

UNIVERSITY OF ECONOMICS AND LAW

FACULTY OF INFORMATION SYSTEMS



FINAL PROJECT REPORT

BUSINESS INTELLIGENCE & DECISION SUPPORT SYSTEMS

TOPIC: ADVENTUREWORK – MANUFACTURING DEPARTMENT

Group: 08

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Ho Chi Minh City, May, 2024

Acknowledgments

First of all, Group 08 gratefully gives acknowledgment of all support and motivation during the time of doing this project. We would like to express our deep gratitude to Mr. Ho Trung Thanh, our research supervisor, who is an enthusiastic and dedicated teacher. He has spent a lot of time teaching and guiding many students including us from the early days until we can finish this last project.

We would also like to extend our sincere appreciation to our classmates, who have provided invaluable support and encouragement throughout this project. Their willingness to collaborate and offer constructive feedback has helped us to improve and refine our work.

Finally, we wish to thank our parents for their support and encouragement throughout our study!

Group 08

Commitment

We commit to project implementation by individuals and groups under the guidance of Assoc. Prof. Ho Trung Thanh, Ph.D., and sources are referenced and fully cited.

Ho Chi Minh City, May 10 2024

Group 08

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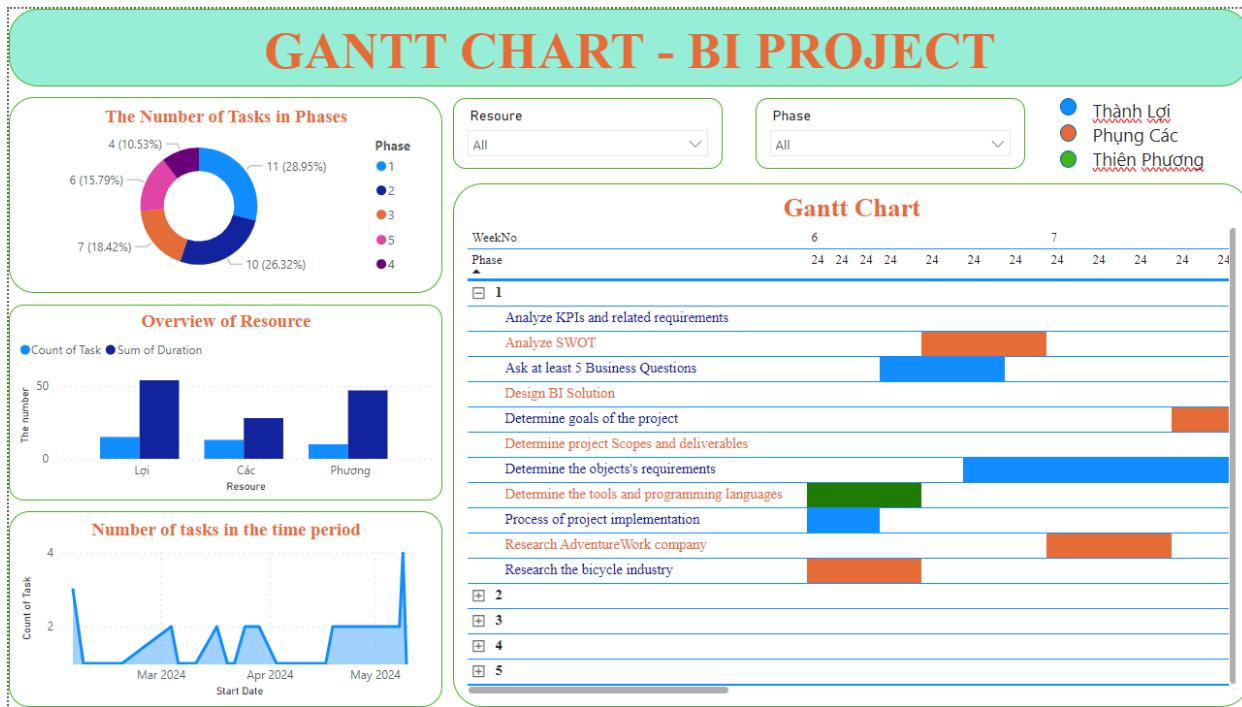
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List of Abbreviations

KPI	Key Performance Indicator
MIS	Management Information Systems
BI	Business Intelligence
SSAS	SQL Server Analysis Services.
SSIS	SQL Server Integration Services
OLAP	Online Analysis Processing
ETL	Extract Transform Load

GANNT CHART



Project Overview

1. Bicycle industry and Adventure Work Company overview

The Bicycle Industry

The bicycle industry has seen significant growth and evolution over the years. According to the FMI analysis report, the bicycle market size in 2022 was US\$ 1,300 million and is predicted to develop a CAGR of 8.92% between 2023 and 2033, totaling around US\$ 6,229.4 million by 2033 (Bicycle Market, 2022). The upward trajectory of this development can be attributed to the fact that residents of developed nations increasingly view cycling as a means to promote a healthy lifestyle. Additionally, there's a growing concern for environmental conservation, coupled with a desire for government backing in enhancing bicycle infrastructure.

