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A Dashboard for Estimating Project Completion Times

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Abstract: With the evolution of ballistic missile capabilities by foreign adversaries, the need for air defense capabilities has grown. The Parts, Materials, and Processes team (PMP) at Lockheed Martin (LMC) is responsible for selecting, testing, and certifying all parts composing the Terminal High Altitude Area Defense platform (THAAD). This paper explores a project management dashboard designed to improve Lockheed Martin's THAAD missile program's timeline estimations. The user-friendly dashboard, built using low-fidelity prototyping, integrates historical data with data visualization tools, allowing users to filter data and view project timelines. This empowers the PMP team to make informed decisions on scheduling and resource allocation, improving efficiency and strengthening contractor relationships through accurate cost estimations. The paper discusses the potential for broader application within LMC and outlines future work on incorporating real-time data, confidence intervals, and financial data for a more comprehensive project management tool.

Keywords: Data Cleansing, Data Visualization, Dashboard

1. Introduction

The United States Army has placed heavy emphasis on the utilization of intermediate to long range ballistic missile systems in defense against enemy land, air, and sea assets. In the most recent publication of the Air Defense Artillery (ADA) Journal, the Army Futures Command emphasized a need to leverage industry partners to better enable the air and missile defense capabilities of our forces in the future (McConville, 2023). As one of those industry partners, Lockheed Martin's main contribution to supporting air and missile defense capabilities is the Terminal High Altitude Air Defense (THAAD) missile program. THAAD missile systems are a vital component of the Ballistic Missile Defense System (BMDS) that protects the United States and its allies from short- to intermediate-range ballistic missiles. THAAD batteries play a strategic role in US foreign policy as they are deployed in Guam, South Korea, the Persian Gulf, and other strategic locations as risk mitigating agents in the regions of US allies (McCall, 2020). The strategic importance coupled with the increasing demand presents challenges in managing the THAAD program and meeting project deadlines. These problems have only compounded since the outbreak of the COVID-19 pandemic, which placed increased stress on international supply lines (Meier & Pinto, 2024).

Lockheed Martin (LMC) seeks an application that will optimize the procurement time of components and labor hour predictions for the THAAD-6 Missile System, intending to integrate it into the development of the future THAAD-7 Missile System. The development of this application will address some of the problems the Parts, Material, and Processes (PMP) team currently faces. First, the team faces challenges in estimating contractor costs related to part procurement and labor hours. Obscured cost estimations lead to deadline and scheduling conflicts that force the PMP team to abruptly move ignored projects to the top of the work queue. This problem is important because, before the initiation of a project, it is critical to understand how long a project is expected to take (Meredith, 2017). Underneath the problems stemming from inaccurate labor cost estimations are issues with collecting metrics involved in the work process such as time to completion for many tasks. The problems stem from inconsistent data collection and not recording relevant project information. These issues compound into a database that is not readily usable. The goal of our proposed solution, a dashboard, is to ensure the PMP engineers can quickly and accurately estimate the number of days to complete a task, project, or phase.

One of the reasons the database is not helpful for management is due to the THAAD team members not recording relevant data for specific projects. These challenges leave key metrics within the PMP team's processes to go unrecorded, hindering the management team's understanding of the problems that are internal to their operations. Accurate reporting impacts the PMP team's ability to identify processes requiring immediate attention and to restructure work queues for meeting review deadlines. This problem compounds when team managers use data that they believe to be correct in order to make estimates on project duration. These estimates impact the overall ability for the THAAD PMP team to complete tasks by established deadlines. Meeting these deadlines ensures the reliability of THAAD launchers, interceptors, and fire control systems over their life-cycle.

To preserve the relationship between LMC and their partners, the dashboard must address the problems facing the PMP team. The issues facing the PMP team evolved into requirements for the product. The solution must address the issue of logging calendar days accurately by communicating how much time each type of part requires. Next, addressing the disorganized databases requires trimming and cleaning to fix inaccurate entries. Lastly, in regard to the issue of cost projection, the dashboard will deliver projections on project time to completion. To provide THAAD PMP management with better visualizations our group focused on an application that utilizes low-fidelity prototyping. This technical report presents a prototype dashboard to inform future development efforts for incorporating data analysis methods and optimization techniques in a dashboard using data visualization.

