# VISUAL ANALYTICS EVALUATION PROCESS: PRACTICE GUIDELINES FOR COMPLEX DOMAIN

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***ABSTRACT***

*Visual analytics fundamentally influences the analytical process. Without proper guidance, the use of visual analytics in complex domain can become an obstacle that hides the usefulness of analytical data. Since evaluation is the only way to identify the effectiveness of visual analytics to represent analytical outcomes, misconception of the evaluation process will bury the relevancy of visualization to support valuable decision. Recently, the nature domain of data has changed and we are now dealing with data that is massive, ambiguous, and dynamic, is often processed in real time. Hence, the data is more complex and cognitive activities that visual analytics facilitates are also getting more complex. Thus, this research revisits the way to evaluate visual analytics in complex cognitive conditions that are natural, uncertain and context dependent. Governed by the Design Science Research Methodology (DSRM), there are three phases involve during the evaluation process; i). demonstration, ii). evaluation and iii). communication. The design process is embedded with the human-activity centered design approach to gain better understanding on the visual analytics users and the complex cognitive activities involved. Thus, the research proposes Focus Group Observation method in conducting the evaluation in authentic setting. By offering a set of evaluation recommendations, this research aims to enhance visual analytics among users. It also recommends the evaluation criteria, sampling strategy and participation, focus group tasks and settings and data management and analysis that are suitable for complex domain in visual analytics.*

***Keywords: Visual Analytics, Evaluation Process, Complex Cognitive Activities, Human-activity centered design, Complex Domain***

## 1.0 INTRODUCTION

Visual Analytics is an integral approach consist visualization, human factors and data analysis. In the application of business intelligence and big data, visual analytics allow decision makers to directly interact with the data analysis capabilities of today's computer, allowing them to make well-informed decisions in their specific domain. Today, organizations are the prime domain of Visual Analytics in the usages of Business Intelligence & Analytics (BIA). However, report from Gartner [1] mentioned that *"60% of Big Data project will fail to go beyond piloting and experimentation, and will be abandoned."* One of the reasons is because the complexities of analytics domain have been expanding rapidly. According to [2], in the complex activities condition - the information that have been characterized as having many parts where those parts interact with each other in multiple ways and layers. Misconception of the evaluation process will hide the chance to identify the rightful of visual analytics to facilitate the business decision in its complex domain. Without proper guidelines, the design and evaluation of visual analytics in its complex condition will become ambiguous or too rigid that lead the top management is unable to define the values of BIA for business decision making.

According to [3] the evaluation process as a part of methodological aspect was a topic in the Visual Analytics research and development (R&D) roadmap. This challenge has been mentioned in Illuminating the Path as a critical aspect of moving research into practice. Among the challenges faced is to get more of the practical evaluation methods of visual analytics. In addition, the evaluation design is not always straightforward. The evaluation needs to go through several cycles in order to determine the best practice in which this is time and source consuming. Moreover, visual analytics has been evolving as the science of analytical reasoning supported by interactive visual interfaces [4], it has an integral approach consisting of visualization, human factors and data analysis, the evaluation process is not only involves assessing the visualizations, interactions, or data processing algorithms themselves but also involves the complex processes that a tool is meant to support (such as exploratory data analysis and reasoning, communication through visualization, or collaborative data analysis) in its complex domain. Kosara and Purchase [5] mentioned this field as the marriage of science and arts. Thus, the evaluation process of visual analytics not only involves assessing the visualizations, interactions, or data processing algorithms themselves but also involves the complex processes that a tool is meant to support human cognitive (such as exploratory data analysis and reasoning, communication through visualization, or collaborative data analysis). The researchers and practitioners in the Visual Analytics field have long identified many of the challenges faced when evaluating a visualization tool or system. One of the challenges is with the nature of the analytical activities that usually involve the complex cognitive activities (CCA) and context dependent environment such as decision making, problem solving, sense making, analytical reasoning and strategy planning. For visual analytics to move from research into practice, the design process must be able to understand the needs, challenges and issues within the process of these complex conditions.

Thus, it is time to revise the way we evaluate Visual Analytics by understanding its complex domain from real environment, business process, activities and users' perspectives. Since evaluation of visual analytics in the real environment is a critical aspect of moving research into practice [3], an effective evaluation process can help to reduce the failures of current big data and BIA projects. One problem with the complex environment is that the nature of BIA-related activities usually involves the complex cognitive activities (CCA) such as decision making, strategy planning, sense making and analytical reasoning [4]. In the organization settings, the challenge increases when more than one person do the analysis. Usually the experts and decision-makers collaboratively use, apply, and manipulate BIA to support and convince the business decision. They all rely heavily on the analytical use of information, combine their human flexibility, creativity and background knowledge with the enormous storage and processing capacities of today's computers to gain insight into complex problem and challenges.

The objective of this article is to provide the description according to the concept of a methodological paper on the evaluation process as well as guidelines for visual analytics in a complex domain. This article is divided into several sections. Section 1 presents the emphasis given on the inadequacy of the evaluation process of visual analytics in the complex domain. Section 2 provides the details on the key concept of the visualization, evaluation and complex domain. In lieu with that, Section 2.1 offers a deeper perspective on the complex condition from collaborative-complex cognitive activities in an organization and Section 2.2 presents the explanation on how the guidelines is derived from three iterative cycle of evaluation. Section 3 offers the proposed evaluation process by explaining each of the evaluation phase and the related guidelines such as the unit of analysis, sampling strategy and participation, task and settings, data collection and analysis that are involved in the evaluation. Section 4 provides the conclusion and the summary of the evaluation guidelines.