Despite predictions of long-term growth in the bicycle market, the emergence of the COVID-19 epidemic has caused disruption and impacts. At the beginning of the pandemic, the blockade and prohibition of vehicle circulation were the main causes of supply depletion, consumption was also significantly affected when travel demand decreased sharply. In other words, a pandemic-induced slowdown has gripped economic growth, with a temporary recovery in 2023 giving way to a long-term forecast of just 0.5% by 2050 (*Fortune Business Insights, 2023*).

In recent times, electric bicycles have become increasingly popular within the bicycle market. This surge in popularity is attributed to several factors including escalating fuel costs, growing concerns about environmental pollution, and increasing traffic congestion, particularly in urban settings. Furthermore, government incentives such as tax incentives and subsidies aimed at promoting the purchase of electric bicycles are anticipated to drive demand even further in the coming years. For instance, in May 2022, Vermont implemented initiatives aimed at encouraging the adoption of electric bicycles and other new vehicles, while also maintaining existing incentives to promote the use of electric vehicles among residents of the state (Bicycle Market, 2022).

The Adventure Works Company

Adventure Works (AW) is an imaginary company specializing in the production of bicycles as outlined by Microsoft in 2014. Their product range consists of 97 different bike brands, categorized into mountain bikes, road bikes, and touring bikes. Besides manufacturing bicycles, AW also produces some components in-house while procuring others from external suppliers, including all accessories and clothing. Although primarily focused on bicycle sales, AW also deals in accessories (e.g., bottles, bike racks, brakes),

clothing (e.g., caps, gloves, jerseys), and components (e.g., brakes, chains, derailleurs), many of which are sourced from external vendors. With a global presence, AW caters to customers across the United States, Canada, Australia, the United Kingdom, France, and Germany. The AW business model segments customers into retail stores that sell bikes and individual customers (*Mitri, M. (2015)*).

Adventure Works, a prominent bicycle industry player, has navigated various market dynamics with adaptive strategies. Firstly, “Quantity discounts” campaigns performed well and resonated more from 2011 to 2013, helping to increase AWC's short-term profits by up to 68% by attracting existing customers as well and new customers. However, in January 2013 and 2014, online sales decreased significantly while online sales of accessories and clothing increased throughout 2013 (*Lim & Mafas**, 2020). Next, the company experienced steady sales growth from 2017 to 2019, reaching a peak in the third quarter of 2019. However, the onset of the COVID-19 pandemic in 2020 led to a decline in sales during the first quarter, highlighting the global impact on consumer behavior and economic activities. In the face of market fluctuations and challenges, Adventure Works has undertaken strategic measures to mitigate risks and sustain its business operations. For instance, the company has diversified its product offerings to cater to evolving consumer preferences and market demands. Additionally, Adventure Works has explored cost optimization strategies to address the high production costs impacting its profitability, such as streamlining supply chain processes and negotiating favorable terms with suppliers. Furthermore, the company has invested in marketing and branding to enhance its visibility and appeal to target consumers, driving sales growth and market penetration.

2. Business demands/problems

- Strengths:**

The bicycle industry benefits from a growing interest in health, fitness, and sustainable transportation solutions, leading to an expanding market for bicycles. Adventure Works, recognizing this trend, must enhance its production capacity to meet the needs of emerging economies. This involves scaling up their existing manufacturing plant or setting up new plants in strategic locations to ensure sufficient production capabilities. Additionally, technological advancements in bicycle design and manufacturing have raised the bar for product innovation and quality. To remain competitive, Adventure Works' manufacturing division must invest in technological upgrades to align with global manufacturing standards and ensure the continued delivery of high-quality products.

- **Weaknesses:**

Intense competition among manufacturers poses a significant challenge for Adventure Works. In response, the company must focus on continuous innovation to develop competitive products. The manufacturing division needs to prioritize flexibility and adaptability to swiftly produce new products in response to market demands. This requires implementing agile manufacturing processes and efficient supply chain management systems to reduce lead times and improve responsiveness. Moreover, the industry's reliance on raw materials like carbon, susceptible to shortages, presents a risk (*Accounting*, 2019). Adventure Works' manufacturing division could mitigate this risk by optimizing material usage, exploring alternative materials, or negotiating better supplier contracts to maintain a steady supply chain while minimizing costs.