2. Related Literature

In addressing the issues related to data collection, timelines, and the production of a viable prediction system, this related literature section focuses on business methods that emphasize prototyping and dashboard implementation in the workplace. Low-fidelity prototyping in this context is the rapid iteration of prototypes that have limited to no functionality in their early stages, but show concepts and ideas well. Gerber and Carroll (2012) were able to show that low-fidelity prototyping can encourage creativity, accelerate development, and improve team communication. This model of product development is useful where requirements are uncertain and evolving from the client. Chen, Chiang, and Storey (2012) highlighted data analytics integration for its ability to enhance decision-making through data visualization and efficient data collection. Accurate data visualization can significantly impact decision-making. Visualizing statistical estimates can facilitate understanding of projected completion times.

Dashboards can be designed to provide interactive data visualization features that enable users to explore specific aspects of data in greater depth. These types of visualizations can aid management teams in making timeline decisions based on their company's historical data. The visualizations follow a straightforward presentation that allows for user inputs and enhances user understanding of the related data. Studies have found that including more information does not lead to a better visualization, with data visualization less is more (Meloncon & Warner, 2017).

Another aspect of data analysis involves presenting meaningful comparisons. To prevent overwhelming the user with excessive information. Comparisons provide context to help users extract meaningful insights from data (Developers, 2013). Furthermore, comparative visualizations enable users to process information, in which, viewers naturally begin to draw conclusions. However, users may also become distracted by a visualization product just as easily as they can be guided by it. Data presentations become crowded and confusing quickly if too much information is being displayed. Balancing the design and the information density is a priority for our client's products. Delivering efficient and informative graphics increases the value of the final dashboard.

To enhance the information within our dashboard, our team conducted a thorough review of business analytics articles that highlight the effectiveness of dashboards. A study conducted by Eckerson (2006) asked 299 senior management officers about their perceived benefits after implementing dashboards into meetings. The overarching benefits of dashboards included the ability to effectively communicate the strategic objectives of management, impact decisions about employment, adjust the execution of strategies, and clear deliver information and insights to employees. The dashboard will be modeled in conjunction with the three most important aspects of dashboards, (1) interactivity with the user, (2) easy to read graphics, and (3) cogent delivery of information (Yigitbasioglu & Velcu, 2012).

The lessons from the different research paths helped move the implementation of the dashboard. Investigating visualization strategies informed the types of graphics used in the final product. Specifically, the utilization of simple visualizations that can be compared and contrasted to make better timeline predictions about related components. Studying dashboards helped us to implement a user interface displaying relevant options to the stakeholder. These options reinforce the idea of interactivity within the application and aid in the visual representation of trends among related products.

3. Methodology

The goal of this project is to develop a tool capable of estimating the time that a multi-stage project would take to complete. The tool gives the user access to a breadth of data that has been organized to present the information with a specific focus. Projects cost money from the beginning to the end, which makes it even more valuable to have an estimate of the total project duration. Initially, the dashboard project required a thorough understanding of the data set that would become the content of the visualizations used within the dashboard. Given that all project entries are broken into three phases, the most important data entries were those that showed when the project stages started and ended. The first phase of the PMP process is the time from the introduction of a build package until it reaches a subject matter expert (SME). The second phase is the time from when that project goes from the SME until it reaches an integrated process team (IPT). The last phase consists of the time a project takes between the IPT stage until it goes to the parts, materials, and process control board (PMPCB). With the question framed, the next phase of the dashboard development is a cycle of drafting data visualizations that adequately tell the story of the data set. The process of creating a data set is a repetitive cycle focused on making the visualizations easily understandable and deliberate with how it displays information. Finally, the creation of a predictive visualization is needed to analyze how many calendar days any part previously completed required. This last step was in line with the initial concerns of the client who desired the capability of estimating how much time a project needs for review.

In our first meeting with our client, our group established that the THAAD PMP Team would benefit most from an application that incorporates data visualization based upon their existing historical records. In subsequent meetings our client laid out specific key design features, which guided the vision of the dashboard. Employing low-fidelity prototyping for data visualizations, our group met with our client several times to validate that the dashboard being provided addressed their scheduling problems and fit their expectations. While the data visualization is extremely important in the delivery of the final product, the biggest contribution of this project was the work done in cleaning and processing the data.

3.1. Data Cleansing

The dashboard uses a dataset from the THAAD PMP team to create the visualizations. The dataset consists of all projects, both completed and active, with information such as part type and which sub-set of the missile the part falls into. This management data of the THAAD program's component approvals contains 4751 records that feature 45 attributes. First, the most important part of the dataset is the project start and completion dates. The time to completion for these projects allows for analysis on how effectively the PMP team completes assignments. Furthermore, there is information that allows for the projects to be filtered, thus allowing for more specific investigation of particular assemblies. For example, filtering by part type enables examining only electrical parts as opposed to mechanical or material parts. However, this dataset presents some challenges requiring data cleaning. Some records have start times outside the established time boundary of the dataset (2018-2023). The ability to recognize and discern between "good" and "bad" data entry significantly influences the efficacy of the product our group intends to produce for LMC.

