Northeastern Aerospace Budgeting Dashboard

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ABSTRACT

Within exploratory budget analysis, it is crucial to be able to investigate every piece of your budget in depth, while also being able to get a quick overview of its general spread. A user trying to explore and allocate funds within a budget needs to be able to compare a current proposal to past budgets to be able to identify areas where funds were unnecessarily prepared or unexpectedly needed in the past. They also require the ability to compare budgets split between different departments of an entity, and then draw conclusions about what proportion of their budget makes sense to allocate to each various department.

1 INTRODUCTION

One of the main goals in the creation of this visualization is to support the allocation of future budgets by providing information about past budgeting and spending in an easy to digest way. The historical information is stored in extensive tables, which are not digestible or easy to analyze. By visualizing this data, we can allow end users to draw conclusions and make decisions more effectively. This visualization is intended to support the user's budget exploration by providing side-by-side details of budgets over time, which allows for easy inspection of trends between budgets and the detection of similarities to a new proposal. Further, it allows for the user to dig into specific areas of the budget for an in-depth breakdown of proposed purchases against actual purchases within a specific subdivision. Here, a user can investigate the usage of each group within their team individually and make judgements upon past spendings to inform decisions on future budgets and purchases.

The end user, specifically for this visualization, is the Northeastern Aerospace Club Treasurer, and other members within the club. Should this visualization be generalized to any other club or company, the end user would be their respective users responsible for proposing and allocating funds across the team.

2 RELATED WORK

A first similar case study describes the successful implementation of a high-level financial reporting system at NASA called the Agency Budget Execution Dashboard (ABED) [1]. This dashboard enabled NASA's management to track their finances as well as manage their resources by displaying the variance from expected expenditure. As we are creating a dashboard to aid budgeting and track spending, it would help to take inspiration from the visualizations presented in the paper. Additionally, being able to record expected spending will enable the board of the club to allocate their resources at the start of the term. The actual spending will be recorded as the term progresses and displaying the variance from the planned expenditure will help the board recognize a need for more funds earlier.

Secondly, we have considered a research article which talks about certain design principles with regard to the color palette used in the dashboards [2]. Overuse and misuse of colors can lead to cognitive overload resulting in difficulties understanding the visualizations and delays in decision making. By categorizing subdivisions of the Northeastern Aerospace Club by color, we allow users to recognize, separate, and understand the specific budgeting data and corresponding visualization that they find important. These color palette choices are decisions which we considered heavily while designing our visualization.

3 USE CASE

The NU Aerospace club is a Northeastern funded, student-run organization on campus. It is split up into 4 subdivisions: Rockets, Planes, Drones, and Satellites. Within these subdivisions, there exist smaller groups which are focused on

specific aspects of the rocket/plane etc. Each semester, the leaders of these subgroups propose a breakdown of funds for their specific needs, and it is then up to the club's Treasurer to allocate funds appropriately.

The visualization detailed in this report is intended to allow for easy examination of past or current proposed and actual spending across the various subdivisions and projects. The end user who would most benefit from this project would be the club's treasurer, and the visualization would allow them to make more informed decisions regarding the allocation of funds by providing an easy-to-digest way to compare what funds are proposed and which are actually used.

With our visualization, the Treasurer could focus into a specific division of the club, specifically Redshift (the rocket division), or Fixed Wing (the plane division) and then investigate past budgets broken down in various ways- by the even smaller project groups within the division, by necessity, by price etc. All of this information would be easy to interpret at a glance. By using this visualization, the process of allocating funds would run more efficiently, using increased ease of access to internal data to back budgeting and funding decisions.

4 Data

Our data was collected by and directly distributed to us by the NU Aerospace Club. It is a manually compiled collection of several separate datasets, each specific to one semester's proposed and actual purchases. The proposed budgets contain information on purchases, such as cost, importance, and subgroup within Redshift. The most evident area of bias within this data set is the level of importance category. Since it is dictated by those proposing the purchase, and thus inherently are desired, it is rare to see "Not necessary" as a level of importance. It is reasonable to suspect that the importance level of some purchases could be inflated. This is clear in the fact that, in actuality, many proposed purchases do not end up being recorded. It is also important to note that our actual purchases do not use the entire allocated budget, which reflects the likelihood that some purchases were not recorded.