- **Opportunities:**

Despite challenges, there are significant opportunities on the horizon for Adventure Works. The bicycle industry can play a crucial role in driving green recovery efforts post-pandemic, presenting an opportunity for Adventure Works to diversify its product line with eco-friendly options. Adventure Works' manufacturing division should collaborate with product development teams to integrate sustainable materials and manufacturing processes into their production lines. Additionally, the expanding electric bicycle market offers avenues for growth (*Xames et al.*, 2022). Adventure Works' manufacturing division should collaborate with engineering teams to develop and produce electric bicycles, catering to a broader audience and capitalizing on the market's shifting preferences.

- **Threats:**

Adventure Works faces threats such as the dominance of Asian imports and economic instability stemming from global events like the COVID-19 pandemic (*Xames et al.*, 2022). To address the competition from Asian imports, Adventure Works' manufacturing division can explore cheaper raw material sources from Asian countries while maintaining stringent quality control measures. This involves establishing robust supplier relationships and conducting thorough quality inspections throughout the manufacturing process. Moreover, potential regulatory changes and trade policies could impact operations. To mitigate these threats, Adventure Works' manufacturing division should strengthen its online presence and e-commerce capabilities. By leveraging digital technologies for production planning, inventory management, and customer engagement, the manufacturing division can improve operational resilience and adaptability in the face of regulatory uncertainties.

3. Business Goals

- **General Goals:**

Creating a BI solution for Adventure World's manufacturing module aims to enhance decision-making accuracy, boost revenue, streamline operations, and secure a competitive edge.

- **Specific Goals:**

- Market and Business Analysis: Conduct an in-depth analysis of AdventureWorks' position in the bicycle industry market and its current business situation, including the production module. Identify key business requirements that need attention.
- BI Solution Proposal: Propose effective BI solutions by selecting appropriate data sources, defining relevant Key Performance Indicators (KPIs), and designing intuitive dashboards to address the identified business requirements.
- Data Preparation and Modeling: Prepare and analyze data to identify necessary dimensions for the BI project. Build a robust data modeling framework and implement an Extract, Transform, Load (ETL) strategy to construct dimension tables and facts tables.
- KPI Analysis and Dashboard Development: Analyze the identified KPIs and utilize aggregated data to develop insightful dashboards. These dashboards will facilitate discussions addressing specific business questions, requirements, and the initial problems identified in the project.

4. Business Questions

These questions aim to address the identified business problems and align with the overarching goals, guiding the data analysis and BI initiatives within the manufacturing subsystem

1. Which type of bicycle is produced the most?
2. Which Sub-Products are most likely to produce errors?
3. Which financial year has the most production?
4. Production volume over the years has developed according to what rules and trends?
5. Is production usually guaranteed on time and cost?

5. Scopes

- **Space scopes:** Adventure Works Company, specifically focusing on the Manufacturing module.

- ***Time scopes***

- The Adventure Works dataset was collected from 2011 to 2014.
- The project was conducted over three months, from January 30, 2024, to May 2, 2024.

6. Project Budget

6.1. Cost estimate

Indirect cost

Writing weekly reports is important for tracking progress and sharing details with stakeholders. It helps the project team stay organized and connected. Investing in IT support, like setting up and maintaining systems for the BI project, is crucial. It ensures the project runs smoothly and meets its goals. Training employees also plays a big role. It helps them develop skills for managing the BI system and grows their personal and professional abilities, ultimately improving the project's success.

Table 0.1: Indirect cost

Indirect cost	Amount
Writing weekly reports	\$8,000
Project management costs	\$10,000
Employee training costs	\$10,000

Sunk cost

The initial research and development costs refer to the money spent on planning and getting ready for the BI project before it starts. These expenses usually cover activities like researching and figuring out if the project can actually be done. Once this money is spent, it can't be gotten back if the project doesn't go ahead. Understanding and looking at these sunk costs is really important when deciding whether to keep going with the project or stop it. Even though you can't get this money back, it shouldn't be the main factor in deciding what to do next. Instead, the decision should be based on things like the potential benefits, risks, and how likely the project is to succeed in the future.

Table 0.2: Sunk cost

Sunk cost	Amount
Market research costs	\$1,000

business research costs	\$1,000
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Learning Curve

In projects, the term "Learning Curve" often refers to the costs involved in learning and experimenting during the project's execution. In the BI Solution for Adventure Works Manufacturing project, the Learning Curve includes the expenses related to trying out and testing different approaches. These trials help ensure that the BI system meets the project's requirements and goals accurately. Despite the possibility that these trials may not be used later on, analyzing the Learning Curve helps assess and manage these costs effectively during the project's implementation.

