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Analysis of Web Content Delivery Effectiveness and Efficiency in Responsive Web Design Using Material Design Guidelines and User Centered Design

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***Abstract*—Nowadays, websites are not only be accessed by computers with a large screen. They were mostly accessed via mobile devices such as tablets and smartphones that relatively have smaller screen size. Almost every website has their different style and visual appearance concerning content and information delivery. Even though they were visually looked different, they were mostly designed and developed by using one of one column, two columns, or three columns layout. The way to properly deliver content and information on a smaller screen size becomes a challenging matter. Responsive Web Design approach allows a single web page to be differently visualized based on the screen size of the accessing device. Such layout changing may affect the amount of information to be displayed on the screen, hence affecting the effectiveness and efficiency of information delivery in a web page. This study compares the effectiveness and efficiency of a web page that is being displayed on a computer screen, tablet, and smartphones. How the implementation of Materials Design Guidelines and User-Centered Design approaches in the design process may affect the effectiveness and efficiency of content and information delivery of a web page on smaller screens were also evaluated and presented. This research shows that User Centered Design and Material Design Guidelines improve the effectiveness and efficiency of content delivery on both tablet and smartphone. Materials Design Guidelines provide better usability improvement than User Centered Design approach for the smartphone screen regarding content delivery efficiency for web pages designed in three columns layout.**

Keywords—usability, Material Design, UCD, layout, design

I. INTRODUCTION

The Web has become a commonly used media to convey the information. In addition to conveying the information, a website is also used as an application and even become an information system. At the beginning of the trend of mobile device usage that can access the internet, the companies or information service providers use two different platforms in providing information services and applications on the internet, i.e. desktop and mobile. Initially, website owners provide several website versions to make website's User Interface (UI) comply with different devices or different browser's screen resolutions. They usually create two versions of their websites which is the main one is targeting for desktop users and the other one is for mobile users. Hence the website designers and developers should be better in arranging their contents in such a way that the website can be well-used regardless the variations in user's platforms, devices, and screen resolutions.

Different browser's resolution size between different devices, especially mobile devices, can lead to a design problem. The problem may occur when a web page is being accessed through a browser which its viewport is below the expected minimum width [1]. This condition may cause critical links, components, as well as some other important information, which should have been presented to users, are being hidden. The needs to do vertical or horizontal scrolling will decrease the deliverable effect of certain values from the website. Moreover, it can reduce the overall website experience for their users [1].

Since its introduction in 2011, responsive design has offered flexibility to adapt UI of a single website to handle different resolution range so that user on different devices can experience the same expected website design by using the HTML5 and CSS3 technologies [1]. A web page design is considered to be responsive if it uses these three points: a flexible grid, flexible images and media, and media queries. By using media queries, website designers can define certain resolution ranges as conditions to use certain CSS definitions called fixed breakpoints [2]. That way, the designer can match which CSS definition will be applied to a given resolution that will create a better visual experienced for the website users.

Nowadays, delivering contents and information towards a wider range of users and handheld devices become a primary need in businesses. They treat mobile devices to differentiate, improve customer satisfaction, and engage more users towards them. Simple, innovative, and intuitive applications or tools yields to an enjoyable flexibility and increased productivity. Many people are using the Web and Internet to get almost on everything they need, e.g., news, product reviews, cooking recipes, and the like. But today, people are also using the Web to book hotels and flights on their future vacation plan or even buy and sell goods making the Web as a marketplace. They tend to access information and application on the Web by using whatever device they might have. It was ranging from a big and bulky desktop computer, laptop, tablet, to smaller mobile devices. The differences in device's screen force content

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provider to be able to deliver their contents to a broader possibility of consumer devices. However, developing one website version for each device screen resolution and every new device seems to be impractical.

Websites come in a different number of column. The typical number of columns used in a web page is a single column page, two columns page, or three columns page. Sometimes it is necessary to make some adjustments to the web page layout when the website is accessed from devices with varying screen sizes or resolutions. Good layout arrangement will attract users' attention better. The layout arrangement itself become an important issue when a desktop website is accessed via tablets or smartphones. In a particular case, the use of smaller screen will certainly reduce application usability [3]. It is caused by the differences of screen size between desktop computers, tablets, and smartphones that affecting the amount of information that is being displayed on the device's screen at a time, hence impacting user's productivity.

