

Framework for Developing Interactive Dashboards and Evaluating Their Usage Effectiveness: A Case Study

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Abstract

This research proposes a framework to develop interactive dashboards and evaluates the effectiveness of using them in improving data management, data analysis, data visualization, and information sharing. A case study in an electronics manufacturing company located in the United States was conducted to implement the proposed framework with a main focus on business and financial information. The framework is comprised of four main phases; pre-assessment to assess the current situation, standardizing the format of the databases, creating interactive dashboards, and post-assessment to evaluate the suggested improvements. The proposed framework proved its effectiveness in creating standardized databases and interactive dashboards based on the results of the pre/post assessment. The assessment showed positive feedback on how the use of dashboards helps in improving the four-evaluation metrics; data management, data analysis, data visualization, and information sharing.

Keywords

Data Analysis, Data Visualization, Interactive Dashboards, Information Sharing, and Data Management.

1. Introduction

In the last decade, with the increased technological development in different industries, the volume of data generated and transferred by different sources continues to grow, this emerges the need of applying effective techniques by companies to manage, analyze and visualize their data in a way that supports the process of making different business decisions and keep them competitive in the market (Hu et al. 2014). However, implementing these techniques in practice remains a challenge due to different factors such as the lack of a well-established systemized framework to transfer from the traditional approaches of making decisions to the use of data analysis and visualization techniques to draw different insights and trends which will help in making key business decisions.

Interactive dashboards are considered one of the main emerging tools that facilitate the process of analyzing and visualizing data by offering a single display that shows the most important business information based on the available data (Alhamadi et al. 2020). Despite the wide adaption of this technique, the number of researchers that discuss the best way to integrate this technique in practice and real case examples is still limited. In addition, the evaluation of the effectiveness of using dashboards to support different business decisions still needs to be further studied using real industry feedback. In this study, a framework to build interactive dashboards has been proposed to improve data management, data analysis, data visualization, and information sharing. This will be applied in an electronics manufacturing company with a main focus on managing the business and financial data of the company projects. *Please note that any examples used herein are with hypothetical values and customer interactions in order to protect confidentiality and IP concerns.*

The proposed framework consists of four main phases. The first stage is pre-assessment of the current state. This phase is comprised of defining the dashboard layout, data selection, data collection, and a pre-assessment survey that will be used to evaluate the current tools in terms of data management, data analysis, data visualization, and

information sharing which the company uses for managing and visualizing their data. The second phase is to standardize databases. This includes standardizing the database form based on the needed data to be included and filling in the missing dataset based on the required fields of the newly developed standardized form. The third phase is creating interactive dashboards. In this phase, the dashboard software will be chosen based on information needs and requirements, also the data from the standardized databases will be transferred to be visualized, the final step in this phase is to finalize the process of creating the interactive dashboards based on the required layout of the dashboards that were defined earlier. The last phase in the proposed framework includes a post-assessment to evaluate the suggested improvements of using the standardized databases and the interactive dashboards to measure the effectiveness of applying them based on the evaluation metrics.

The suggested framework aims to provide businesses with a process guideline to improve their data management and visualization, which will lead to enhanced decision-making processes and improved business performance while reducing the time and effort required to develop interactive dashboards of their data. Also, the evaluation of the effectiveness of adopting the proposed improvements will help businesses to decide on integrating dashboard usage within their processes.

1.1 Objectives

The research aims to propose a framework for developing interactive dashboards and applying it in a real case. But to repeat an earlier point, examples within this paper are hypothesized. Also, the effectiveness of using dashboards in terms of improving data management, data analysis, data visualization, and information sharing will be evaluated.

2. Literature Review

Recently, with the increased interest in utilizing the available data for the benefit of making different business decisions, many studies investigate the role of managing and analyzing data using different visualization tools. A review study by Qi and Li (2020) includes an overview of data visualization, which defines data visualization as “the science of visual representation of ‘data’”, indicating that data visualization has many visual forms. The main visual forms which can be combined in a single display using dashboards include trees, scatter plots, charts, tables, maps, diagrams, and graphs.