## 2.0 BACKGROUND AND RELATED WORKS

The field of visual analytics is interdisciplinary, one that incorporates scientific, technological and cognitive aspects. This field begins with information visualization that focuses on amplifying human cognition to promote efficiency in well-defined tasks [6-8]. It has been used as a communication mediator to build common understanding, insight, and decision-making within organizations' environments [9-11]. After more than 30 years of advancement, visualizations has become very important, and almost indispensable, used in many domains of applications [12-13]. Recently, Visual Analytics has been evolving as the science of analytical reasoning supported by interactive visual interfaces [14] and assists people to understand large amount of heteregeneous data by integrating multiple data analysis methodologies [15]. According to [3], visual analytics systems are becoming more popular. More domains now use interactive visualizations to analyze the ever-increasing amount and heterogeneity of data. More novel visualizations are being developed for more users'

activities and tasks. Thus, the visualization community need to ensure that these systems can be evaluated to determine that they are both useful and usable. While many of the typical human-computer interaction (HCI) evaluation methodologies can be applied as is, but for more effective evaluation – these methodologies need some modification to adapt the activities, tasks and functionalities of visual analytics. In the other hand, the domains that use visual analytics are varied, expanding and become more complex. In the complex domain, the usefulness and effectiveness of visual analytics functionalities depending on its context of usage. For this case, the activities, tasks and users need to be involved in the evaluation process. The work users do and the obstacles in their current activities need to be understood in order to determine both the types of evaluation needed, the settings, sampling strategy and analysis to be used in the evaluation.

At this point of time, there are limited published efforts to describe more than informal evaluation especially in a complex domain. There are no standard processes and metrics for the evaluation process. According to [16], evaluation approaches can be based on three desirable factors; i) generalization - the evaluation guidelines can be generalized and useful for different people and situations, ii) precision – précised relationship between measurement and parameter and iii) realism – the evaluation should be realistic for the final context targeted. Even though the approaches of generalization and precision evaluation are ideal for the use of simple and straightforward domain, for complex domain the realism approach is more relevant. Schwandt [17] has defined realism as 'the view that theories refer to real features of the world' According to [18], realism is 'the view that entities exist independently of being perceived, or independently of our theories about them. From visual analytics point of view, the application of visual analytics is uncertain and it depends on the organizational context it is used. The variance of users' roles, knowledge and organizational domain will lead to different perception and suitability of visual analytics. Thus, by understanding the importance of realism approach for visual analytics in a complex domain the evaluation should provide more context-dependent and pragmatic approaches to generate valuable and realistic findings. Furthermore, realism focuses more on specific problems, target specific users and consider their capabilities and interests during the evaluation process. For realism approach, the fuzzy environment does not lend itself well to precision through quantitative approach and it is often unclear if results from one domain can be transferred to another. On the other hand, traditional HCI methods such as laboratory experiments and usability test fall short for realism because they use simple task and non-real experts in the natural scenario. Due to the context of visual analytics which always complex, uncertain and context dependent. This research intend to further discuss the guidelines based on realism approach for visual analytics in the complex domain.

By taking into account the realism approach, [3] and [19] have emphasized the importance of user centric during the evaluation process. By understanding multiple people as users, the evaluation is expected to provide further understanding on the difficulties in handling visual analytics in completing activities and tasks. However, by focusing and centralizing only on single user might lead to insufficient understanding on the root cause of the problem. The culture and geography can be the greatest shortcomings to generalize users' understandings. Besides, primarily people think about what they want instead of what they need and they always change the thinking and requirements based on the context and situation [20]. In order to evaluate a specific visual analytics design by referring to a single user alone might improve the design for some group of people and it is at the cost of making it worse for others. The more consideration that is tailored for any particular likes, dislikes, skills and needs of a particular target population, the less likely it will be appropriate for others. Thus, [21] has suggested an Activity Centered Approach (ACD) to further define the evaluation design. ACD can be defined as actions taken by users to achieve the desired goal and has its theoretical underpinnings in Activity Theory. Since ACD is an enhancement from Human Centered Design, it requires deeper understanding on technology, tools and reasons for activities done as well as understanding on users. Therefore, this research work is intended to develop guidelines for visual analytics evaluation by gaining more understanding on users' activity and come out with the term Human-Activity Centric Evaluation Design (HACE). This study intends to identify the dynamic sequential operation underlies the processes' activities and tests within these processes. Through HACE, an understanding on users and the activities they are doing are becoming more significant for visual analytics practices.

### 2.1 Collaborative-Complex Cognitive Activities as the Complex Domain

To further investigate the capability of Human-Activity Centric in evaluating complex domain, this paper focus on the complex cognitive activities in the organization. Complex Cognitive Activities-CCA (e.g decision making, problem solving and strategy planning) is a prime applicant when dealing with information complexities and uncertainties. There are numerous of Visual Analytics application that have been pursued to

facilitate CCA in the organization such as Decision Support System, Business Intelligent Dashboard and Big Data. From the visualization perspectives, CCA require interactions between various parts of tasks, actions, and events to solve a higher level of cognitive activities [4]. In contrast with basic cognition, CCA are a higher cognitive process that involves more than storing and encoding memories as it must come with the ability to presuppose the availability of knowledge and put it to use. [22] has recognized CCA as the processes that led to the understanding and ability to transform and use knowledge in the appropriate context. Since CCA often involve a higher level of thinking and knowledge, they tend to answer the questions of "how" and "why" require an understanding of the lower level of knowledge (remembering, understanding, and knowing) before a user can make an analysis and a synthesis in response to higher levels of knowledge [23]. Thus, the visual analytics is required to support the reasoning in these kind of cognitive processes.

