical data warehouse schema of the old system is created with the shape of a constellation schema. The next thing to do is to develop a proper BI Application.
- **BI Application Track with Design Thinking**
  This process involved every stage of design thinking with UX Laws consideration in the ideation and prototyping stage. Below are the results for each stage.
  - **Empathize**
    User interviews are conducted both offline and online with groups of people that have been using the old dashboard system. Feedback and thoughts from these interviews are used to form two user personas which contain information about user needs, goals, pain points, and characteristics.
  - **Define and Ideate**
    From the two personas that were created in the previous stage, user needs, pain points, and problems were able to be defined. Solutions for these defined problems were explored in the ideation stage with a method called HMW (How Might We). The results for define stage and ideate stage can be seen in Table 1.
  - **Prototype and Testing**
    From a list of solutions that were found in the ideate stage, prototypes were created and tested with two iterations. The testing stage itself uses a design critique session to test each prototype.

After the prototype was accepted with all the people involved in the design critique session. Comparison of the dashboard system can be seen in Figure 6.

4.2. **Usability evaluation result.** Unmoderated usability testing was conducted with four participants. Each participant was given nine prompts they needed to finish within the two dashboards followed by a heuristic evaluation questionnaire and system usability scale form. Results are obtained as follows.

- **Time on Task**
  The result for each participant's time on task can be seen in Table 2. These numbers were evaluated using statistical t-tests to see if there are significant differences that can be used to deny the null hypothesis that states, "system one is not different from system two".

TABLE 1. Results from define stage and ideate stage with HMW method

No.	Defined problems	Solution from HMW method
1	Color contrast used between background and text causes eye strain.	- Consider using background and foreground colors that follow WCAG AA standards. - Use colors that reflect the presented data. For example, green for recovered, yellow for active case, and red for death case. - Avoid using deep black (#000000) on white (#FFFFFF).
2	Difficulties in finding and understanding information due to visual size of graph and text.	- Evaluate and apply better visual hierarchy. - Use icons that reflect the data or information according to the real world. - Apply *Miller's Law*[2] on the main page for data with long records.
3	Difficulties in operating the dashboard due to an unfamiliar layout.	- Apply *Jakob's Law*[3] and follow design patterns used on other covid dashboard/website.
4	Some data shows the wrong value or simplified value that confuses users.	- Evaluate data integrity or calculation - Apply *Tesler's Law*[4] for high complexity data
5	Users need the information of regulations of the COVID pandemic in the user's surrounding area.	- Add a new section containing regulations and health tips during the pandemic
6	Daily and monthly data trends are difficult to find due to their placement and size.	- Moved this functionality to the main page to make it more accessible.
7	Search and filter features are confusing to use.	- Apply *Hick's Law*[5]

The hypotheses that we wanted to check using t-test are explained in Lemma 4.1.

Lemma 4.1. *Null Hypothesis (1) and Alternative Hypothesis (2).*

$$H0\text{: } \mu 1 = \mu 2 \rightarrow \textit{ State system one is similar to system two} \quad (1)$$

$$H1\text{: } \mu 1 \neq \mu 2 \rightarrow \textit{ State system one is not similar to system two} \quad (2)$$

To deny the null hypothesis, the t-test calculation must result in a probability p-value lower than 0.05. Despite the number that shows quicker time from the new dashboard (*dark gray*) compared to the old dashboard (*light gray*), this step still needs to be done to see if our results are valid. The calculation was done using Google Sheets formula and the p-value of 0.02553 was obtained. Hence, we can deny the null hypothesis and conclude that the new dashboard system is significantly different in terms of user time on task; the new dashboard is chosen to be the better dashboard due to the lower average time users need to complete tasks. This improvement is obtained through a better visual hierarchy and placement that considers what users need the most when using the dashboard.

[2]The average person can only keep 7 (plus or minus 2) items in their working memory. Do not show too much data.

[3]Users prefer our site to work the same way as all the other sites they already know.

[4]There is a certain amount of complexity which cannot be reduced from a system.

[5]The time it takes to make a decision increase with the number and complexity of choices. Consider the use of search bar, dropdown, searchable dropdown, radio button, toggle, or select form wisely.