Our group first analyzed the dataset by converting the date ranges to numbers. Next, we identified and eliminated data entries that had either no recorded value or were negative. The removal of these entries were effective in gaining insights into which subsets of components are considered the most time-consuming. The final step in preparing the data was taking a 90% trim of the data to exclude outliers. With the data cleaned, our group created several data sets that correspond with each data visualization presented in the dashboard. Graphical representations of calendar days in relation to phase completion times for each component revealed key determinants affecting project completion time. These include the categorization of the component as material, mechanical, or electronic; the assembly it belongs to (Missile, TFCC, or Launcher); and whether it's classified as a standard or non-standard part. This analysis and cleansing laid the foundation for our future work.

3.2. Modeling Historical Data

Predictive models are created from historical data with a high degree of confidence in the accuracy of the model. These models can provide estimates for the total number of days LMC takes to complete a project from the initiation to completion. These estimates are based upon the percentage of projects that are completed at the selected quantiles. For example, when a user selects a lower quantile of 10% and an upper quantile of 80% the visualization displays the range of days that span from 10% of the projects completed to 80% of the projects completed within the filtered data. Percentiles provide users with the flexibility to accurately assess, adjust, or experiment with the estimated number of days needed to complete a project. By giving the user this capability they can develop models which accurately define their project deadlines with their selected degree of confidence. When using the predictive model it will return outputs in total days for the specified percentiles. The estimated total days are calculated with

$$ETD_i = \sum_{j=1}^{N} Q_{ij} \tag{1}$$

This equation yields, ETD = Estimated Total Days which is calculated from the sum of, Q = Number of Calendar Days where *i* is a percentile value that the user can select based on their desired level of confidence in the time required to complete a project. This equation is simply a summarization of the three phases of data. Percentile values can be chosen from a preset list of values e.g., .10, .25, .5, .75, .90, and .95. These values of *i* are commonly used in statistics and will give the user enough flexibility in their modeling without overwhelming the dashboard with excessive options. *j* is the phase of the project: 1, 2, or 3. These three phases correspond with the PMP design process with each phase having certain requirements that parts and components need to meet to move to the next stage.

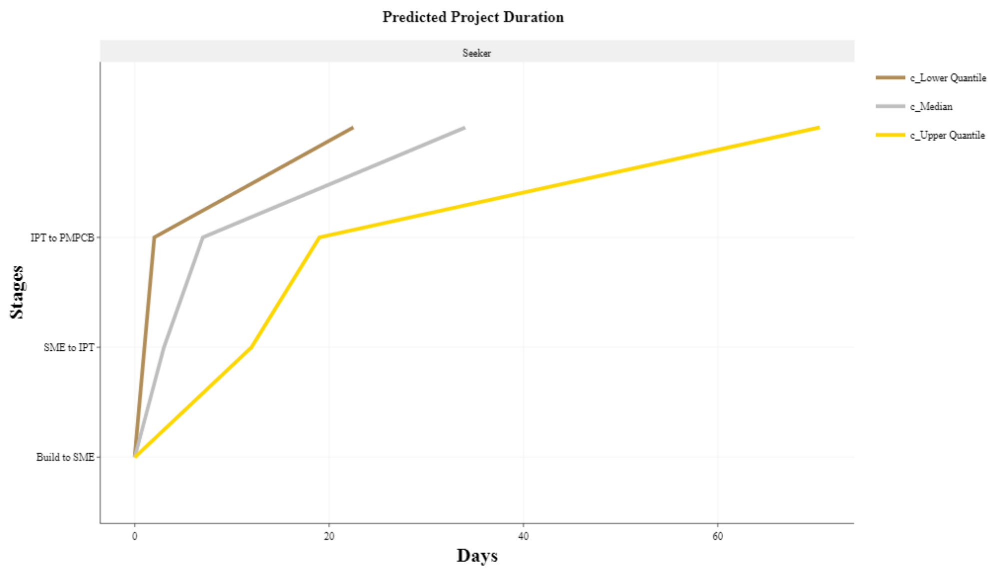

Figure 1: Line chart showing the predicted days until completion. Each color depicts a different quantile prediction in the production timeline.