A study by Gupta et al. (2016) indicates the importance of data visualization and analytics in decision-making in different sectors. They emphasized on the big role of utilizing data in visual means to lead to new business opportunities and on representing innovative ideation which will help in improving companies’ performance.

Yigitbasioglu and Velcu (2012) define dashboards as “a visual and interactive performance management tool that displays on a single screen the most important information to achieve one or several individual and/or organizational objectives, allowing the user to identify, explore, and communicate problem areas that need corrective action.” Their study shows that the using of dashboards for data visualization and analysis improves decision-making by amplifying cognition and capitalizing on human perceptual capabilities by optimizing the selection of relevant information to be focused on. They also indicate that there is a lack of current research on the uses of dashboards in business and further studies are needed in this field.

Few studies have been found that suggest a framework to develop dashboards. A recent study by Conrow et al. (2023) proposes a conceptual framework for big mobility data dashboard design and development as shown in Figure 1. They suggest five essential components in their framework; data selection, data transformation, comparison, visualization, assembly, and, the last step, is dashboard display. They applied the proposed framework to different applications, and the results show that following this framework can help developers understand and develop dashboards in an effective way.

Noonpakdee et al. (2018) suggest a framework for analyzing and developing dashboard templates for small and medium enterprises. Figure 2 shows the proposed framework that consists of four main stages, namely, event/business operation, attribute list, visualization, and dashboard capabilities. They applied the proposed framework in 40 different SMEs for 6-9 months, and they evaluated the effectiveness of applying it, the results show by applying dashboards, the companies were able to reduce cost, save time, and make better decisions.

Lempinen (2012) proposed a framework to develop dashboards as indicated in Figure 3. The framework aims to answer three main questions:

- What to measure?
- Where and how to capture data?
- How to deliver performance information to the users?

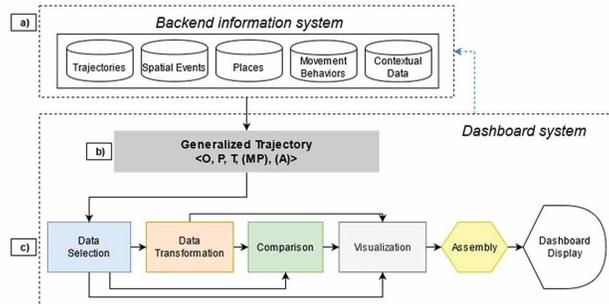


Figure 1. A Conceptual Framework for Developing Dashboards for Big Mobility Data (Conrow et al. 2023)

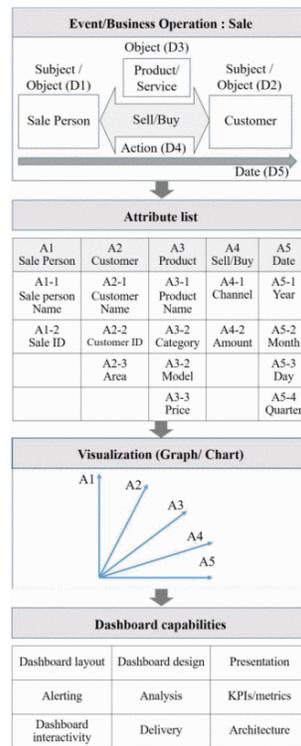


Figure 2. Framework for Analyzing and Developing Dashboard Templates (Noonpakdee et al. 2018)

The framework has been applied in a real case study in Finland, and the results show that the framework is useful in addressing the main steps in developing and designing dashboards.

A framework shown in Figure 4 proposed by Vilarinho et al. (2017) consists of the first diagnosis of the production area of the company, requirements for the dashboard, defining a template for the dashboard, assuring the existence of necessary resources and the last step is the implementation, evaluation, and improvement of the dashboard.