Furthermore, [24] has observed that CCA always occurs in the collaborative settings. According to [25-26], experts and decision makers are among the most potential users that are involved during the face-to-face collaboration in the organization. The higher level management teams that hold the higher ranks, roles and knowledge always come in place. Apparently, the meetings, discussions and brainstorming are among the familiar settings to induce higher level thinking and reasoning in the organization. This is because, developing a comprehensive CCA outcomes is not feasible by a single person; the organization needs the views and opinions from experts and skilful managers from various domains. Based on [27], collaboration enhances the traditional interactions by bringing together many experts so that each can contribute towards the common goal of understanding the object, phenomenon or data under investigation. In this condition, an experts and decision-makers need to collaborate in handling the increasingly large, complex, and varied domains and fields involved. Nevertheless, it is difficult to communicate tacit knowledge, such as the statement of personal opinion and experience which is highly crucial for management to make decisions. It differs in terms of what is communicated, and how one communicates with another. Furthermore, with different individual backgrounds, extensive scopes, and diverse ideas, it is difficult to grasp the big picture, especially when the integration is carried out between various domains of knowledge [28-29]. Thus, collaboration leads to higher level of cognitive complexities; and at the same time, increases the difficulties to communicate among the group members; and poses numerous cognitive overload, and emotional and social challenges [30]. [31] term this condition as Collaborative-CCA and as the consequences, [32, 33] have described three main challenges for Collaborative-CCA which could be summarized as: i) the different mental model in achieving the shared goals, ii) the lack of understanding the importance of convergence, and iii) the evolving emergent information. It is essential for the evaluation process to tackle these complex challenges. Thus, the evaluation process is not only meant to identify the visual analytics usability in the complexities of information. Hence, it must be able to handle the users (in this case, experts and decision-makers) and its natural activities and environment.

### 2.2 The Improvements for the Evaluation Guidelines

There are difficulties and uncertainties on how to set the tasks and observe the visual analytics facilitation for the evaluation. [34-35] have already mentioned the difficulties to set the control elements in the context dependent and in the natural condition of the complex domain. Therefore, the guidelines proposed in this paper are based on the improvements and assessment after going through three cycles of trial and error as shown in Fig 1. In the end, we suggest to provide a minimal element of control during evaluation in order to give users more freedom to act comfortably in natural settings. From the Design Sign Research Methodology (DSRM) perspective, these three cycles of trial and error are also known as an iterative of design cycle [36] by going through between the design theory and evaluation guidelines. The iterative cycles of the evaluation process has helped us to improve the evaluation guidelines, especially from the perspective of sampling criterion, task and settings. The research found the improvements are very beneficial for more practical usefulness value based on the activities in natural settings. Based on the design cycle, this research has developed the evaluation guidelines after going through three levels of the iteration process: i) Iteration Level 1 - Follow the evaluation guidelines from LR, ii) Iteration Level 2 - Participate in studies conducted in more natural settings, and iii) Iteration Level 3 - Provide settings based on users' needs and situations.

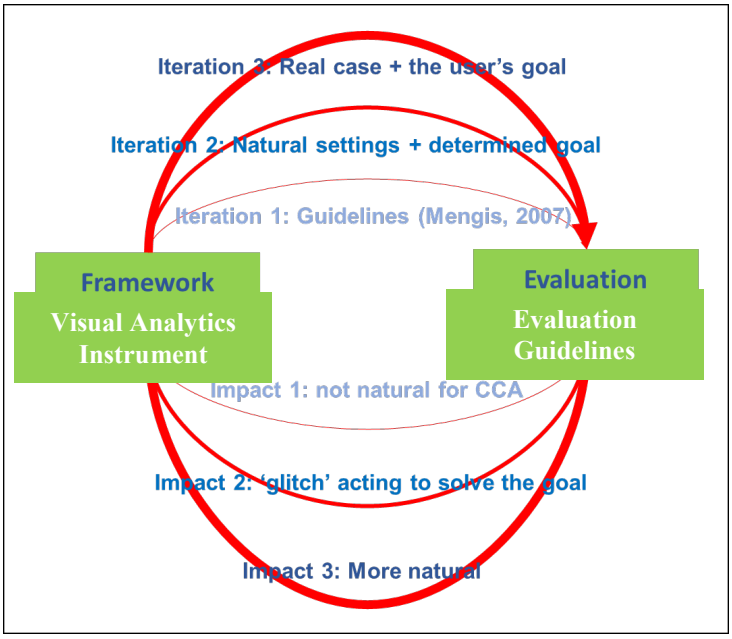


Fig.1. Three Level of Design Cycle Iteration

First iteration, the research has followed [37-38] in order to achieve the similar natural setting goals for evaluation guidelines by performing experimental class by applying case study. In Mengis' case, she selected the participants among the students and determined the topic for their discussion. However, we found the determined topic and participants for the case study were not suitable for the complex domain. In CCA, the participant's cognitive background plays an important role to digest and execute the activities. By taking students as the participants, we found their blurriness in digesting the complex problem. They seemed to be awkward to remember and think based on their roles and most probably, the roles given are not suitable according to their level of thinking, knowledge and personality. Other than that, the participants were having a hard time to discuss about the topic since they didn't have well experience according to the organization settings (e.g. decision makers roles, sales manager roles or secretariat) and domain problem (e.g sales for shipping company, food and franchising modus operandi and Vendor as IT Integrator).