Figure 1 shows what the client's model could look like based on their specifications. Using the dashboard, th PMP team can create models like this one. The three lines represent three different percentile values which are chosen by the user. The bronze line is the lower quantile where the percentile is 0.25. The silver line is the median which shows how long the project took for the middle value observation. The gold line is the upper quantile where the percentile is 0.75. The three phases are shown on the y-axis each one corresponds with a phase number (1,2,3) used in the estimated total days equation. To create this graph the user will choose the desired percentile values and the dashboard will output a model like in Figure 1.

4. Results

This project has encapsulated fundamental elements that are integral to engineering and systems management. Employing low-fidelity prototyping, our group has worked collaboratively with LMC to produce a dashboard for the THAAD PMP Manager. This dashboard helps the manager achieve the objective of creating project duration estimation tools and enhancing the decision-making capabilities for PMP management. The PMP team can use the model and dashboard features to increase consistency and information accuracy in project estimations. These estimations will empower them to make strategically informed decisions during business interactions with contractors. While this application is tailored to the THAAD missile system, the general construction of this application can be re-framed and applied outside of THAAD. By focusing on a specific system, our group produced a dashboard that provides THAAD PMP managers with project completion estimates and a proof of concept application with functionality across different disciplines.

Our work cleaning the PMP team's dataset communicated a clearer understanding of THAAD project time to completion. Furthermore, cleaning the dataset enabled the development of the dashboard. The dashboard our project team developed allows the client to interact with custom graphical visualizations. For instance, by hovering their cursor over bar charts our client can see specific metrics such as the average number of days, the minimum and maximum recorded duration, and the bounds of the data. This level of interactivity can be most valuable when utilized in assisting PMP team managers in making better informed decisions during business interactions with contractors and in goal-setting discussions with their engineering teams.

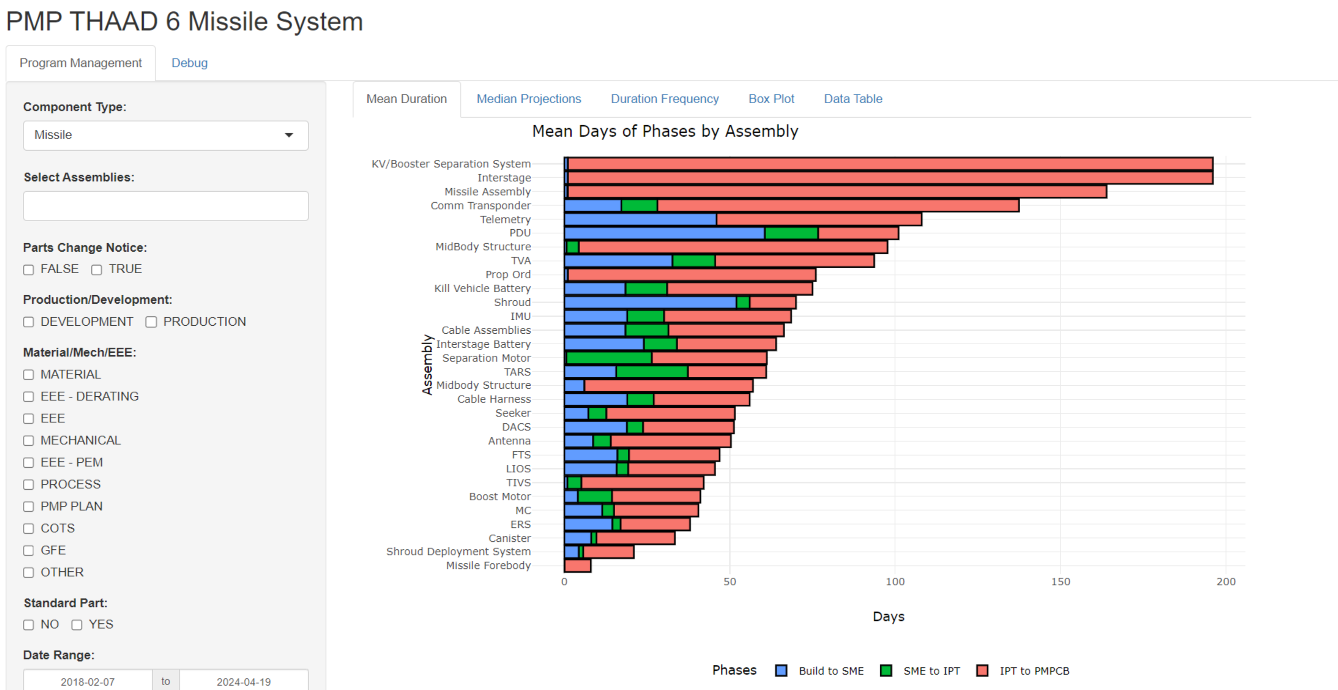

Figure 2: THAAD PMP Dashboard Prototype. Example of what the assembly bar chart page of the dashboard looks like. The elements within the graphic can be individually chosen by the client to see only the desired assembly pieces.