User-Centered Design is a user-centric approach that focuses on user's needs, behaviors, wants, and limitations in the software development process lifecycle. When end users were involved in the design process, they will help to reduce the lag in information system's usability by focusing on making a product that fit user needs rather than forcing users to change their behavior to accommodate the product [4]. Material Design Guidelines (MDG) is a design language developed by Google in 2014 that provides best practices on how to put user perception and high level of accessibility into a mobile UI design. MDG allows a user to experience a unified experience across different platforms and devices regardless the screen size of all devices in the hope that users will get a better engagement, better UI/UX and cost-effective with the products [5]. Both UCD and MDG offer a better user experience in using a product, hence making a product quality better.

The quality of a product can be measured by its effectiveness and efficiency [6]. The effectiveness of a product is one variable that determines the success of a product [7]. In assessing software product usability, its effectiveness and efficiency of use need to be measured. This research will try to describe how a web page layout transformation on a responsive web page may affect its usability. This study will also try to explain how UCD and MDG will improve the effectiveness and efficiency of content delivery of a web page when it comes to a tablet or smartphone screens.

The effect of the implementation of User Centered Design (UCD) and Material Design Guidelines (MDG) in making a layout arrangement of a web page will be elaborated in this research. The arrangement of web page elements inside a web page layout will be targeting tablet and smartphone screens by referring to the MDG and UCD in the layout design process.

II. Literature Review

A. Responsive Web Design

Responsive Web Design (RWD) is taking HTML5 and CSS3 web technologies into account in building a responsive web page or front-end layout. Responsive web design uses three main ingredients, i.e., a fluid and flexible grid-based layout, flexible images and media, and a module from CSS3: media queries [1]. Fluid layout assigns relative units to the page elements instead of absolute units like pixels or points. In RWD, the design of a web page can respond to user's needs by adapting it to the constraints of the browser window or device that renders it. Therefore, RWD ensures a web page screen-layout, texts, images, navigation elements, video players, and other UI elements will re-adjust themselves.

Images, videos, and other media types need to be scalable, changing their size as the size of the viewport changes. One quick way to make media scalable is by using an element's max-width property with a value of 100% or specifies the width of the content area as percentages of its viewport [8]. By doing so, when the viewport gets smaller any media will also be scaled down following its container width. Media queries make possible to switch between different style sheets based on the features of the device in which the webpage is rendered, mainly the width of the screen.

According to [9], there are several advantages of RWD in designing a web page. The website will be very flexible because the contents may move freely across all screen resolutions. The user experience will be excellent, and it will be cost-effective as it is easier to manage, to share, and to interact with the content.

B. Material Design Guidelines

Material Design Guidelines (MDG) provides several patterns in designing Responsive UI when transforming desktop web page layout into a tablet computer and smartphone screen, i.e., Reveal, Transform, Divide, Reflow, Expand, and Position [10].

In maximizing the available space on a small screen size, MDG Reveal pattern suggests UI element be hidden entirely or partially as if in a hamburger menu. The Transform pattern transforms one UI appearance into another look, such as converting the grid view into a linear list view. MDG also suggests a guidance to organize column conversion into one, two or three columns. The Divide pattern converts columns by arranging layout elements, such as layers, side navigations, list contents, detailed contents, left and right panels, and tab controls. Reflow pattern provides a concept of how to convert multiple columns into a smaller number of columns by changing the layout combination. As the screen size is changing, the Expand pattern enables resizing and reshaping the contents. Lastly, the Position pattern moves web page contents and elements to a specified position to be fit in the available space.

C. User-Centered Design

User-Centered Design (UCD) is a term used to describe a design process that involves end users to engage in the design process of web page design [11]. UCD is a user-centered approach to support the system development process. To build a system that is easy to use for the user, this concept is very suitable to implement. It put an added value to the user, because of user's needs, wants, and interests become the focus of a usability in web page design. User's familiarity with the

user interface will provide a better experience in mobile application usability [12]. However, in determining the target of users, users can be selected from any category but must still be following the user criteria [13], and they should not know about the being evaluated products.

There are four core principles in UCD according to [14] that must be put into considerations when developing a product using UCD. First, the requirements analysis and specification were centered on usage. Second, the design of user interface is structured and put innovation into natural interaction. Third, performs early and continuous usability assessment, evaluation, and improvement. Lastly, the project management quality procedures are human-centric. When these principles are implemented in all of the software development phases, it will undoubtedly yield a useful product.