In addition, we were able to obtain a short file containing details of rocket parts broken during launches. This data is often not formally tracked as it occurs, and thus is likely incomplete data, however it is still helpful in noting areas of potentially higher required investment due to necessary replacement parts.

Our data cleaning consisted of several steps, starting with the compilation of our numerous data sets into one standardized Excel file for ease of use. The compiled data [1] did not have a pre-populated column for the designated semester of the budget, so this was added manually as we compiled. We also standardized a few columns to be entirely capital letters, as there was inconsistent capitalization. We also removed disrupted rows from the file which were misaligned or missing crucial data, like the item name or cost/price.

5 Design Process

Prior to creating our final dashboard design, we took the time to brainstorm visual encoding for individual pieces of the data which we hoped to provide to our end user. Below are 3 partial sketches of specific areas of our visualization.

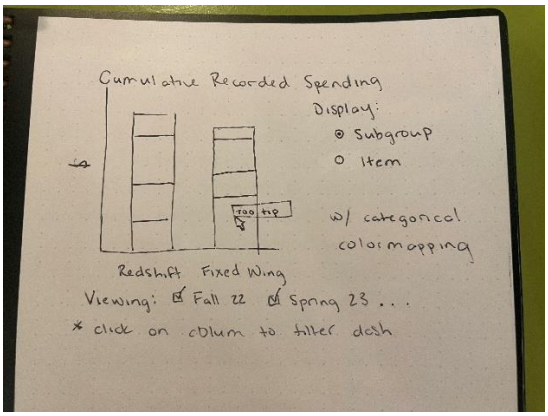


Figure 1: Partial Sketch 1, Budget Overview.

The first sketch we produced is intended to provide a general overview of the budgeting for each of our two considered divisions, rockets and planes. We would provide a segmented bar for each division which has a height representing the total spending for that group. Each segment would initially be shown as a subgroup of that division but would allow for the user to select a item by item breakdown, with a tooltip for additional information. The initial overview

would be cumulative over the semesters of data, but also allow for filtering by one or multiple semesters. Further, clicking on the rocket or plane column would filter other sections of the dashboard to the respective Aerospace group, or introduce new, division specific tiles if applicable.

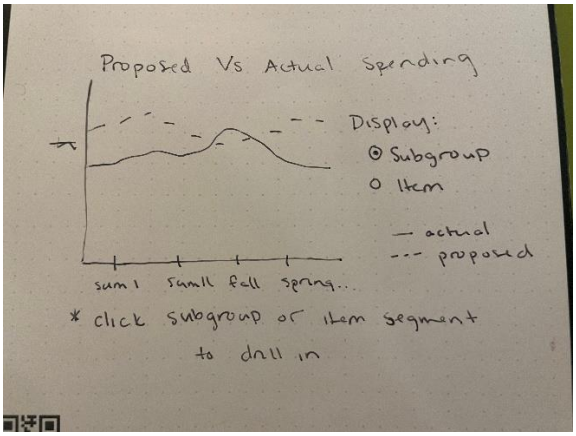


Figure 2: Partial Sketch 2, Actual and Proposed Spending over semesters.

Figure 2, above, depicts a second section of our dashboard which would show a line chart of the proposed vs. actual spending records over time. This would provide an easy analysis of how spending changes within different semesters, since it makes sense logically that summer spending, when less students are on campus, would differ from school-year spending. The same tooltip capabilities from Figure 1 are also intended.

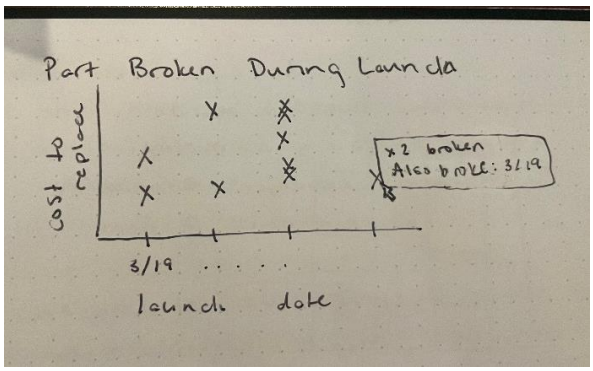


Figure 3: Partial Sketch 3, Redshift Launch Investigation.