Reserve

Contingency Reserve

The Contingency Reserve in the BI Solution project for Adventure Works Manufacturing is applied to address hidden risks and ensure the continuity and effectiveness of the project. It is utilized to enhance or replace data when quality issues are detected, adjust scope or resources in case of changes in customer requirements, and resolve technological instabilities or issues. Costs and time for contingency are carefully estimated and allocated to ensure that the Contingency Reserve is efficiently utilized without affecting the project's official budget and timeline. In summary, the Contingency Reserve plays a crucial role in dealing with unforeseen circumstances and ensuring the success of the project.

Activity Contingency Reserve

The Activity Contingency Reserve, a portion of the overall Contingency Reserve, is set aside to help with particular tasks in the project. First, it's vital to pinpoint the key tasks and areas of high risk in the BI Solution project. Jobs like merging data, creating main reports, and rolling out systems usually come first. Then, assigning contingency funds according to how crucial and risky each task is ensures they get done within budget and without problems. It's important to manage and watch over this reserve carefully, making sure it's used well and only when really needed, and keeping an eye on how things are progressing and any risks that might pop up.

Management Reserve

Management Reserve is an essential concept in project management, particularly in BI Solution projects. It is a portion of the contingency budget set aside specifically to address unforeseeable project risks. In the context of BI Solution projects, Management Reserve may be utilized to respond to sudden changes such as new requirements from clients, shifts in the business environment, or even alterations in project scope. The allocation of Management Reserve is typically carried out by the project management team after careful evaluation of overarching and potential risks. This may involve identifying potential risks and assessing their impact on the project. Managing the Reserve requires careful oversight

to ensure it is sufficient to handle unexpected situations without affecting the project's schedule or quality.

Table 0.3: Management Reserve

Reserve	Amount
Activity Contingency Reserve	\$5,000
Contingency Reserve	\$10,000
Management Reserve	\$15,000

6.2. Determine budget

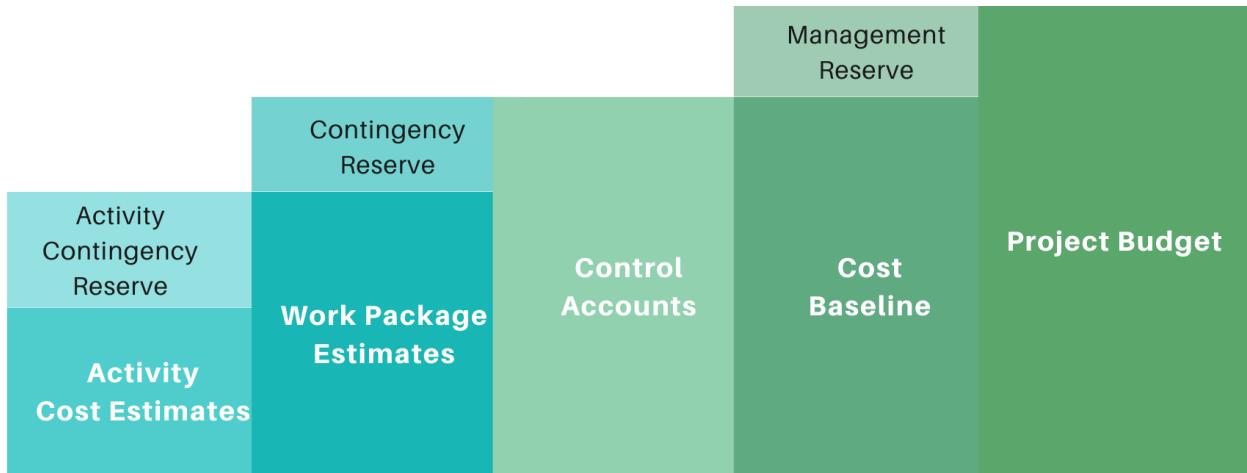


Figure 0.1: Process of determine budget

Table 0.4: Project Budget

Project budget		Amount
Direct cost	Hardware	\$17,000
	Software	\$20,000
	System implementation cost	\$10,000
Indirect cost	Training and support cost	\$15,000
	Employee training costs	\$10,000
	Writing weekly reports	\$8,000

	Project management cost	\$20,000
Sunk cost	Market research costs	\$3,000
	Business research costs	\$2,000
Reserve	Activity Contingency Reserve	\$5,000
	Contingency Reserve	\$10,000
	Management Reserve	\$15,000
Total		\$135,000

The budget for the BI Solution project for Adventure Works Manufacturing has been meticulously organized and detailed. Each expense for hardware, software, system deployment, employee training, weekly reporting, and project management is categorized and listed clearly, facilitating efficient project expenditure management and tracking. Three types of reserves, including operational reserves, contingency reserves, and management reserves, have been identified to address potential risks, providing an appropriate contingency plan. Transparency in budget calculations is demonstrated through the inclusion of sunk costs, ensuring accurate future budget decisions. In summary, the establishment and organization of the budget have ensured that expenses are estimated and managed effectively throughout the project implementation process.