III. METHODOLOGY

This study aims to compare the effectiveness and efficiency of a web page content delivery that is displayed on a computer, tablet, and smartphone screen. This research presents on how the effectiveness and efficiency of content delivery in a web page content layout, which is designed using Google Material Design Guidelines (MDG) and User-Centered Design (UCD) approach, might be improved on smaller screens.

A. Specifying Target

Several responsive website layouts come in one column, two columns, or three columns which are targeting typical computer screen resolution by default. However, due to the smaller screen size of tablet and smartphone, it is uncommon that a web page is displayed in three columns layout. This research specifies three web pages as the evaluation target, i.e., Jurnal Pengembangan TIIK website [15] as one column web page, Jurnal UB website [16] as two columns web page, and VLM UB website [17] as three columns web page.

The web page evaluation process involves several particular users. They will run several tasks to measure the effectiveness and efficiency of the evaluated web page layout. The measurement result of the initial page layout and the modeled page layout were compared. The modeling layout was designed based on UCD and MDG by gathering user feedback or as specified in the guidelines.

Target users are determined based on the environmental analysis, which identifies the environment and the target user. Also, user characteristics are identified to assess user's eligibility to be involved in the design, evaluation, and analysis phase. This research specifies criteria that the users are familiar with browsing a website and ever been using the target websites. They were also never accessing the target websites through devices other than desktop and laptop computers. Also, the requirements elicitation process is performed as the primary task in evaluating the prototype's layout resulting from the UCD and MDG approach.

User test scenarios are designed based on task analysis. The tasks cover three difficulties level: easy, medium, and hard. They were specified based on the user interview process towards their activities within the website. The tasks that fall into the easy level are determined based on the most frequently used features on the web page. The medium level tasks are determined based on features that are less often used by most users. The hard level tasks are determined based on features that exist on the web page, but they are unnoticeable by most users. The evaluation tasks to measure the effectiveness and efficiency of a particular method, which was used in the evaluation process, are described in Table 1.

TABLE I. TASKS DESCRIPTION

Column[a]	Description	Difficulties	Code
1	Search for some articles	Easy	T1
	Find submission information	Medium	T2
	Find "about us" information	Hard	T3
2	Find "login" features	Easy	T4
	Search articles by author	Medium	T5
	Find "about us" information	Hard	T6
3	Find "login" features	Easy	T7
	Change the language	Medium	T8
	Search for some articles	Hard	T9

[a.] The number of columns in a web page as its layout

B. Preliminary Measurement

Preliminary measurements were performed to assess current web page layouts towards the effectiveness and efficiency of content delivery in desktop, tablet, and smartphone screen. The preliminary assessment will serve as a basis for describing how the implementation of MDG and UCD in the transformation process of a web page layout design will affect the usability regarding effectiveness and efficiency.

TABLE II. USER PERFORMANCE RECORDS FOR ONE WEB PAGE

Participant	Time spent (s)			Status[a]			Steps taken (n)		
	T1	*T2*	*T3*	*T1*	*T2*	*T3*	*T1*	*T2*	*T3*
P1	4	10	28	1	1	1	3	4	6
P2	3	11	6	1	1	1	1	6	3
P3	3	7	10	1	1	1	1	2	4
P4	4	13	19	1	1	1	2	4	7
P5	4	10	19	1	1	1	1	4	8
P6	4	17	17	1	1	1	2	3	5
P7	3	8	14	1	1	1	2	4	5
P8	3	8	7	1	1	1	1	2	4
P9	5	12	16	1	1	0	2	2	7
P10	4	11	10	1	1	1	3	2	5
P11	4	10	21	1	1	1	1	2	5

[b.] ask completion status, 1 denote a successful task, 0 denote an incomplete or unsuccessful task

The measurements were performed based on the tasks as described in Table 1. The measurements involve 11 to 15 users,

and their performance was measured in a two-week interval to avoid bias in the measurement as users may become more proficient in learning and remembering the layout. Users are requested to perform the task on a tablet computer in the first measurement and perform the same tasks on a smartphone in the second measurement process.

The evaluation and measurement process of the prototype utilizes several instruments, such as desktop computer or laptop, tablet computers, and smartphones. Stopwatches and a printed version of the task description were also prepared. The users were requested to perform a specific task using the prototypes that were installed on the specified devices. When a user is performing a task, the facilitator records every step that a user performs while measuring the time required to complete. The user performances in performing the tasks for every evaluated web page are recorded as in Table 2.