The final partial sketch is an additional, Redshift (rocket) focused visualization which provides an additional insight to some potentially unforeseen expenses- damages due to launch. It is always important to keep in mind that in launching rockets, unpredictable expenses often arise, so allocating room in your budget is crucial. This chart shows pieces which have broken during a launch, with x-coordinates as the launch date, and y-coordinates as the average expenses to replace. This gives some incentive to leave room for repair budgeting in distributing funds.

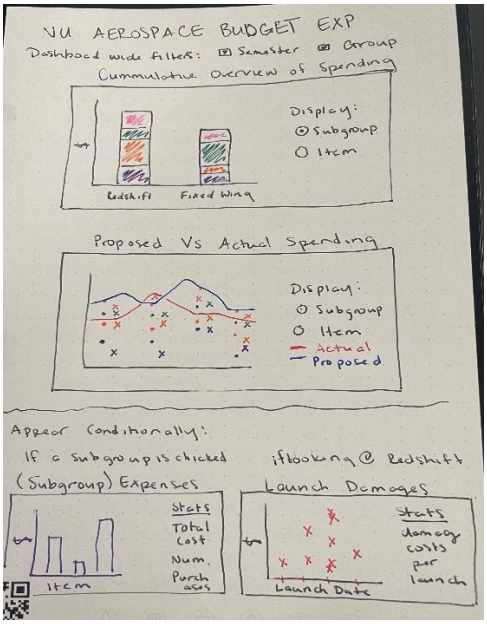


Figure 4: Polished Final Sketch.

We felt that our initial 3 pieces were strong components for our final dashboard, and so we kept most of our initial sketching, and focused on finding ways to connect the various pieces in our dashboard-style visualization.

Our visualization sketch makes use of areas, lines, and points as marks. The areas contained in the top overview bar chart use length as a channel to represent total costs. They also use horizontal position to dictate which Aerospace division is being represented, and color to distinguish between separate subgroups within the division. The points, used in the “Proposed VS Actual” and “Launch Damages” sections, make use of horizontal and vertical position to represent times and costs respectively. These lines in the second section also use color to differentiate between the proposed and actual totals, while the points use color to distinguish between subgroups and shape to distinguish proposed and actual costs. Note that the shape distinction is not

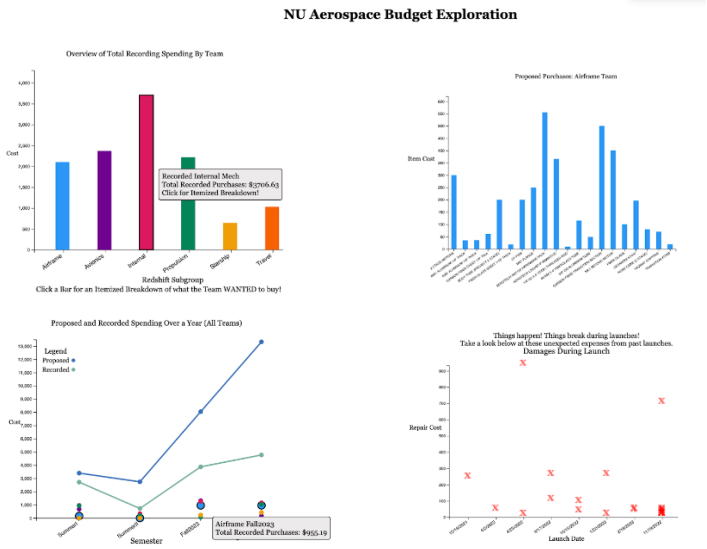
used in the final product as only recorded subgroup costs were plotted.

As for the functionality incorporated into our dashboard, all of our individual pieces are designed to include some sort of highlighting functionality, as well as a tooltip that includes additional information about a subgroup or item being hovered over. We also had allotted two dashboard wide filters in our sketch, one which allows for filtering the entire board down to only Redshift or Fixed Wing focused, and one to select a specific singular or multiple semesters, but these did not end up being included. Instead, our overview graph was linked to the itemized breakdown via click. By clicking on a subgroup bar in our final overview visualization, a new bar chart tile related to the selected subgroup is added to the visualization. Lastly, all subgroup information is linked, so that when you hover over anything related to one subgroup, all other areas where that subgroup is relevant will also be highlighted.