7. Project deliverables

- **Phase 1 (Project Overview & Chapter 1):**
 - Requirement Documents
 - KPIs will be used in this project.
 - The BI solution is suitable for the manufacturing subsystem.
- **Phase 2 (Chapter 2 & Chapter 3):**
 - Data Model, Bus Matrix
 - Data mart Purchasing (data warehouse)
 - ETL (Extract, Transform, Load) Scripts or Procedures
 - OLAP Cubes
- **Phase 3 (Chapter 4):**
 - MDX query to build KPI
 - Documents analyzing KPIs
- **Phase 4 (Chapter 5 & Conclusion):**

- Interactive Dashboards
- Decision support documents.

8. Models/Process

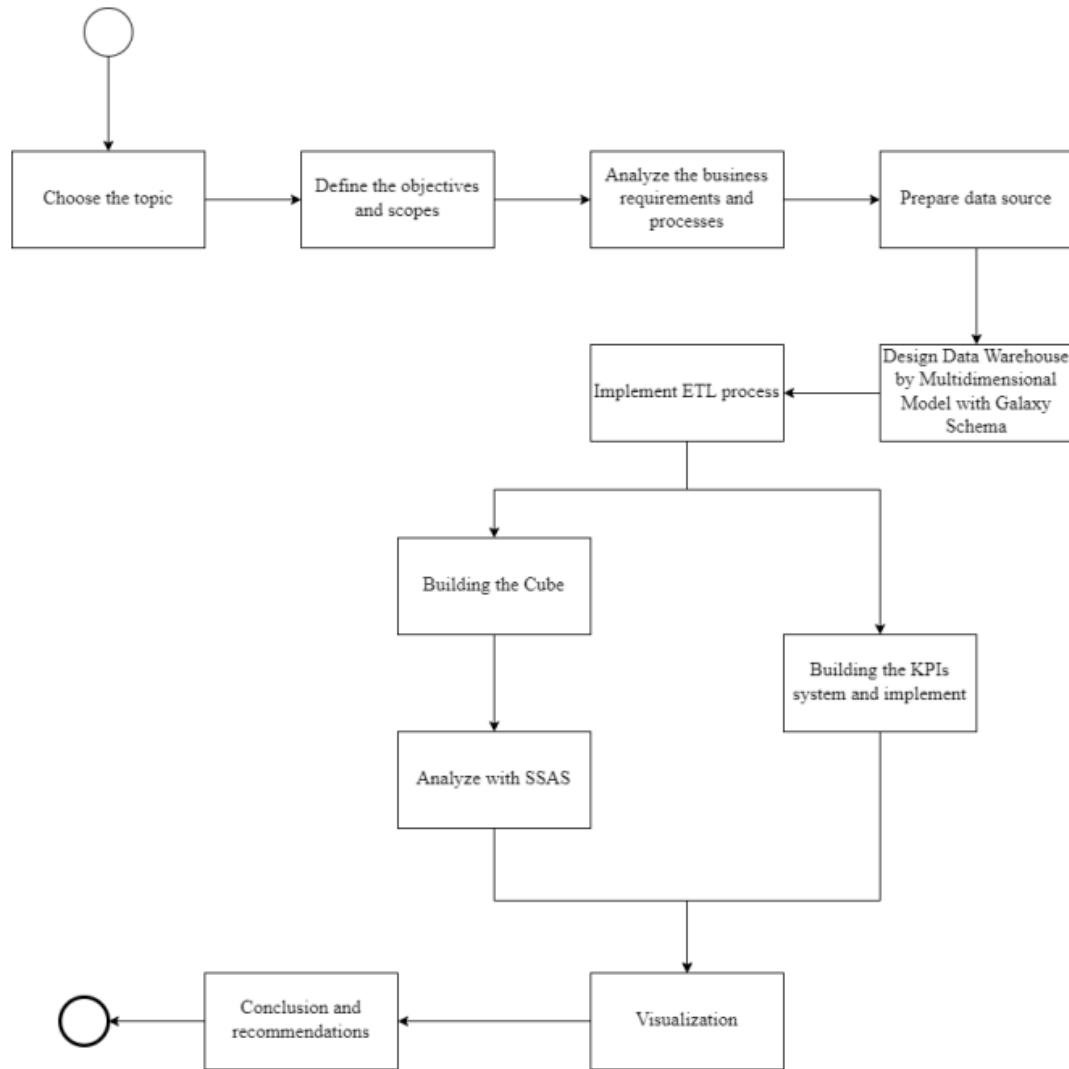


Figure 0.2: Project process (Source: Authors)

9. Tools, Methods, and Programming Languages

In our project, SSIS (SQL Server Integration Services) played a pivotal role in simplifying the data integration process. It efficiently extracted and transformed data from various sources, automated workflows, and seamlessly loaded processed data into the MS SQL

Server database. This ETL (Extract, Transform, Load) tool ensured regular updates, minimized manual errors, and upheld data consistency.