Design challenge	What to measure?	Where and how to capture data?	How to deliver performance information to the users?
Design principles (product related)	P1: Define a general performance measurement framework	P3: Analyze systematically how each measure should be put into operation	P5: Design for efficient integration to source systems
	P2: Follow a structured process for selecting key measures	P4: Ensure completeness and quality of data	P6: Design for an effective user interface
Emerging principles (process related)	P7: Use an iterative, agile development process		
	P8: Use a modular approach in system design		
	P9: Facilitate interaction between the interest groups and individuals		
	P10: Ensure user involvement at each phase		

Figure 3. A Design Framework for Performance Dashboards (Lempinen 2012)

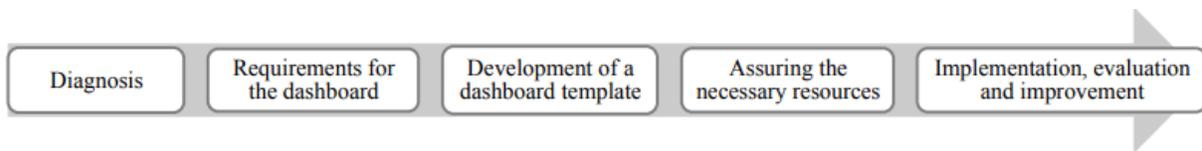


Figure 4. Main Stages for The Dashboard Design Procedure (Vilarinho et al. 2017)

3. Methods

3.1 Develop the Framework

The proposed framework for developing an interactive dashboard has been adapted from Vilarinho et al. (2017), with modifications made to enhance the model and make it more compatible with the objectives of this study. The framework proposed by Vilarinho et al. (2017) did not include a stage for standardizing databases to ensure all databases have the same format or a post-assessment step to evaluate the effectiveness of using the dashboard. In our proposed framework, we have addressed these gaps by including these additional steps. A literature review was conducted first to check the available studies, the full review is available in the literature review section. Figure 5 shows the proposed framework's main components with the steps involved in each phase.

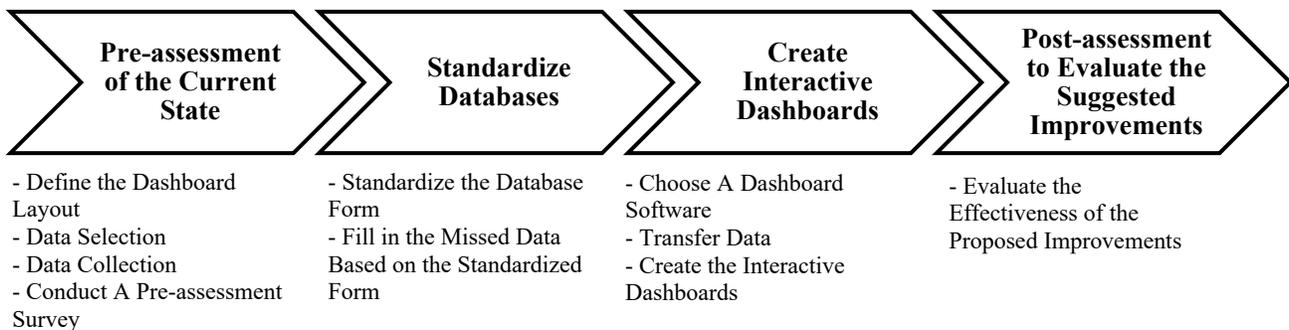


Figure 5. The Proposed Framework

3.1.1 Pre-Assessment of the Current State

This step is important to define the objectives of building the interactive dashboards and to define the layout of the dashboard including charts and interactive elements such as drop-down lists or filters. The next step is to specify the data that will be considered, data selection depends on the information that needs to be drawn by the users of the dashboards. After defining the data to be considered, the next step is collecting the data. This depends on the current data managing technique used by the company. If the company has already a system to collect data, this will make this step easier, and only data cleaning will be needed to make sure all the needed data are available for all inputs. In case the company does not have a ready-to-use database, the process of collecting data should take place by either

measuring it or requiring it from different sources. A standardized data collection process should be followed by specifying the data sources, defining the method of collecting data, developing the data collection instrument, collecting the data, verifying the data, cleaning the data, and then storing the data (Willison and Miller 2014). The data can be stored using different applications, spreadsheet software such as Excel and Google Sheets which is considered one of the most widely used applications, Enterprise Resource Planning (ERP) software like SAP, NoSQL Databases, and Relational Database Management Systems (RDBMS) such as MySQL, Oracle, and Microsoft SQL Server.