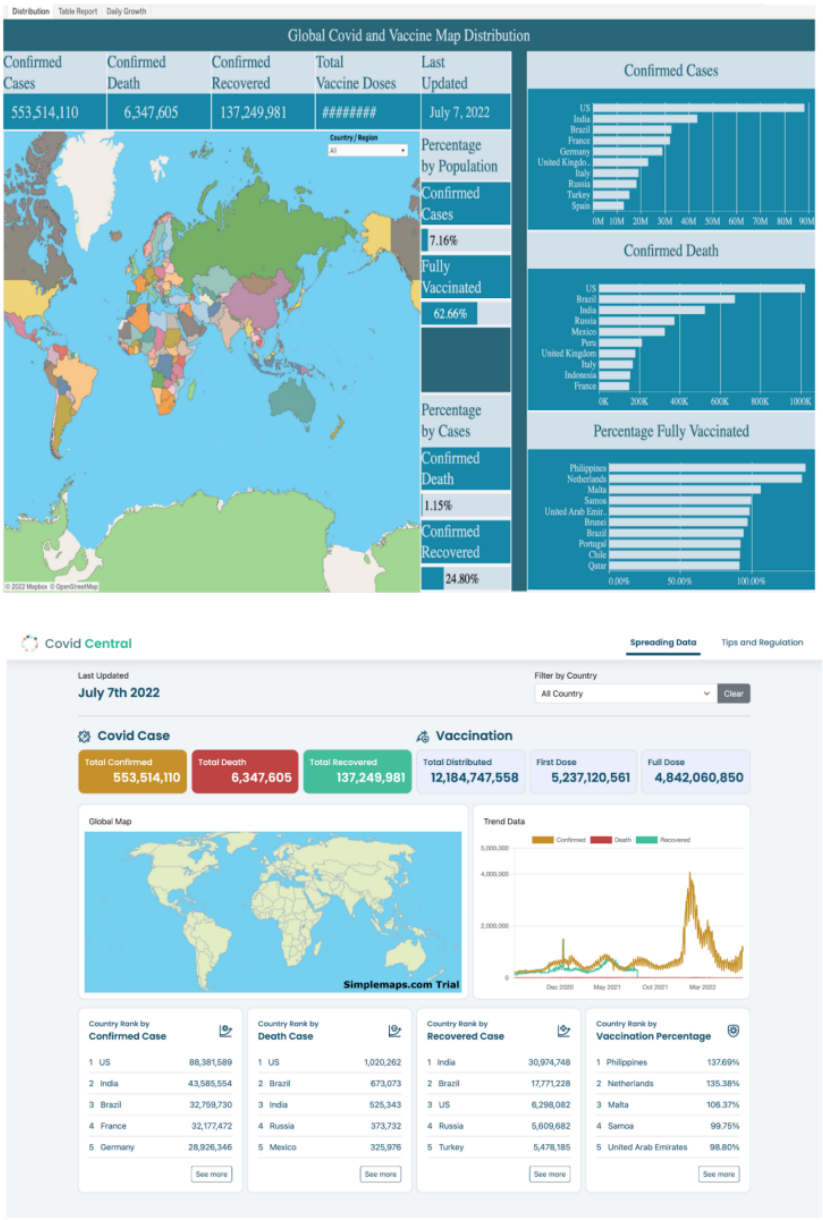

FIGURE 6. Comparison of the old dashboard (upper) and the new dashboard (lower)

- **Heuristic Evaluation Questionnaire**

  The result for each participant's answer on 8 heuristic evaluation statements can be seen in Table 3. Each statement represents a certain number of Jakob Nielsen usability heuristic rules with details that can be seen in Table 4.

  The heuristic evaluation questionnaire has shown the lack of execution on certain Jakob Nielsen usability heuristic rules on the old dashboard system; nevertheless, the new dashboard has already provided better usability with this consideration. Of the four participants above, none of them has stated "agree" with statement number four when using the old dashboard system. This shows that most participants felt confused, likely due to the bad implementation of Jakob Nielsen usability heuristic rule number three (*User control and freedom*), five (*Error prevention*), and seven (*Flexibility and efficiency of use*).