To meet project requirements, SSAS (SQL Server Analysis Services) was employed to construct multidimensional or tabular data models. This facilitated the creation of OLAP cubes, boosting query performance, enabling advanced analytics, and supporting insightful data mining. SSAS served as a crucial component in establishing a semantic layer over raw data, simplifying the analytical process for end-users.

As the central repository for integrated and transformed data, MS SQL Server provided a secure and scalable database environment. Its features, including data security, access control, and performance optimization, supported efficient data retrieval and storage, ensuring the reliability of the underlying data infrastructure.

Power BI served as the front-end data visualization and reporting tool. Its integration with SSAS allowed direct connectivity to analytical models, enhancing reporting capabilities. Power BI's self-service features empowered users to independently explore and discover insights, fostering a user-friendly environment for data interaction.

In summary, the combination of SSIS, SSAS, MS SQL Server, and Power BI presented a comprehensive solution for extracting actionable insights from raw data. This collaborative effort streamlined data integration, analysis, and visualization, ultimately supporting well-informed decision-making within the organization.

10. Structure of project

This project consists of 6 chapters:

- *Chapter 0: Overview of the project*

This section summarizes the entire project, covering its purpose, objectives, scope, and expected outcomes for the Business Intelligence & Decision Support Systems. It lays the groundwork for subsequent chapters by offering readers a clear understanding of what to expect.

- *Chapter 1: Defining requirements business/KPIs, data, and quality*

This chapter focuses on understanding and documenting the business requirements and key performance indicators (KPIs) relevant to the project. It involves analyzing data needs, quality requirements, and functional aspects essential for the development of

Business Intelligence solutions while using techniques to ensure the accuracy, consistency, and reliability of data.

- ***Chapter 2: Data preparation and Data modeling***

This chapter focuses on preparing data and designing models for Business Intelligence, covering tasks like data collection, exploration, and model creation. It also includes creating a bus matrix and detailed data models.

- ***Chapter 3: Data Integration***

This chapter deals with integrating data from various sources into either a designed data warehouse or data marts. It includes strategies and techniques for the Extract, Transform, Load (ETL) process, as well as data integration workflows. This chapter may also encompass implementation details using tools like SQL Server Integration Services (SSIS) and presenting the results of the data integration process for the assigned subsystem.

- ***Chapter 4: Multi-dimensional data analysis***

This chapter focuses on analyzing integrated data using multi-dimensional analysis techniques. It involves understanding the significance of multi-dimensional databases and OLAP (Online Analytical Processing) for exploring complex datasets. The chapter includes building OLAP cubes, writing MDX (Multi-Dimensional Expressions) queries, and analyzing KPIs using SSAS (SQL Server Analysis Services).

- ***Chapter 5: Visualization and Discussion***

This chapter emphasizes visualizing analyzed data using tools like Power BI to create interactive dashboards and reports. It aims to explain insights derived from the data and their impact on decision-making, based on identified business requirements and KPIs.

- ***Chapter 6: Conclusion and Future Works***

The conclusion chapter summarizes the project's key findings, achievements, and limitations. It also proposes potential areas for future research or improvements to the Business Intelligence solution, offering a brief overview of the report's insights.

Chapter 1. Defining requirements for business/KPIs, data, and quality

1.1. Business Requirements Analysis

Table 1.1: Object's Requirements

No.	Role	What	What for/How	Why/What for
1	Production Manager	A comprehensive dashboard overviewing production activities, including performance metrics such as efficiency, quality, and costs. A dashboard for production category analysis, including a Product Category Page for more detailed analysis.	1. To monitor overall manufacturing performance and identify general trends. 2. To analyze specific production categories in detail, pinpointing precise areas for improvement.	1. To ensure the Production Manager has a holistic understanding of manufacturing operations, facilitating broad strategic decisions. 2. To enable targeted analysis within specific production categories, allowing for the identification and resolution of nuanced issues that affect manufacturing efficiency, cost management, or product quality.

1.2. Key Performance Indicators (KPIs) Identification

1.2.1. Production Overview Analysis

Business Demands/Problems:

- Need to gain insights into overall production performance and efficiency.
- Address inefficiencies in production processes and resource utilization.

Business Goals:

- Enhance overall production efficiency and productivity.
- Identify areas for improvement and optimization within the production process.