After that, the process of conducting a pre-assessment using surveys will take place. In this study, we are interested to evaluate the current improvements in terms of data management, data analysis, data visualization, and information sharing. The survey will include questions that evaluate each metric, and a 5- Likert scale will be used to fill the survey questions. The pre-assessment should include the users who work on the data and are responsible to draw insights and make business decisions based on it.

3.1.2 Standardize Databases

After collecting and cleaning data, the datasets will be organized into standardized databases to ensure consistency and compatibility across different databases and to make sure that all of them have the same type of data arrangement. The choice of standardized format depends on the users' preferences which should be arranged in a logical way based on unique ID numbers and with the same unit of measurement for each input data.

3.1.3 Create Interactive Dashboards

Standardized databases can be used to create interactive dashboards. The first step is to evaluate the software used to create dashboards and choose the one that fits users' requirements, the complexity of data, ease of use, available features, and the technical expertise of the users, examples of popular dashboard software are Tableau, Microsoft Power BI, and Google Data Studio.

After choosing the appropriate software, the databases will be transferred, and based on the planned layout of the dashboard, different chart types (such as bar, line, or pie charts) can be created to convey the data. In addition to building the charts, the interactive elements of the dashboard will also be considered in this step. At the end of this phase, the dashboards would be ready to be used.

3.1.4 Post-assessment to Evaluate the Suggested Improvements

The last step of the proposed framework is to evaluate the effectiveness of the standardized databases and the interactive dashboards using the same measures used in the pre-assessment; data management, data analysis, data visualization, information sharing, and collecting feedback from the same users. This stage includes the implementation of the suggested improvements and then conducting the post-assessment. Based on the results of comparing the pre-and post-assessment improvement actions, the effectiveness of using suggested improvements will be evaluated.

3.2 Apply the Framework in A Real Case

A case study in an electronics manufacturing company located in the United States (US) was conducted to implement the proposed framework. The company was interested to have a dashboard per project with a main focus on business and financial data. The data included in this study has been subject to scaling and transformation for analytical purposes. Also, for confidentiality reasons, the name of projects and customers have been modified.

3.2.1 Pre-Assessment of The Current State

The case study is a company located in the US that specializes in producing electronic products and adopts a projects-based approach in managing their operations, each project has multiple phases. Based on their request, the objective of creating the interactive dashboards is to assist the business and program department in better analyzing and visualizing the financial data for each project, which will inform the decision-making and will make the process of identifying the delays and errors easier with fewer efforts and time required.

The company was interested in having an interactive dashboard for each project that shows the following information with the interactive elements in the dashboard being the project phase and the year quarter:

- The total number of purchase orders (POs) received.

- The total number of POs that have been invoiced.
- The total value of the POs received in dollars.
- The total value of the POs invoiced in dollars.
- The differences between POs' total amount received and invoiced per quarter.
- The differences between POs' total amount received and invoiced per product.

The below databases were considered for each project:

- POs logs, including PO number, product, quantity, total amount, and PO date.
- Invoices logs including invoice number, invoice date, and invoice amount.

The company uses Google Sheets to store its data and also utilizes SAP software to collect the related data. The data needed to create the dashboard was already available by the company, they only need to standardize the databases for all projects, which will be shown in the next phase. They depend on the data available on sheets to make decisions and financial reporting. With these huge and multi databases, this is expected to need a lot of time and effort with the possibility of making errors and losing data.

To evaluate the current state based on the four measures of data management, data analysis, data visualization, and information sharing, a pre-assessment survey was distributed to the business program managers working at the business department and deal with these data on a daily basis and need to draw a significant amount of business decisions based on it.

The pre/post-assessment survey was designed with questions that aimed to evaluate the above-mentioned measures using a 5- Likert scale with these response options (1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly agree). The response rate was 100% (all of the employees working in the department participated in the study). Table 1 shows the survey questions with the corresponding measures.