C. *Effectiveness Measurement*

Effectiveness is defined as the accuracy of task completeness [18]. The task completeness value will be set as "1" if the user can complete the task or "0" if the user has failed to complete the task [19] [20]. The overall integral product effectiveness is defined as the percentage of the number users that completed the tasks divided by the multiplication of the number of respondents and the total number of scenarios [20]. The effectiveness calculation follows the formula as in [20].

This research takes 11-15 respondents to reveal 90-95% of the effectiveness problems with a statistical error rate of 10%. The degree of the overall product effectiveness can be determined from its value in the representation of confidence interval as shown in Fig. 1 [20].

Fig. 1. Confidence interval of the overall product efficiency

D. *Efficiency Measurement*

Efficiency is defined as time spent by a user to complete the tasks [18]. This research measures the time base efficiency and overall relative efficiency. Time-based efficiency can be represented as the average time that user spent in completing a task as formula written on [20]. If there are any incomplete scenarios, then the time measurement will continue to proceed until the user is giving up.

Overall relative efficiency provides the time ratio between the time spent of satisfying users and the total time spent by users regardless the success status. The overall relative efficiency is formulated as in [20]. By calculating the value of user performance as recorded in Table 2, the overall integral product effectiveness, time-based efficiency, and overall relative efficiency of the current web page layout design are described in Table 3. By entering the values obtained from user performance records as in Table 2 into (1), (2), and (3), The overall integral product effectiveness, time-based efficiency, and overall relative efficiency of the current web page layout design are described in Table 3.

TABLE III. PRELIMINARY MEASUREMENT RESULTS

Web (Platform)	Effectiveness	Efficiency	
	Overall Integral Product (%)	*Time-based Efficiency (goals/sec)*	*Overall Relative Efficiency (%)*
J-PTIIK (Desktop)	100	0.37	100
J-PTIIK (Tablet)	96.96	0.15	95.07
J-PTIIK (Smartphone)	96.96	0.13	94.17
Jurnal UB (Desktop)	81.81	0.27	63.19
Jurnal UB (Tablet)	81.81	0.13	62.85
Jurnal UB (Smartphone)	81.81	0.11	61.95
VLM UB (Desktop	75.75	0.42	48.06
VLM UB (Tablet)	72.72	0.17	44.20
VLM UB (Smartphone)	72.72	0.15	44.86

c.

Referring to Fig. 1 and Table 3, the effectiveness of content and information delivery of a web page in one column layout, two columns layout, and three columns layout are considered as good, normal, and normal-to-bad category respectively. The test result as shown in Table 3 indicates that there are slightly drops of all evaluated web layout concerning effectivity and efficiency of information and content delivery. The effectivity and efficiency are lower on web page layouts that use more than one column. Three columns web page layout scores the worst in both effectivity and efficiency. The time-based efficiency for a user to accomplish a task tends to decline when one has to complete on devices with smaller screen size. On average, the conversion of a web page layout from desktop resolution to a tablet or smartphone screen will reduce the effectiveness of contents and information delivery by 2%. The transformation of a web page desktop layout to tablet and smartphone will also lessen the time-based efficiency for about 21.3% on average. However, the conversion only drops approximately 3.3% on average regarding the overall relative efficiency.

E. *MDG and UCD Prototyping*

In both UCD and MDG approach, the design of a web page layout that is presented in one column layout for the desktop screen tend to not have much differences in the designed layout for the tablet and smartphone screen. This research adopts a UCD checklist, which is developed by [21], and used as an instrument to obtain user recommendations. In UCD, most users recommend adding more frequently used icons and shortcuts somewhere near the page header and moving the menu to the top-right side of the screen. On the other hand, MDG recommends to put the menu on the top-left side of the screen and represents several functionalities with icons.

In two columns web page layout, most users recommend to just reposition the page elements without changing the visual representation. The content layout that previously represented in two columns transformed into one column layout for both tablet and smartphone. In MDG, there is no change in the default tablet and smartphone screen layout transformation.

However, the menu is moved to the top-left portion of the device's screen.