Data Requirements:

- Data Sources: Production records, machine performance data.
- Data Content: Production quantities, machine uptime/downtime, production line information.
- Data Transformations: Aggregation of production data by time periods and production lines.
- Data Quality: Accuracy and completeness of production records, reliability of machine performance data.
- Data Integration: Correlation of production data with machine performance data for comprehensive analysis.

Functional Requirements:

- Real-time production monitoring dashboards for instant insights.
- Historical data analysis tools for identifying trends and patterns.
- Alerts for detecting anomalies or deviations from expected production levels.

Technical Requirements:

- Integration with production line management systems for data capture.
- Scalable databases to store and analyze large sets of production data.
- Advanced computing solutions for real-time data processing and analysis.

KPIs:

- Fiscal YTD - Production: Total quantity of products manufactured within the fiscal year, providing an overview of production output.
 - Formula: **Total Production = Sum(Quantity Produced per WorkOrder)**
 - Detailed Explanation: Captures the total count of all products manufactured during the fiscal year, providing a basis for evaluating whether production is on track to meet annual goals.

- Completion Rate: Measure the ratio of completed products compared to the total number of products ordered, helping to evaluate the efficiency of the production process.
 - Formula: Completion Rate = [StockedQty] / [OrderQty]
 - Detail Explanation: This KPI evaluates the efficiency of the production process by measuring the ratio of completed products to the total number of products ordered. It calculates the Completion Rate by dividing the quantity of stocked products (StockedQty) by the total number of products ordered (OrderQty). This metric offers valuable insights into the effectiveness of production operations and helps assess the company's ability to meet customer demand and fulfill orders accurately.
- Fiscal YTD - Resource Hours Production
 - Formula: Sum (ActualResourceHrs per year)

Detail Explanation: Fiscal YTD - Resource Hours Production tracks the total number of actual resource hours dedicated to production activities throughout the fiscal year. It aggregates the sum of actual resource hours spent on production tasks within each year of the fiscal period. This metric provides a comprehensive overview of the labor input into production processes over time, facilitating analysis of resource utilization, productivity, and efficiency trends.

1.2.2. Product Quality Control Analysis

Business Demands/Problems:

- Ensure consistent product quality to meet customer expectations and regulatory standards.
- Identify and address factors contributing to product defects or quality issues.

Business Goals:

- Improve product quality and reduce the occurrence of defects.
- Implement proactive quality control measures to prevent quality issues before they occur.

Data Requirements:

- Data Sources: Quality inspection reports, customer feedback data.
- Data Content: Defect types, defect quantities, inspection results.

- Data Transformations: Analysis of defect trends over time, correlation with production processes.
- Data Quality: Accuracy and completeness of quality inspection records, reliability of customer feedback data.
- Data Integration: Linking quality control data with production data for root cause analysis.

Functional Requirements:

- Quality control dashboards for real-time monitoring of defect rates.
- Trend analysis tools for identifying patterns in quality issues.
- Integration with customer feedback systems for proactive quality improvement.

Technical Requirements:

- Integration with quality inspection equipment for automated data capture.
- Advanced analytics capabilities for predictive quality control.
- Data visualization tools for presenting quality control metrics and insights.

KPIs:

- **Fiscal YTD - Waste:**
 - Formula: **Total Waste = [ScrappedQty]*Product StandardCost**
 - Detailed Explanation: This KPI aggregates the total quantity of waste generated across the entire production process within the fiscal year, providing a metric to measure against waste reduction targets.
- **Waste Percent:**
 - Formula: **Waste Percent = (Total ScrappedQty / Order Quantity) * 100**
 - Detailed Explanation: This represents the proportion of materials that become waste in comparison to the total amount used, reflecting the efficiency of material usage and the effectiveness of waste management strategies.

1.2.3. Production Performance Control Analysis

Business Demands/Problems:

- Ensure optimal performance of production processes to meet production targets and customer demands.
- Identify and mitigate factors that impact production performance and efficiency.

Business Goals:

- Improve overall production performance and efficiency.
- Decrease Cost Variance

Data Requirements:

- Data Sources: Production records, machine performance data, maintenance logs,
- Data Content: Production uptime/downtime, machine utilization rates, maintenance schedules.
- Data Transformations: Analysis of production downtime causes, correlation with maintenance activities.
- Data Quality: Accuracy and timeliness of production and machine performance data.
- Data Integration: Linking production performance data with maintenance and machine data for analysis.

Functional Requirements:

- Real-time production performance monitoring dashboards for instant insights.
- Root cause analysis tools for identifying factors contributing to production downtime.
- Predictive maintenance capabilities for proactive equipment maintenance.

Technical Requirements:

- Integration with machine monitoring systems for real-time data capture.
- Machine learning algorithms for predictive maintenance analysis.
- Scalable databases to store and analyze large sets of production and machine data.