Table 1. Pre/Post Assessment Survey Questions

Measure	Survey Questions
Managing Dataset	Standardized sheets to collect and track PO details are available
	PO's tracking sheets are easy to use and understand
Data Visualization	The used technique of data visualization provides a quick and effective way to communicate information using visual information
	The used technique of data visualization is effective and simple which can provide immediate answers to the most important questions about the dataset
	The used technique of data visualization allows for easy data filtering
Data Analysis	The technique used for data analysis is effective to extract information and general statistics from the dataset including identifying patterns and trends
	Search for specific Information does not need a lot of time using the current technique of data analysis
	You can find the information you need using the available data analysis technique
	The information is up to date and relevant using the available data analysis technique
	The information is available in one source when using the available data analysis technique
Information Sharing	You are satisfied with the process of sharing information and areas of knowledge across teams or departments
	You are able to quickly answer repetitive questions or help others look for information they need to perform their duties by using the available data analysis and visualization technique

3.2.2 Standardize Databases

The databases were standardized based on the employees' suggestions, needs, and ease of use. The company uses Google Sheets with different formats and input data for each project as the only tool to analyze and visualize data, these sheets were used as databases to create one standardized sheet that has all the required data to create the dashboard per project. The unique PO number was used as a key element to link the two databases.

3.2.3 Create Interactive Dashboards

After comparing the available software, Google Data Studio was used to create the dashboards based on the following features:

- Easy integration and transferring data between Google products: since the current format of the standardized sheet in Google Sheets, there is an available option to directly link the data sheets with the software, with live synchronization and real-time data refresh. Any changes or updates in the standardized sheet will directly be reflected in the dashboards.
- It offers interactive and dynamic visualizations.
- Collaboration features.
- It is available for free.

The data is then transferred and uploaded to Google Data Studio. Based on the planned layout of the dashboard, the charts and the interactive elements will be added. The developer of the dashboard should test it to make sure that it is ready to be used. In our case, the dashboards are tested by trying to return some information based on the project phase and the year quarter.

3.2.4 Post-Assessment to Evaluate the Suggested Improvements

The employees in the business department were requested to start using standardized sheets and dashboards in their daily work instead of the previous sheets. After that, the post-assessment survey was distributed with the same questions used for the pre-assessment to evaluate the suggested improvements.

After implementing the proposed framework, and in order to evaluate the effectiveness of using the dashboards, we performed analysis on the pre-and post-assessment survey results. The Likert scale is considered ordinal data and normally it is analyzed using the median and mode as descriptive statistics and by using non-parametric tests (Wilison and Miller 2014).

The Wilcoxon Signed-Rank test is a useful tool for analyzing paired data and was used in our case since it is a non-parametric test and is usually used to compare the differences between two measurements taken from the same individual or group at different time points which will be helpful to check the effectiveness of adapt improvements (Woolson 2007).

The hypothesis for the Likert-type questions is:

- H_0 : Using dashboards does not have a significant effect on the metrics and it is not effective to use it
vs. H_a : Using dashboards has a significant effect on the metrics and it is effective to use it

After finding the test statistic (W) which measures the degree to which the positive differences between paired observations are larger than the negative differences, and determining the corresponding P-value, the null hypothesis was rejected if the P-value was below the level of significance (Sil et al. 2019).

5. Results and Discussion

5.1 Standardize Databases

Table 2 shows a sample of the standardized databases for one of the company projects. This form applies to all projects and will be used to create the dashboards. As indicated before, it contains all the related data for each PO with the corresponding invoices. Using this format of databases organizes the project data and combines all of its related information in one sheet which allows for better analysis.