Second iteration, to improve the participants and topic selection, the evaluation form the collaboration settings (e.g meetings, discussion and group work's assignment) from different backgrounds of the participants. Then, the elements like the selection of group members, what to achieve and the CCA topic of discussion have been identified and well-documented in graphic charts, reports and persona storytelling. The document must be given to the participants three days before the experiment takes place. However, we still found some glitches to mock up this kind of evaluation. The participants were awkward among each other because they didn't have a bonding and the topics sound unfamiliar to certain participants. Other than that, the elements of acting and the staggered information and idea flows make the discussion seemed not natural at all. Third iteration, we improved the settings by lessening the determined control settings and provided the settings based on the users' goal and condition. We selected the participants from the group which they already have their bonding – which meant we must take the group from one organization/company. It was easier because each people in the group already have the same vision to achieve and understand their own roles and what to expect from others. Within that, we eliminated the awkwardness among the users since they have natural bonding. In spite of the mocked up and determined topic and CCA for them, the research got a deeper understanding about their needs and the Collaborative-CCA to be performed and let the experiments be the platform to solve their own CCA's problem. After having the success for the first group on executing this kind of evaluation, the research gained confidence and executed the same process for two other groups. Therefore, the evaluation has change from determined and strict control environment of experimental class by applying case study into more natural settings and activity of focus group observation. The proposed evaluation process and guidelines in Section 3 are based on these final improvements.

## 3.0 THE PROPOSED EVALUATION PROCESS

This section intend to offer the Human-Activity Centric as a potential evaluation process for visual analytics in the complex domain. In conjunction with that, since the central attention in this methodological paper is visual analytics yet the visualization field itself is lack of the suitable evaluation process, the research decide to apply Design Science Research Methodology (DSRM) that is generally used as the comprehensive and rigorous backbone to govern the evaluation process especially in visualization and HCI larger extent – Information Science (IS) discipline. Furthermore, DSRM is suitable to guide and conduct visual analytics evaluation process since it has been congruent with the realism and pragmatic philosophical worldview, supports an exploratory mode and is relevant to the complex activities' nature phenomenon. Basically, for the whole desing process, there are three main activities involved: i) Activity 1 is to identify the complex domian and its challenges, ii) Activity 2 is to develop the visual analytics design as the solution for complex domain, and iii) Activity 3 is to evaluate the usefulness of the visual analytics design.

To achieve the objective of this research, we only focus on Activity 3 – the evaluation process. Basically, there are three phases involved in the evaluation process; i) Phase 1- Demonstration, ii) Phase 2- Evaluation and iii) Phase 3- Communication and these are shown in Fig 2. Nevertheless, DSRM alone is insufficient to handle the complex-environment visual analytics evaluation process. There is a need to embed HCD-ACD and consider the collaborative perspective within the process. Hence, this research focuses on group observation method to demonstrate and access the effectiveness of visual analytics using three different scenarios. During these evaluations, the visual analytics design are identified and observed to solve Collaborative-CCA challenges by comparing the objectives set with the observed findings in a natural setting. The practicality of the evaluation is also essential since the artifact is new and it is in an explorative mode [39]. By undergoing the evaluation process based on DSRM, the foundation for each phase is grounded from a credible knowledge base (shown as the right box in the Fig. 2). Knowledge base contains all the related knowledge as a foundation to support the evaluation process. Since DSRM concerns about the growth of knowledge over time, the proposed evaluation process needs to prescribe all the related knowledge involved. As these knowledge from different sources are employed in the evaluation process over time, additional prescriptive knowledge may be discovered to increase the current knowledge on their use.