When a web page was presented in three columns layout, the page tends to have much information and functionalities to serve on one screen. In three columns layout, there is a significant overhaul regarding page layout design using MDG. Most page elements and functionalities were simplified into icons and menus. In UCD, users are recommending to remove several features that are considered inappropriate or useless. The design resulting from the MDG and UCD approach are then manifested in prototypes using high-fidelity prototyping software. The software is used to speed up the implementation process without having to hard-code the whole web page for testing.

F. *Prototype Evaluation*

The prototypes were evaluated using the same procedure as the previous measurement of the target web page. This time, the evaluation and measurement process was performed using the resulting prototypes that target the tablet and smartphone screen using the MDG and UCD approach. All the tests were evaluated using the latest Google Chrome web browser on all platforms being assessed to eliminate browser factors from the evaluation process.

Table 4 describes the evaluation and measurement results that were performed to the prototypes. It shows that MDG and UCD show some slight improvement regarding information and content delivery effectiveness. However, both method also shows noticeable improvements in the efficiency of information and content delivery of a web page in smartphone and tablet screen.

TABLE IV. MEASUREMENT RESULTS OF UCD AND MDG PROTOTYPES

Web (Platform[a])	**Method**	**Effectiveness**	**Efficiency**	
		Overall Integral Product (%)	***Time-Based Efficiency (goal/sec)***	***Overall Relative Efficiency (%)***
J-PTIIK (T)	UCD	100	0.57	100
J-PTIIK (T)	MDG	97.32	0.45	98.68
J-PTIIK (S)	UCD	98.09	0.44	98.23
J-PTIIK (S)	MDG	97.32	0.26	97.57
Jurnal UB (T)	UCD	85.14	0.48	85.35
Jurnal UB (T)	MDG	82.45	0.26	82.25
Jurnal UB (S)	UCD	85.14	0.33	85.87
Jurnal UB (S)	MDG	82.45	0.16	70.23
VLM UB (T)	UCD	74.27	0.5	80.82
VLM UB (T)	MDG	74.18	0.51	82.75
VLM UB (S)	UCD	74.27	0.31	75.38
VLM UB (S)	MDG	73.98	0.38	78.76

[a] T for Tablet, S for Smartphone

IV. RESULTS AND DISCUSSION

User-Centered Design (UCD) and Material Design Guidelines (MDG) in product design usability improvement use a different approach in its design process. MDG creates visual languages that synthesize principles of good design with the fundamentals of user perception and put accessibility into considerations to help and encourage developers and designers accommodate all of their user's needs that is primarily applies to mobile UI design. MDG promotes several patterns or best practices in transforming a web page layout into smaller screens. UCD uses a more user-centric approach in the design processes. Rather than developing user interfaces and user experiences for general users, UCD directly engages potential users who will use the web or applications that are being designed and developed.

Based on the preliminary evaluation of current responsive layout implementation of several web pages built on a responsive HTML5 framework in one column, two columns, and three columns, there is a decrease in the level of evaluation and efficiency regarding contents and information delivery of a responsive web page. Smaller user's devices screen size forces web page designer to use different visual layout when delivering the same materials as provided on a desktop computer screen. As the presentation layout in different screen size is different, it may confuse and slows down users in finding contents or information needed or performing something that they have to accomplish.

Figure 2 describes the comparison result of UCD and MDG effect on effectiveness. It shows the level of effectiveness of the website in one column, two columns, and three columns using UCD and MDG approach. UCD approach shows the most effective value compared to MDG. Figure 3 describes the comparison result in time-based efficiency. On the one column and two columns website shows the highest time-based efficiency value was gained by using UCD method, while on the three columns website the MDG approach offers the best time-based efficiency. Figure 4 describes the comparison of overall efficiency, and it shows that UCD and MDG approach has the highest result.

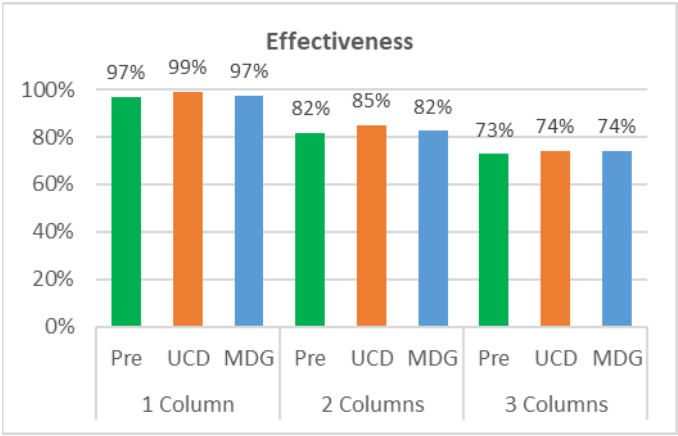

Fig. 2. The effect of UCD and MDG on content delivery effectiveness.