Table 2. Sample of The Standardized Databases (Hypothetical Data)

PO #	Phase	Product	QTY	U/P	Sub Total	Total	PO Date	Need By	Invoice d	Invoice #	Invoice date	Due date	QT Y	Invoice Total Amount
Q1/23														
580000000	XY	BLUE	60	\$2,270.66	\$136,239.30	\$136,239.30	1/3/2023	1/13/2023	Yes	888000001	1/10/2023	2/24/2023	60	\$136,239.30
680000000	ZY	RED	149	\$2,425.92	\$360,248.38	\$687,222.70	1/3/2023	1/13/2023	Yes	888000002	1/6/2023	2/20/2023	149	\$292.50
		BLUE	144	\$2,270.66	\$326,974.32					888000003	1/6/2023	2/20/2023	144	
780000000	OL	BLUE	1050	\$2,270.66	\$2,384,187.75	\$19,324,990.16	1/4/2023	1/13/2023	No	888000004	1/6/2023	2/20/2023	1050	\$8,347.50
		BLUE	356	\$2,383.16	\$847,211.60					888000005	1/10/2023	2/24/2023	356	
										888000006	1/11/2023	2/25/2023		
										888000007	1/11/2023	2/25/2023		
		RED	960	\$2,425.92	\$2,328,878.40					888000008	1/6/2023	2/20/2023	960	
										888000009	1/9/2023	2/23/2023		
		BLUE	1232	\$2,270.66	\$2,796,311.63					888000010	1/9/2023	2/23/2023	1232	
										888000011	1/11/2023	2/25/2023		
		BLUE	1526	\$2,270.66	\$3,463,884.20					888000012	1/9/2023	2/23/2023	1526	
										888000013	1/6/2023	2/20/2023		
		BLUE	1646	\$2,270.66	\$3,736,362.80					888000014	1/11/2023	2/25/2023	1646	
										888000015	1/9/2023	2/23/2023		
RED	351	\$2,425.92	\$851,496.17	888000016	1/10/2023	2/24/2023	351							
				888000017	1/10/2023	2/24/2023								
RED	819	\$2,425.92	\$1,986,824.39	888000018	1/12/2023	2/26/2023	819							
				888000019	1/11/2023	2/25/2023								
BLUE	590	\$2,270.66	\$1,338,551.12	888000020	1/11/2023	2/25/2023	590							
				888000021	1/11/2023	2/25/2023								
BLUE	870	\$2,270.66	\$1,975,469.85	888000022	1/12/2023	2/26/2023	870							

5.2 Create the Interactive Dashboards

The interactive dashboards can be created from the results of transferring and uploading the standard databases to Google Data Studio based on the planned layout that contains the required information and charts requested by the business and projects team. Figure 6 shows the interactive dashboard for one of the company projects that contains the data for the years 2022/2023. The interactive elements are the phase and quarter which can be chosen from a drop-down list, a combination of donut charts, column charts, column charts with trend lines, and scorecards has been used in the dashboard design to reflect different required information. The use of the dashboard and the update of data is simple and does not require a lot of time or effort, for example, to show the required information for Quarter one (Q1) of the 2023 year, it only requires choosing it from the quarter drop-down list, Figure 7 shows the interactive dashboard for Q1 of the 2023 year.

The dashboard is capable to provide the requested information and will make the process of reporting easier, for example for XY project we can see from the dashboard in Figure 7 that the total value of POs received for year 22/23 is \$684,015,856.48 (These are not actual values, but are used for demonstration purposes), and the total amount invoiced for that period is \$666,951,583.24 which indicates that there is a mismatch between the two values and the business department needs to follow up with the related teams to determine the discrepancy. The total number of POs

received, the total number of POs that have been invoiced, the total value of the POs received in dollars, the total value of the POs invoiced in dollars, the differences between POs' total amount received and invoiced per quarter and the differences between POs' total amount received and invoiced per product can be indicated using the dashboard.