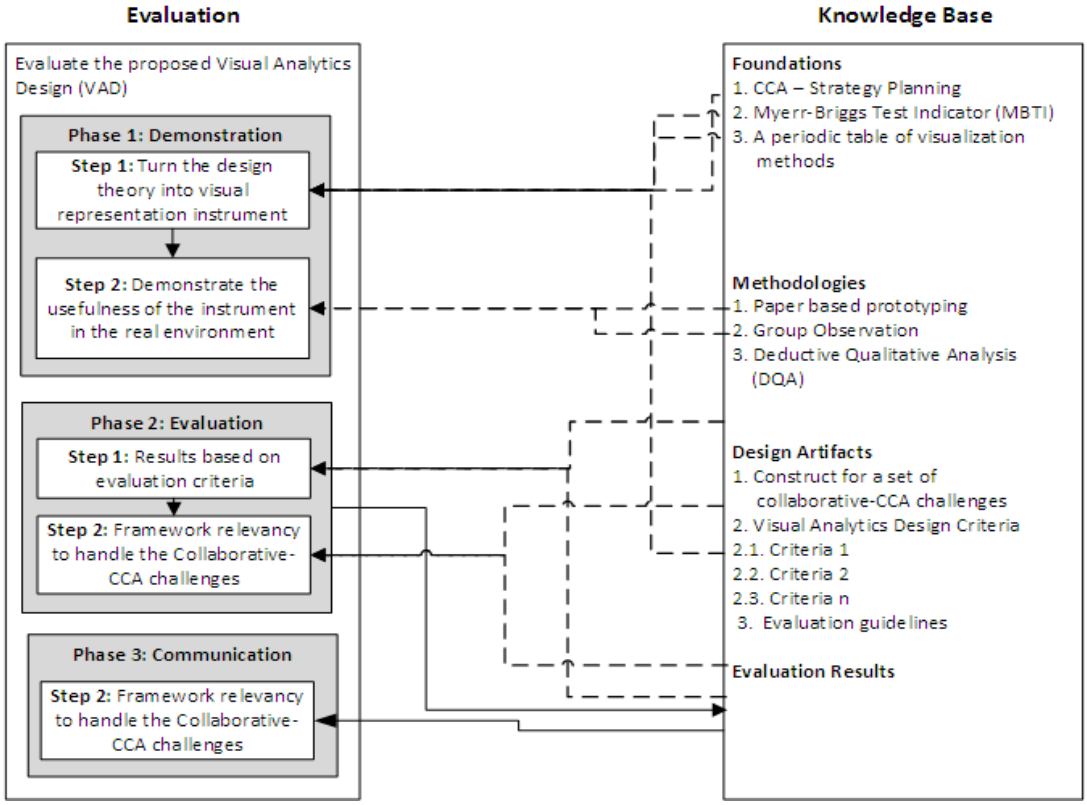


Fig 2. The Evaluation Process in the Complex Domain

### 3.1 Phase 1 of the Evaluation Process - The Demonstration

The demonstration phase is important to gather the users' context use and then demonstrate the design theory into visual analytics as an instrument that can be used during the evaluation later. According to [40], demonstration is the process to demonstrate the use of the artifact to prove that the artifact works by solving one or more instances of the problems. The most important part during the demonstration is to explain on the 'how' knowledge to use the artifact to solve the problem and further describe how the applicable visual design is workable for users'. Here, there are demonstation cornerstone for the complex domain. Since complex situation is in more natural and context dependent, the demonstration only can take place after the sampling and criterion of the users and activities have been identified. Therefore by knowing which context to be investigate, then the demonstration artifact can be customised accordingly. Further than that, the demonstration is quite challenging since the research focused more about prescribing design theory and principles instead of desribing the design elements. Generally, according to [41], design theory and principles are conceptual and at the higher level of abstraction since they are explaining why the theories or principles prescribed is neccessary to support specific complex domain while the visual representation instrument must be workable for the visual analytics usage in which is more on describing what the design elements are and how to implement them.

From the ontological point of view, the design theory and principles can be translated and working from a diverse of the technological point of view. Due to the iterative cycle as mentioned in paragraph 2.2, the research found the set limitations for the demonstration. In this case, the research demonstrated the design theory and principles into visual analytics instruments by putting some limits on the scope and utilising the previous tools and methods as described in the list of Table 1. However, the research does not limit this as the only way to demonstrate and apply the design theory of visualization. It can be diversified according to the developer's creativity and technological point of view. In this demonstration, we scoped down the complex cognitive activities by focusing only on a certain CCA type. Even though the description will generally describe the evalution from Collaborative-CCA perspectives, this paper will mainly use the Strategy Planning as one type of CCA for the purpose of consistency. Furthermore, based on the knowledge base as shown in Fig 2, the demonstration also utilised the prior visualization and other research works such as Knowledge Visualization Framework (KVF), Myer-Briggs Testing Indicatior (MBTI) [42] and visualization taxonomy to help during the demonstration and minimized the cost and time consumed on developing the mockup of the visual representation instrument conception on the paper based platform. The execution of the demonstration will be further explained in the next paragraph.

Table 1. The Limitation for the Demonstration based on Complex - CCA Types
(For the purpose of consistency, the limitation focus on the Strategy Planning as CCA Type)

| No of Limitation | Description |
|---|---|
| Limitation 1 – CCA Type | Since there are numerous type of CCA and each of it has more details and its own field of study, we recommend the evaluation to research concentrate only on one type of CCA (e.g. Strategy Planning, Decision Making and Sense Making). In this case, we used Strategy planning as the CCA type for this particular demonstration and evaluation. Since the strategy planning always involve multi division, roles and people in the organization, thus it is suitable for the collaborative case. Other than that, strategy planning is also related to other type of CCA like decision making, problem solving and sense making. |
| Limitation 2 – Identifying Individual cognitive type using MBTI | For identifying the personalization during the context of use, Myerr-Briggs Testing Indicator (MBTI) has been used to identify the user's cognitive type and personality that have been involved in the Collaboration. The use of MBTI is important during the process of understanding the users and their context of use to create a shared understanding. |
| Limitation 3 - Individual cognitive type for the awareness of different mental model | Individual cognitive type based on MBTI can be widely used to elaborate about personalization and behaviourism. It can help to let an individual get more understanding about their learning type, potential career and why they behave a certain way. However, for this particular demonstration, the research used MBTI results to bring awareness to the users about their different cognitive style. This will help to explain why they may face different opinions and thoughts during the collaborative-CCA process. By understanding their own and group members' cognitive styles, it might help to lose some tense and bring more understanding about him/herself and also their peers during the constructive arguments. |
| Limitation 4 – The selection of visual structure - periodic table of the visualization menthods | The visualization field has developed various taxonomy, classification and aggregation. Most of them are based on task, data type and function [43]. Based on the strategy planning as the CCA type, this demonstration is referring to a periodic table of visualization methods as the classification for the management tasks in the organization [44]. Thus, the selection of the visual structure will be focused only from this table. |
| Limitation 5 – Paper based prototyping | Paper-based mockup is well known and widely used in a user-centered design process. This method of prototyping enables the visual representation design to be the visual representation instrument. It is simple, cost-saving and practical to be used. Another benefit of paper based prototyping is being more flexible and free-and-easy to use since the users can see, write, draw, delete and add information on the visual structure based on their needs during the evaluation. More over, it is capable to cater the needs of perceived finishednes and modifiability on the visual structure and allow the dynamic interactivity that is seldom and expensive to have due to current market technologies. |