In the time-based efficiency measurement result, as shown in Fig. 3, MDG has better efficiency value than UCD for the

three columns website. Based on this research observation on the measurement and interview process, MDG method increases the familiarity of user interface and controls as users might have experienced several similar three columns websites which desktop layout is transformed into the mobile layout on their smartphones that follow the MDG approach.

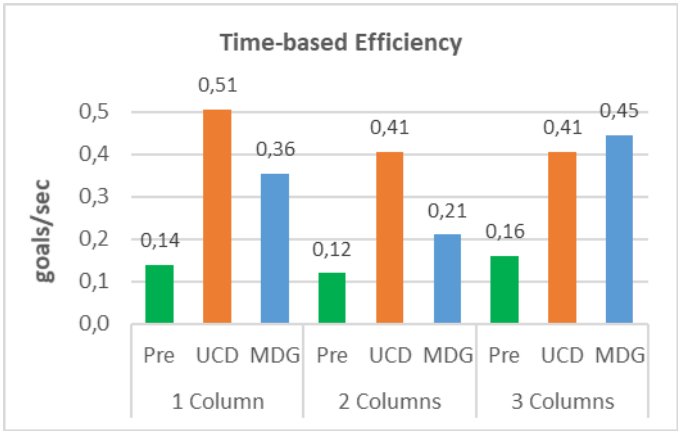

Fig. 3. The effect of UCD and MDG in time-based efficiency

The overall efficiency of users in completing the task was significantly decreasing as web page contents were delivered in two and three columns layout as shown in Fig. 4. However, by performing a comparison the effectiveness and efficiency measurement results between the preliminary testing results and this research prototypes, both MDG and UCD methods were able to improve the effectiveness and efficiency of content delivery in all evaluated column layouts. The effect of utilizing MDG and UCD in designing web page layout may enhance the effectiveness of content delivery for up to 3% in all column layouts. UCD tends to provide better effectiveness improvement than MDG. The graphical depiction of the effectiveness improvement from the preliminary evaluation is shown in Fig. 5.

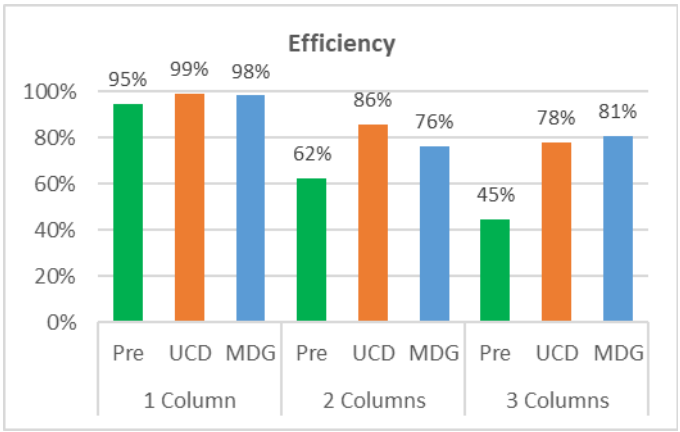

Fig. 4. The effect of UCD and MDG in overall efficiency

Regarding the time-based efficiency, UCD also tends to provide better improvement than MDG, except in 3 columns layout transformation that targets both tablet and smartphone screen as depicted in Fig. 6. Concerning the overall efficiency improvement, both UCD and MDG approach was able to provide better improvements for up to 24% and 39% in two columns and 3 columns layout transformation respectively. In the conversion of one column layout desktop screen into tablet and smartphone screen, there is not much improvement as there are almost no differences in the page elements positioning among them. The overall efficiency improvement of UCD and MDG utilization in web page layout transformation is shown in Fig. 7.