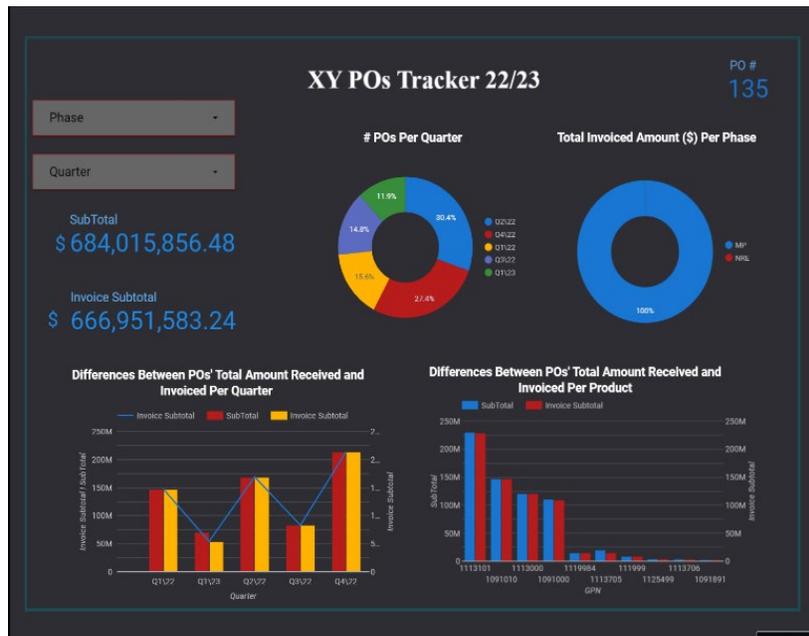


Figure 6. Interactive Dashboard for Year 22/23 (Hypothetical Data)

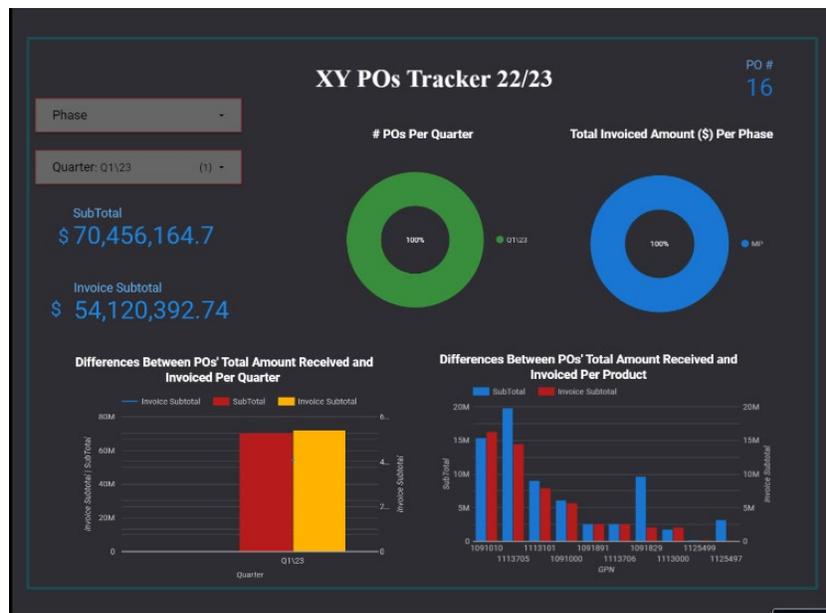


Figure 7. Interactive Dashboard for Q1/2023 (Hypothetical Data)

5.3 Pre/Post Assessment Results

The mean and mode of the responses for each question of the pre- and post-assessment survey can be shown in Table 3. The values of the means and modes for each question are much higher in the post-assessment responses compared to the pre-assessment values, this can be shown more obviously in Figure 8. This indicates based on the users' feedback

that using the standardized databases and dashboards improves the four measures, namely, data management, data analysis, data visualization, and information sharing.

Table 3. Mean and Mode for the Pre/Post-Assessment Responses

Metrics	Survey Questions	Pre-Assessment Responses Mean	Pre-Assessment Responses Mode	Post-Assessment Responses Mean	Post-Assessment Responses Mode
Managing Dataset	Standardized sheets to collect and track POs details are available	1.83	2	4.83	5
	PO's tracking sheets are easy to use and understand	1.83	1	4.67	5
Data Visualization	The used technique of data visualization provides a quick and effective way to communicate information using visual information	1.50	2	5.00	5
	The used technique of data visualization is effective and simple which can provide immediate answers to the most important questions about the dataset	1.50	2	4.67	5
	The used technique of data visualization allows for easy data filtering	1.83	2	4.50	5
Data Analysis	The technique used for data analysis is effective to extract information and general statistics from the dataset including identifying patterns and trends	1.50	2	4.83	5
	Search for specific Information doesn't need a lot of time using the current technique of data analysis	1.50	2	4.50	5
	You can find the information you need using the available data analysis technique	3.00	4	4.67	5
	The Information is up to date and relevant using the available data analysis technique	1.17	1	3.00	3
	The information is available in one source when using the available data analysis technique	2.33	2	4.17	5
Information Sharing	You are satisfied with the process of sharing information and areas of knowledge across teams or departments	1.67	2	5.00	5
	You are able to quickly answer repetitive questions or help others look for information they need to perform their duties by using the available data analysis and visualization technique	1.17	1	4.33	5