### 3.2 Phase 2 of the Evaluation Process - The Evaluation

Based from the activity central point of view, the evaluation should be able to observe how the visual analytics instrument is able to facilitate the Collaborative-CCA process. By taking into account the necessity of sampling and research method based on the activities and processes, the focus group observation is chosen as the method to evaluate the visual analytics. Using this method, the research was able to observe the interactive collective process while the participants performed CCA face-to-face in a collaborative setting (e.g., meetings, discussions, and workgroups). The method is selected to balance between the values of freedom of qualitative methods and the control environment for the deductive process. This is because, the investigation of complex phenomena especially when dealing with the activities is not a straightforward process [45]. Even though the usage of visual analytics is essential for evaluation criteria, the natural settings for activities are also important.

Thus, the evaluation phase has embedded the qualitative component by observing the activities in a real setting. The evaluation can only take place when the visual analytics instrument as the outcomes from the demonstration is completed. It will act as the control environment during the evaluation process. Based on the iterative cycle as mentioned in paragraph 2.2, the evaluation guidelines suggest to provide a minimal elements of control during the focus group observation in order to give the participants more freedom to act comfortably in the natural settings. The research found there are two essential elements to control the evaluation:

- The goal/aim of the complex cognitive activities to be performed as a group. To lessen the control, we recommend the researcher to discuss and set the goal based on the agreement with the participants during the understanding for the context of use earlier in demonstration phase.
- The visual analytics instrument that had been derived from the VAD demonstration to facilitate the participants.

Due to the collaborative setting, there are approximately four to six users in the group, thus time duration of 90 to 120 minutes are sufficient to give them ample opportunity to speak their mind and go into details regarding certain points. During that time, the participants in the group should be gathered in a meeting setting. Based on the goal, the groups are to discuss as in a normal meeting or discussion group as long as they would refer and utilize the provided visual analytics instrument. Then, the researcher should observe and record the activity as an evidence on how the visual analytics instrument is able to facilitate the complex domain.

### 3.2.1 The Unit of Analysis and Criteria for the Evaluation Assessment

Along with the collaborative consideration, the unit of analysis for the evaluation is the interactivity between users and visual analytics instrument. In spite of evaluating the usability that weight more on instruments's ease of use, the research focused on the usefulness to highlight the instrument's quality of being useful [19]. Thus, in this research, the interactivity will be observe through an interactive collective analytical process. Based on this unit of analysis, the criteria for the evaluation is based from the reflection of the VAD roles and Collaborative-CCA challenges and presented in Table 2

Table 2. The Criteria, Sub-Criteria and Unit of Analysis for the Evaluation

| Criteria | Elements of the criteria | Unit of analysis |
|---|---|---|
| **Criteria 1:**<br>Capabilities to centralize the complex cognitive activities. | - Centralized mental model<br>- Clarities on how knowledge can be formed | Interactive collective analytical process |
| **Criteria 2:**<br>Capabilities to facilitate the convergence. | - Show clarity about the main drivers<br>- Can observe and draw the interconnection between various elements | Interactive collective analytical process |
| **Criteria 3:**<br>Capabilities to handle the emergent patterns | - Contextual guidelines for knowledge Construction.<br>- Extent mental model for constructive Content | Interactive collective analytical process |

Based on the need to understand the interactivity process, the researcher will observe the focus group throughout the Collaborative-CCA process [25, 46]. The method requires that events must be in natural settings to perform better within the real context. Thus, the qualitative method is the most relevant one [47-49]. However, since we are evaluating the VAD, the evaluation must be able to access the VAD capabilities to play the intention roles. Then, the evaluation analysis will be carry out deductively by using deductive qualitative analysis (DQA) [50, 51]. By having deductive approach, the evaluation will become more specific and focus on accessing the usefulness of VAD principles based on these criteria. By following Hevner's [35] suggestion, in order to access the utility (effectiveness) of the VAD to handle and facilitate the collaborative-CCA process. Therefore, each of the criteria is the reflection from the challenges identified in previous research as mentioned in paragraph 2.1 and it must be able to play the visual analytics roles.

### 3.2.2 The Sampling Strategy and Participation

Sampling is the process of selecting units from a population of interest. Purposeful sampling is well-described by [51] with variation of 16 types of it. In this study, this sampling is employed based on [53] to investigate the effectiveness and the value of the VAD in facilitating the Collaborative-CCA process. Based on the purposeful sampling strategy and collaborative-CCA activity-based, the participation is based on the CCA. For example, for CCA type of strategy planning, the participants are the management team who execute the strategy planning in the selected organization. Three (3) groups of users have been selected from different organizations from the public and private sectors in Malaysia. The examples of sampling strategy and participation for focus group observation are shown in the Table 3.