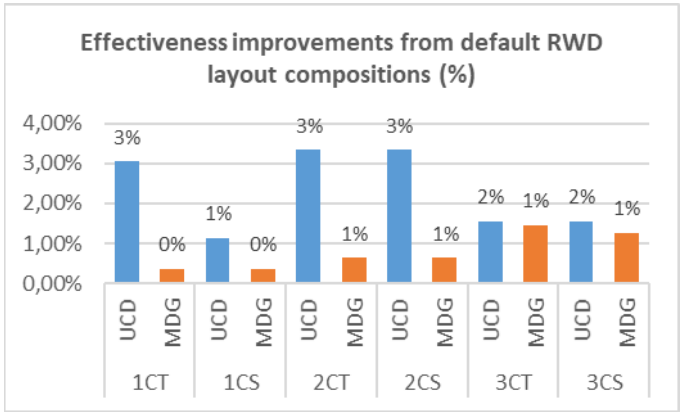

Fig. 5. Content delivery effectiveness improvement in using UCD and MDG

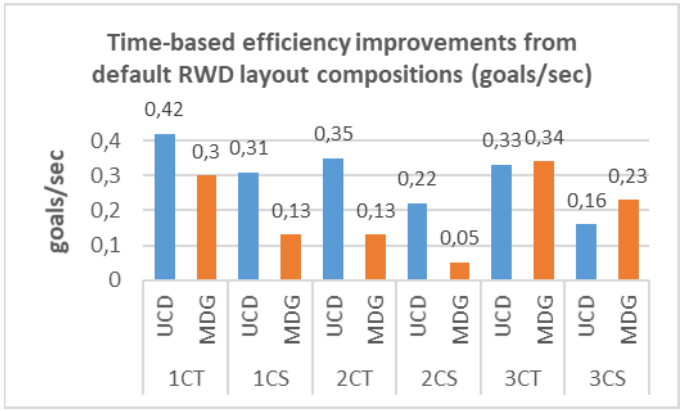

Fig. 6. Time-based efficiency improvement of UCD and MDG

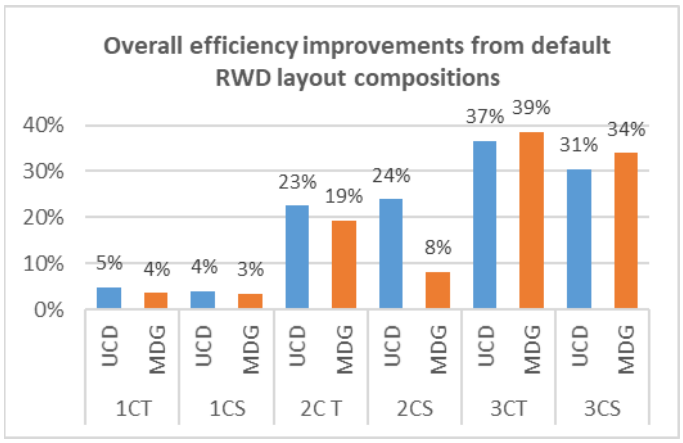

Fig. 7. Overall efficiency improvement of UCD and MDG

In UCD, the prospective users were involved in the design process. They were not involved in the design process of MDG approach. Instead of asking potential users on how they may perform the best in accomplishing a task, designers were

following the design guidelines, patterns, and best practices provided by MDG in their design. Therefore, the design process of MDG will be technically faster than UCD. Despite the fact that UCD is slower than MDG, UCD offers a better usability improvement in the resulting design even though developers were able to apply both MDG and UCD approach simultaneously to gain maximum exposure in usability.

V. CONCLUSION

In Responsive Web Design (RWD), the layout of a single web document in can be more flexibly made. When a responsive web is well implemented, it can improve the overall user experience. Responsive web design is probably the best solution to develop custom solutions in delivering information to a broader range of users and devices for a better user experience in web.

It is true that information and content delivery of a web page on a device with smaller screen size would limit the number of content that is being displayed, hence reducing the effectivity and efficiency of information delivery. However, the drop in the usability of content delivery efficiency and effectivity can be reduced by utilizing Material Design Guidelines (MDG) and User-Centered Design (UCD) approach in the transformation process of web page content layout to adapt smaller screen size.

However, this research shows that the effectivity and efficiency of information delivery of web pages that are being displayed on smaller screens, e.g., tablet computer and smartphone screen, could be improved by using MDG and UCD approaches. Both methods yield a slightly different amount of usability improvement on a tablet and smartphone screen. Web page layouts, which are designed to be displayed on the tablet computer and smartphone screen that are designed using UCD, tends to yield better usability than MDG concerning the effectivity and efficiency of information delivery on all the observed web page layouts.

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