The results of the Wilcoxon Signed-Rank test are shown in Table 4. For all metrics, we rejected the null hypothesis, since the P- values are less than our significance level (0.05), which means that using dashboards has a significant effect on the metrics and it is effective to use them to improve the metrics being measured.

6. Conclusion

A framework to create interactive dashboards has been proposed in this research to improve data visualization and analysis. The framework consists of four main phases, namely, pre-assessment to assess the current situation, standardizing the databases, creating interactive dashboards, and post-assessment to evaluate the suggested

improvements. The framework has been applied in an electronics manufacturing company located in the US, in which they were interested to standardize their databases and create dashboards for their projects to help the business and projects team to analyze financial data and facilitate the process of reporting. The results of the evaluation of applying the framework and using the dashboards in terms of improving data management, data analysis, data visualization, and information sharing showed positive feedback, this was measured by collecting responses using pre- and post-assessment surveys from business and projects department employees.

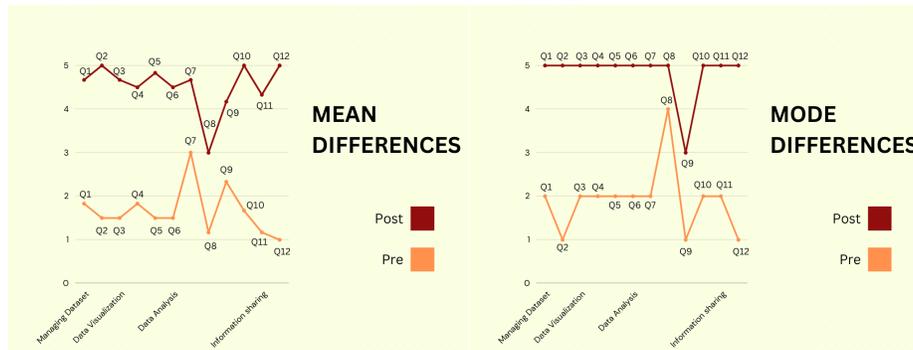


Figure 8. Trend Line View for Mean and Mode of the Pre/Post Assessment Responses

Table 4. Results of the Wilcoxon Signed-Rank test

Metric	Wilcoxon Signed-Rank Test Results
Managing Dataset	W-value: 0
	Mean Difference: 2.17
	Sum of pos. ranks: 0
	Sum of neg. ranks: 21
	Z-value: -2.2014
	P-Value: 0.0275 The result is significant at $p < .05$.
Data Visualization	W-value: 0
	Mean Difference: 1.78
	Sum of pos. ranks: 0
	Sum of neg. ranks: 45
	Z-value: -2.6656
	P-Value: 0.0076 The result is significant at $p < .05$
Data Analysis	W-value: 0
	Mean Difference: 1.87
	Sum of pos. ranks: 0
	Sum of neg. ranks: 120
	Z-value: -3.4078
	P-Value: 0.0006 The result is significant at $p < .05$
Information Sharing	W-value: 0
	Mean Difference: 1.33
	Sum of pos. ranks: 0
	Sum of neg. ranks: 21
	Z-value: -2.2014
	P-Value: 0.0275 The result is significant at $p < .05$.

The main limitation of the research paper is that it has only been applied in one company, which makes it difficult to generalize the results, but as noted by the surveys, it has been well received at the implementation site. Further research should verify the findings in other companies and in different industries. In addition, future research may test the

framework using other dashboards software. Another aspect that may be considered in future research is to evaluate the use of dashboards using other metrics such as decision-making and user engagement.

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