Table 3 The Example of Sampling Strategy and Participation for Focus Group Observation.

| Group | Goal to achieve | Subject Domain |
|---|---|---|
| Group 1<br>(4 participants) | Product Development Strategy | Agriculture investment for 18 acres of land in Nilai, Negeri Sembilan |
| Group 2<br>(5 participants) | Business Developement strategy | Business investment on 2500 square feet of land at Kuala Lumpur |
| Group 3<br>(5 participants) | Inclusiveness and ownership Strategy for Public Sector Transfromation Programme | Collaborative decision strategy for public sector professionalism (Public Sector Department) |

Furthermore, the evaluation focuses on activities, thus, the sampling must come from the Collaborative-CCA activity-based and in real settings. As a result, less restriction has been put on the participants' individual criteria since the focus group observation needs to be more flexible and adapts the real case necessities [38].

### 3.2.3 The tasks and settings

Since the main concern of the evaluation is to observe how the visual analytics facilitates the Collaborative-CCA process, the visual analytics instrument must act as the control environment (instrument) for activities' enablement. The design of this study does not limit the freedom of participants to act, think, draw and express their views during the Collaborative-CCA process. Based on the focus group, the evaluation should be able to observe the feedback loops between participants and the instrument for visual representation. Basically the tasks and settings for focus group observation are divided into three stages: before, during and after the observation. Before the observation, the consent form has been given to each of the participants. Then the researcher demonstrates the VAD into the visual representation instrument that would be used during the focus group activity. During the observation, the practicality of the instrument will be observed and evaluated. Then, after the observation is the data gathered will be analysed to get the valauble findings.

### 3.2.4 Data Collection and Management

As noted earlier, the main goal for the evaluation is to see how the VAD is useful to facilitate the participants in handling the complexities in the collaboration while performing CCA. In order to capture how the visual analytics is used, the research uses three types of data-capturing devices so that the triangulation of the analysis can be done. This includes (1) audio recording of the discussions among the users, (2) video recording to capture the human interactions not easily recorded using audio; and (3) annotation in the visual representation application [48]. A summary on the data collection method is provided in Table 4.

Table 4: Data Collection Methods

| **Data collection methods** | **Type of data** | **Samples of data** |
|---|---|---|
| Audio recordings for the discussions | Verbal language, suggestion, ideas or arguments and communication between the users while referring to visual representation | *"I can see the interconnection clearly"* |
| Video recordings | • Physical actions and gestures during communication among the users and visual representation.<br>• Physical actions and gestures while communicating between the users by referring to visual representation<br>• *(body language – posture, gesture, facial expression, eye movements)* | • The users pointing to the visual representation<br>• Clarification of the expressions<br>• Users writing the input, sketches or links within the visual representation |
| Content records in the visual representation instruments | • Sketching<br>• Writing text, important points and symbols on the visual structure | • Drawings lines or symbols between two parts.<br>• Writing something onto the visual representation |

### 3.2.5 Deductive Qualitative Analysis

Thematic analysis was carried out after the transcription for the three cases. The analysis was conducted based on the deductive qualitative analysis – DQA [51]. The thematic analysis process based on open coding was carried out as usual and the codes for a theme had been assigned according to the criteria and unit of data analysis. We first transcribed the relevant verbal expressions into quotations. Each quotation would then be grouped according to similarities, after which themes/subthemes would emerge. Since we are evaluating the visual structure, triangulation was essential to complement each of the quotations with video observations and content records in the visual structure that were related. To avoid misleading interpretation, the researcher also made the peer-review session to check the themes and findings interpretation. During that session, the peers reviewed the quotation, video observation and content records in the visual structure. Then the peers agreed, disagreed or gave an opinion for each of the identified interpretation for each of the sub themes. After the peer review session, the result and findings from the evaluation were finally discussed appropriately.

## 3.3 Phase 3 of the Evaluation Process - The Communication

Finally, communication phase will let the research to justify the contribution of the research outcomes towards the visualization fields and its users. This phase is relevant within the perspective of realism since the findings need to be disseminated among academicians and practitioners and their feedback would indicate whether the evaluation approach is useful for users or otherwise [55]. After finishing all of the demonstration and evaluation phases, the research findings need to be communicated in order to understand how well it contributes to the body of knowledge and the users. Generally, Gregor & Hevner [56] have identified four key questions to be addressed during the communication phase; i). Are the problems discussed in the paper of substantial interest? Would solutions of this problem materially advance knowledge of theory, methods or applications? ii). Does the solution make contributions that improves substantially upon previous work? iii) Are the methods of solution new? Can the proposed solution methods be used to solve other problem of interest? and iii). Does the exposition help to clarify our understanding on this area of research and application? Since this research is rooted from the visualization field that applied DSRM for having an effective visual representation design for the Collaborative-CCA process. That means, the research must be able to present and communicate the outcomes from the visualization as the body of knowledge, then from here – it will explain how the visualization outcomes will bring benefit to the visualization field and it's users. After drafting the outcomes, the reseach will communicate the process and the outcomes by having the review and discussion with the experts from the methodological, visualization and subject matter.