We aimed to eliminate distractions and enhance visual clarity by carefully selecting how the data is presented, while also limiting undesired information on the display. Excess information that obscures a graphic is referred to as visual noise. To reduce the impact of visual noise the data is first filtered, giving our clients the ability to select specific portions to be observed in tailored, organized check-boxes. Our clients need a product that they can use every day to track changes and the progress of projects with a high degree of precision. Our dashboard creates visualizations that allow our clients to collapse the data into small pieces that can be examined at the single-component level, or observed at a more general assembly level. These visualizations combine the simple characteristics of good data visualization while giving the clients the ability to control the quantity and class of data they wish to see. The intended purpose behind this is to allow managers to analyze the trends of a single component and combine this with their professional knowledge to better inform their estimates.

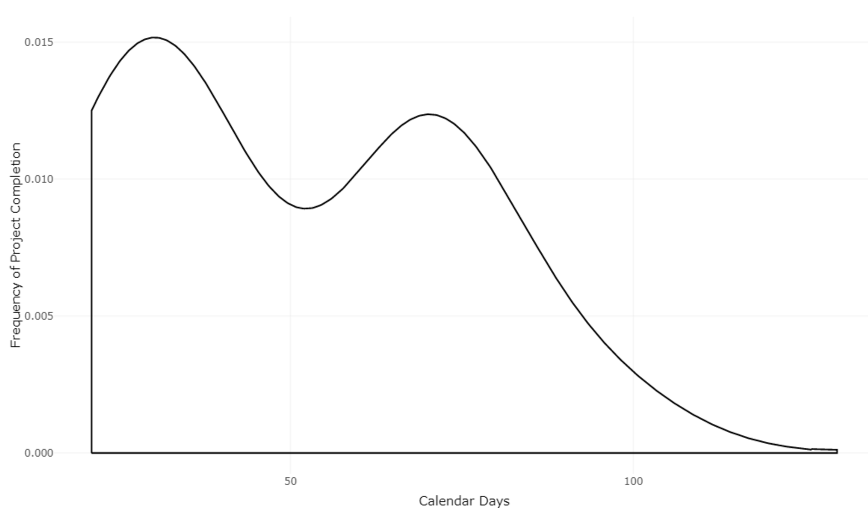

Figure 3: Duration Frequency Plot. Example of a bimodal population shown with a single component without any other filtering.

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As a user is selecting a component with no additional filtering this situation can occur. Figure 3 shows the presence of two populations thus requiring the user to correct their screening criteria to limit the scope of the observed data to a single population. If this is not corrected any estimation would include data from both populations and any conclusions made would be incorrect for both. The inclusion of this visual on the dashboard can serve as a corrective control measure to estimate on a single population.

5. Conclusion and Future Work

The dashboard, when effectively integrated with project management practices, can prove to be a valuable tool for the THAAD PMP team and a proof of concept for the efficacy of dashboards in project management for LMC as a whole. Real-time data input and updates enable the generation of insightful graphics that provide PMP management with a better understanding of how their strategic decisions are affecting the timelines of the components they are producing. In recent conversations with PMP management, they expressed a desire to see what can be done with their yearly financial report data as it pertains to tracking the number of labor hours that are allocated to specific projects. A limitation with the yearly financial data LMC has provided our group is that more than half of the records are insufficient in providing a description for the product which hampers our group's ability to join the data sets together. In the future, LMC's cooperation in amending the existing data, will direct some attention toward the ability to join the data sets. The number of labor hours spent on a project in relation to the actual days that a project took from inception to approval would give LMC better insight as to how their internal supply chain functions. Future work should be directed at establishing the reasons for discrepancies in labor hours and actual days. This work would yield results that give LMC and PMP management better insights as to what components, processes, or resources are causing timeline delays. Furthermore, as seen in Figure 3, multiple assemblies have multi-modal distributions as it pertains to project completion. An internal review that establishes control standards on the calendar-day duration of specific assemblies could be extremely helpful in identifying the underlying issues contributing to their timeline delays.

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