Much of our initial design was incorporated into our final product without any major change, like the "Proposed and Recorded Spending over a Year" line chart and the "Damages During Launch" scatter plot. Almost all of our design changes ended up being due to limitations within our data. Our initial idea was to allow the entire dashboard to be filtered down to one of the major groups within the club, like rockets, planes, or drones. However, we were only able to procure information about rocket and plane divisions, and even then, we were not able to use the plane data due to irregularities in data structure and crucial missing data. The structures that captured information were so different that we could not prepare the plane data so that we could directly compare it with the rocket data in the ways we had envisioned. This meant that our original stacked bar chart idea and dashboard wide division filters had to be removed from our design. To replace the stacked bars, we decided to use a standard bar chart showing total spendings within different subgroups of the rocket division of the club. This, combined with our linked bar chart containing an itemized breakdown for a chosen subgroup, completed our design for the dashboard.

To evaluate the effectiveness of our visualizations, we conducted usability tests. We used our working prototype at the time as a high-fidelity test for participants to answer specific questions based on findings from our dashboard. We asked participants a set of questions, such as which Redshift Subgroup had the 3rd highest total spending, or what were some of their most expensive items. We wanted participants to have to come to conclusions based on the data presented to them, and we wanted to determine if we were displaying that data efficiently. By timing participants and evaluating the accuracy of their answers, we were able to determine which visualizations were most effective. From our usability testing, we realized we needed to make it clearer to an end user that they needed to click a bar for an itemized breakdown, but largely our usability testing reinforced our theory that our visualizations were indeed effective at displaying the budgeting data.

6 Final Design



The final visualization tool is designed to be reminiscent of a traditional professional dashboard. We created each subsection of the dashboard with a minimalistic intention, so that the various pieces of information would be as digestible as possible for our end user. The top right graph depicts a "drill down" into an

itemized breakdown of the proposed budget for the subgroup of the corresponding color in the top left bar chart. Any subgroup can be seen in this breakdown view by clicking on its colored bar in the upper left chart. This allows the end user to examine which groups request the most/least purchases, as well as information about each request, like price, importance, and vendor. The bottom left and right charts display additional information which allow for comparisons between proposed/actual budgets and between subgroup purchases over time, and for an idea of what some unexpected expenses, in the form of launch damages, may look like in a semester. All of this information, together in an easy-to-understand format, paints a good picture of where money is wanted and where it ends up within the Aerospace club.

Our tool was created to assist those in the Northeastern Aerospace club in budgeting decisions. Whether it be a member of the board, or a worker on a project proposing a purchase, our tool can be used to inform decisions. First, any user should read the motivation and data sections, to understand the tool, and watch the corresponding video to understand how the tool can be used. Then, a user can view our subgroup bar chart on the top left and click on a specific bar to see the breakdown of their spending. For example, a project lead on the Redshift Propulsion team could click on their green bar to see an itemized view of purchases. This view can provide context for a proposed purchase. Any purchase for the Propulsion Team over $500 would surely draw attention, but on the Internal Team, purchases of that price are relatively more common. By viewing the line chart on the bottom left, a user can see spending patterns over time. Our data shows that in summer semesters, expenses are reduced significantly. This chart helps a user understand the allocation of resources on a yearly basis. On the bottom right, users can evaluate the success of launches and the costs associated with launch damages. On April 2nd, 2022, only one item was damaged, for only $39.40. However, on November 19th, 2022, numerous damages from launch totaled to well over $700. Users with knowledge of these launches may be able to understand why these damages occurred and take the necessary steps to reduce risk when repeating similar launches in the future.

7 Discussion

We found our tool to be effective at fulfilling the domain situation it aims to solve, but the domain situation itself changed over the course of the project. We are able to extract trends and analyze budgets for the Redshift division of the Northeastern Aerospace club, providing the club with a tool to make better decisions about proposed purchases and project financing. Its design is simplistic but effective, with appropriate linking and interactivity to provide a user with the engagement necessary to inform decision making. The development and adaptation of the tool was mainly enforced by our data, which limited our ability to create more complex, thorough visualizations, especially in displaying data for other divisions within the club. Our tool is almost certainly limited by the data it utilizes, which offers a subset of true purchasing data, since many purchases are not formally recorded.