## 4.0 DISCUSSION AND CONCLUSION

This research work has proposed the Human-Activity Centric Evaluation as a potential evaluation process for visual analytics in a complex domain. Using a suitable methodology has been a challenge in visual analytics evaluation especially in a complex domain. By reflecting to [3], [56] and [57], a complex domain is usually the domain that organization users who are usually experts and decision makers, use visual analytics to solve open ended, unstructured, complex problems involving extensive and recursive decision making. In addition, the evaluation design is not always straightforward. The evaluation needs to go through several cycles in order to determine the best practice and this requires more time and cost. Often, experts and decision makers have different level of knowledge, roles and expectation. Thus, this raises the most appropriate manner to evaluate visualization among different target users. Therefore, an evaluation should be practical in representing specific types of visual data for specific type of users. Furthermore, there is also need to study how people develop and use visual analytics in a wider context of their tasks and activities. Hence, instead of centralizing and involving only the users during the evaluation process, this research work also focuses more on the rationales based on the activities of the Collaborative-CCA phenomenon. It has gone beyond users and discovered more on the contexts of use and the activities involved. This is done so that the evaluation should be able to identify the effectiveness of the visualization solution. Since the visualization field itself lacks a suitable evaluation process, DSRM has been used as the backbone of the evaluation. One of the advantages of using DSRM is the flexibility for the phases to be combined with other appropriate methods. The adaptation of other theories and methods is needed most since a complex domain is uncertain and it is context dependent. Therefore, it can be said that the expansion of DSRM is capable in guiding the evaluation under these conditions.

More natural evaluation guidelines in its environment is essential to move visual analytics' field from research to practices. This is because, evaluation for visual analytics is usually based on experiments and quantitative approach [34]. From realism perspective, we bring some cornerstone to evaluate the visual analytics in more natural settings and qualitative approach. Furthermore, the evaluation emphasized the suitability of visualization design by accessing its usefulness to handle the identified challenges. By offering a set of evaluation recommendations, this research aimed to improve the experience for the visualization community to evaluate in a more flexible, dynamic and intuitive way. At the same time, brings balance between the environmental control and context's natural settings. Furthermore, it will properly guide the evaluation by explaining the evaluation criteria, sampling strategy and participation, focus group tasks and settings and finally data management and analysis as summarized in Table 5.

Table 5: Summary of Evaluation Guidelines for Visual Analytics in the Complex Domain

| No. | Scope of guidelines | Descriptions |
|---|---|---|
| 1 | Evaluation Method | The evaluation method used for Visual Analytics's environment evaluation is the Focus Group Observation. This evaluation is aimed to understand the practical usefulness of the visualization design theories in facilitating the context of use. In order to do that, the evaluation need to observe the interactive collective process of the users while performing their activities |
| 2 | Evaluation Criteria | Unit of Analysis is the interactivity between the users and visual analytics instrument in the natural settings of the collaborative-CCA phenomenon. Evalution criteria for effectiveness is the reflection from the identified challenges from Visual Analytics' environment. |
| 3 | Sampling strategy and participation | The evaluation used purposeful sampling strategy. Through an iterative process, the research loosened the criteria of sampling because the evaluation intends to observe the activities during the interactivity process in a natural way. Thus the focus group observation seems to be more flexible and open ended to adapt the real participants and activities' necessities. Due to the consideration of intensity and richness of qualitative data collection, analysis and interpretation, the research found three (3) groups have been sufficient to show the effectiveness of visual design. Approximately 4-6 users in the group. |
| 4. | Duration | 90-120 minutes. |
| 5 | Focus Group tasks and settings, | <u>Before the Focus Group Observation</u><br>• Gather the group context of use.<br>• Demonstrate the visual design theories into visual representation instruments that can be used during the focus group observation.<br><br><u>During the Focus Group Observation - accessing the usefulness criteria.</u><br>• Visual representation instruments as the probe during the focus group.<br>• The participants in the group of 4-6 people were gathered in the meeting room.<br>• The group were to discuss as in a normal meeting or discussion group as long as they would refer and utilize the provided visual representation.<br>• The focus group lasted around 90-120 minutes.<br>• The research observed and recorded the interactivity as evidence on how the visual representation would be able to facilitate the context of use. |
| 6 | Data management and analysis. | Three types of data-capturing device to collect, store and manage the data:<br>• Audio recording of the discussions among the users.<br>• Video recording to capture the human interactions not easily recorded using audio.<br>• Annotation in the visual representation application.<br><br>Deductive Qualitative Analysis (DQA)<br>• The thematic analysis process based on open coding was carried out as usual, but the codes for a theme had been assigned according to the unit of data analysis and evaluation criteria as mentioned in the second row above.<br>• Transcribed the relevant verbal expressions.<br>• Quoted any appropriate from transcriptions. Each quotation would then be grouped according to identified themes/subthemes.<br>• Triangulated the interactivity from video observations and contents records in the visual structure to complement the identified quotation /subtheme /theme |

HACE provides more practical guidelines. The visual analytics evaluation for complex domain will be more systematic and the outcomes can be more rigor, relevant and trusted. This research has sensed the potential of HACE as an evaluation process to guide users in doing visual analytics for specific use and in natural setting. The capabilities of DSRM to play the directive and macro-manage role let the evaluation process guided on the right path and yet at the same time is able to give freedom in evaluating visual analytics according to its function, quality and context. The balance between guidance and freedom is essential in a complex evaluation process. Too rigid on the guidance will kill the creativity, ideas and exploration of visualization practices. However, if it is too loose, then we will come back to square one – no comprehensive guidelines for evaluating the practices of visual analytics in its environment settings.

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