TABLE 2. Participant's time on task result (in seconds)

Task No.	Old dashboard				New dashboard			
	Participant-1	Participant-2	Participant-3	Participant-4	Participant-1	Participant-2	Participant-3	Participant-4
1	37	6	4	5	2	3	3	3
2	26	34	20	31	20	11	19	15
3	93	108	134	260	51	2	5	9
4	8	5	5	6	6	3	5	12
5	58	19	78	138	60	5	10	36
6	155	63	73	281	19	53	7	14
7	86	86	110	30	39	15	16	12
8	203	112	82	260	9	6	15	10
9	46	13	28	41	33	10	8	6
Total time	712	446	534	1052	239	108	88	117
Average time	79.11	49.56	59.33	116.89	26.56	12	9.78	13

TABLE 3. Participant's answer on 8 Jakob Nielsen's heuristic evaluation statements

Statement No.	Old dashboard				New dashboard			
	Participant-1	Participant-2	Participant-3	Participant-4	Participant-1	Participant-2	Participant-3	Participant-4
1		✓			✓	✓	✓	✓
2	✓	✓	✓		✓	✓	✓	✓
3	✓				✓	✓	✓	✓
4					✓	✓	✓	✓
5	✓		✓		✓	✓	✓	✓
6		✓			✓	✓	✓	✓
7	✓		✓	✓	✓	✓	✓	✓
8	✓				✓	✓	✓	✓

- **System Usability Scale**

  The standard system usability scale form was used, consisting of 10 statements and **answers** ranging from 1 – "strongly disagree" to 5 – "strongly agree". Results for each participant's system usability scale form have been scored according to the scoring contribution guide by Brooke where statement numbers 1, 3, 5, 7, and 9 score with (**answer**-1); while statement numbers 2, 4, 6, 8, and 10 score with (5-**answer**) [22]. Obtained answers from participants that have been scored can be seen in Table 5 with the average final score showing higher results for the new dashboard system compared to the old dashboard system.

Table 4. Statement used in the questionnaire with their correlated Nielsen rules

No.	Statement	Nielsen rule number
1	Label, sentence, and icons are easy to understand	2
2	I can go back or cancel my previous action if I made an error	3
3	Design feels consistent and the color used in the dashboard helps me understand the given information	2, 4, 9
4	I am not feeling confused when performing the prompted task	3, 5, 7
5	I do not need to remember my previous action when performing a follow up prompt	6
6	As a user, I can understand and perform the prompted task with ease	2, 8
7	I can navigate freely between pages	3
8	I can find certain page or information with ease	1, 3, 6

Table 5. Participant's score on system usability scale

Statement No.	Old dashboard				New dashboard			
	Participant-1	Participant-2	Participant-3	Participant-4	Participant-1	Participant-2	Participant-3	Participant-4
1	2	1	1	0	4	3	3	4
2	2	0	1	0	4	3	3	0
3	1	1	1	1	4	4	3	4
4	1	1	0	1	4	3	4	4
5	3	1	1	1	4	4	4	4
6	2	1	1	2	4	4	4	4
7	2	1	1	0	4	3	3	4
8	2	1	0	1	4	3	3	4
9	1	0	1	0	4	4	3	4
10	1	1	0	0	4	4	0	4
Sum value	17	8	7	6	40	35	30	36
Final score (Sum * 2.5)	42.5	20	17.5	15	100	87.5	75	90
	Average final score			**23.75**	**Average final score**			**88.13**

Scores that were obtained through the system usability scale represent what the user actually feels when using the two dashboards. The old dashboard system scores only 23.75 on average compared to the new dashboard system with 88.13 on average.

5. **Conclusions and Future Works.** This study has successfully demonstrated how human-centered approaches can be implemented in the BI development process with the help of a framework called "Design Thinking" that has been embedded inside the "BI Application Track" of the Kimball lifecycle. An implementation of this particular framework has shown a positive impact on dashboard usability and overall user experiences which has been proven with results obtained through usability testing.

This study took advantage of the five iterative collaboration stages of design thinking by directly integrating it into the BI design process without making too many changes to the Kimball process itself. Hence, the overall process is shorter compared to the study conducted by Chiasera et al. [15]; on the other hand, this method also involved a deep understanding process of issues the users were facing which address problems more specific compared to another study without actual understanding process conducted by Wutthikhet et al. [13]. New ideas and solutions have been found in the development process that help deliver what users need and want from the system. The ideation stage of design thinking that utilizes HMW method has helped interpret problems and find solutions for issues that were found in the define and empathize stage. These solutions were implemented in the prototyping stage by also considering the UX Laws aspect that has been mentioned in the ideation stage.

Nevertheless, this particular BI development process still takes longer time compared to the original Kimball lifecycle without the design thinking process inside it; this time constraint might be an issue due to the iterative collaboration process of design thinking. This research gap will need to be explored in further study regarding a better user experience framework that can be used for BI processes with time constraints. Some user experience frameworks that have shorter steps and become popular among user-centered approaches include Google Design Sprint, Lean UX, Agile UX, and Hooked Model.

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