If we were to continue developing this visualization, we would want to expand this visualization into the different divisions of the aerospace club, which we had originally intended. This would include rigorous data procuring and cleaning to ensure that each division's data was compatible. This data would lead to the extension of our dashboard to feature cumulative data for the club as well as dashboard-wide filters that would allow any particular club division to be inspected. We would even be able to reintroduce our initial stacked bar chart idea to allow comparisons both within and between divisions. All of the changes would be in an effort to support our end users' data exploration even more by displaying additional data to consider and allowing for new types of comparison and analysis within the Aerospace budget.

8 Conclusion

We were able to effectively leverage various marks (points, areas, lines) and channels (colors, position, area) to create visual encodings that facilitate the budgeting process for the Northeastern Aerospace Club. Given the data

provided to us by the club, we created visualizations that display spending by subgroup, spending trends across semesters, and unexpected expenditures as a result of damages. Additionally, by applying tooltips and linking, users of the dashboard have the ability to deep-dive into particular subgroups to understand spending habits and plan future budgets accordingly. All these functionalities fulfill the domain situation by aiding the budget exploration process and revealing trends in the club's expenditure that were not visible when the data was a scattered collection of poorly maintained spreadsheets.

REFERENCES

[1] P. Putz and H. Finger, "Development and deployment of NASA's Budget Execution Dashboard," 2010 IEEE Aerospace Conference, Big Sky, MT, USA, 2010, pp. 1-7, doi: 10.1109/AERO.2010.5446875.

[2] Palash Bera. 2016. How colors in business dashboards affect users' decision making. Commun. ACM 59, 4 (April 2016), 50–57. https://doi.org/10.1145/2818993

[3] Redshift Rocket Data, Compiled March 2023. https://docs.google.com/spreadsheets/d/1bCLl-Fn6f-2yeBntou9yhGc4JCTuLddlxALZIQmqPOw/edit?usp=sharing

Appendix A: Data Abstraction

Dataset 1, Redshift Proposed Budgets

Items.

Each row corresponds to one proposed purchase for Redshift.

Attributes.

Item: Categorical. The name of an item purchased.

Description: Categorical. A short description of the proposed purpose.

Importance: Categorical. The level of necessity of an item.

Vendor: Categorical. The company which provides the proposed item.

Price: Quantitative, Sequential. The price of 1 unit of an item purchased.

Quantity: Quantitative, Sequential. The number of units purchased of one item.

Cost: Quantitative, Sequential. The total cost of the number of units of an item purchased.

Subgroup: Categorical. The name of the Redshift group which purchased the item.

Group: Categorical. The department of NU Aero which purchased the item.

Semester: Ordinal, Sequential. The Northeastern semester in which the purchase was made.

Dataset 2, Redshift Recorded Expenses

Items.

Each row corresponds to one recorded purchase for Redshift.

Attributes.

Item: Categorical. The name of an item purchased.

Price: Quantitative, Sequential. The price of 1 unit of an item purchased.

Quantity: Quantitative, Sequential. The number of units purchased of one item.

Cost: Quantitative, Sequential. The total cost of the number of units of an item purchased.

Subgroup: Categorical. The name of the Redshift group which purchased the item.

Group: Categorical. The department of NU Aero which purchased the item.

Semester: Ordinal, Sequential. The Northeastern semester in which the purchase was made.

Dataset 3, Redshift Launch Record

Items.

Each row corresponds to one item that was broken during the launch of a Redshift rocket.

Attributes.

Item: Categorical. The name of a part on the rocket launched.

Launch Date: Quantitative, Sequential. The date of the rocket launch in which the given item broke.

Appendix B: Task Abstraction

Domain Task 1

Compare a current proposal to past budgets.

High level action: Consume, Discover. Explore and consider various aspects of past budgets.

Medium level action: Explore. With no specific target or location, observe all aspects of multiple budgets side-by-side.

Low level action: Compare. Observe multiple budgets to locate similar patterns.

Target: Attributes Similarity. Look for similarities and differences between past budgets and whatever budgets you are trying to compare.

Domain Task 2

Examine different departments of the club separately and in depth.

High level action: Consume, Present. Present the user in-depth data of a distinct department.

Medium level action: Browse. Explore within this known section of the visualization (a specific department).

Low level action: Summarize. Display all data for a given department in a simple way.

Targets: Trends, Outliers. Look for distinguishing factors or patterns in the data which could be meaningful, like trends our outliers.