KPIs:

- Average Production Lead Time:
 - Formula: **Sum (Lead Time per Product) / Total Number of Products**

- Detailed Explanation: Evaluate the average duration required to produce each product, highlighting efficiency and identifying potential bottlenecks within the production process.
- Cost Variance:
 - Formula: **[ActualCost] - [PlannedCost]**
 - Detail Explanation: Measuring the variance between planned and actual costs helps assess the effectiveness of cost management in the production process.
- On-time Production rate
 - Formula: **Sum([ActualEndDate] - [ScheduledEndDate])**

Detail Explanation: Measuring the rate of on-time task completion compared to the planned schedule helps evaluate the performance of task execution efficiency.

1.3. BI and Data Warehouse Frameworks/Solutions

1.3.1. Business Intelligence Architecture

Business Intelligence (BI) encompasses the strategies, technologies, and tools used by companies like AdventureWorks to analyze business information data. BI solutions provide historical, current, and predictive views of business operations.

The BI architecture for AdventureWorks integrates data from various sources across the company into a unified repository, supporting reporting, analysis, and decision-making processes. This architecture includes data sources, ETL processes, data warehouses/data marts, and BI applications.

For AdventureWorks, the advantages include improved decision-making based on data-driven insights, enhanced operational efficiency, better customer understanding, and the ability to identify market trends and performance improvements.

AdventureWorks' BI strategy involves aligning BI initiatives with business goals, focusing on areas with the highest ROI. Key strategies include adopting a phased approach to BI implementation, ensuring data quality, and fostering a data-driven culture.

1.3.2. Data warehouse and Data mart approach

Data Mart for the Manufacturing Subsystem:

Objective: The primary goal of the Manufacturing Data Mart is to provide in-depth, real-time insights into the manufacturing process. This includes material management,

production workflows, quality control, and labor efficiency. The Data Mart aims to support strategic decisions to optimize manufacturing processes, reduce costs, and improve product quality and throughput.

Significance: The dedicated Manufacturing Data Mart serves as a pivotal element in harnessing data-driven insights for operational excellence. By focusing on key performance indicators (KPIs) and metrics specific to manufacturing, the organization can identify bottlenecks, streamline operations, and leverage opportunities for improvement. This contributes to competitive advantage and aligns manufacturing operations with broader business strategies.

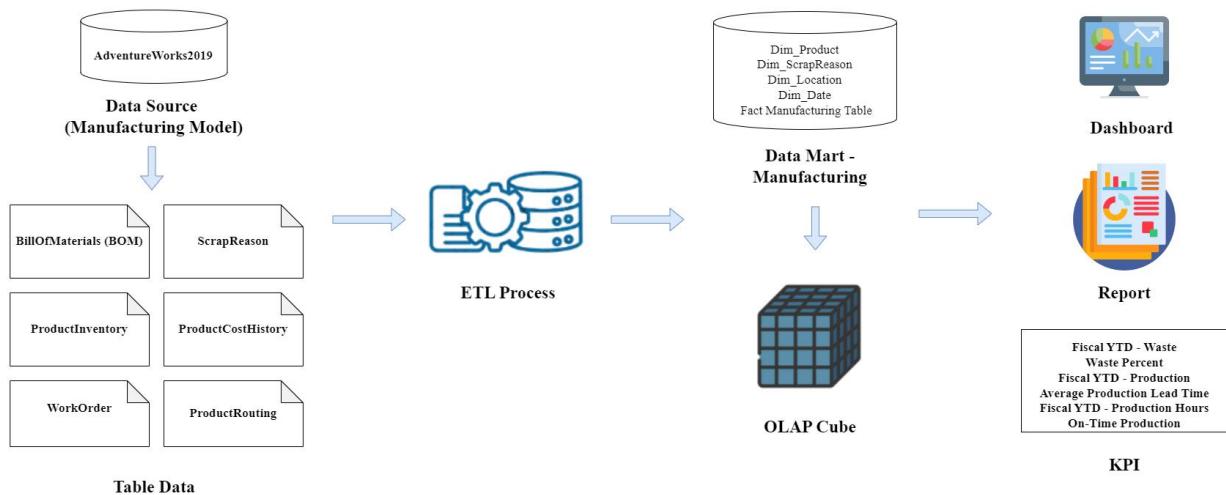


Figure 1.1: BI Solution for Data Mart of Manufacturing

Description:

- **Approach:** Bottom-Up
- **Structure:** Utilizes a star schema optimized for query performance and analytical processing, facilitating easy access to manufacturing metrics.
- **Data Sources:** Incorporates data from several key tables within the AdventureWorks database, including:
 - **BillOfMaterials (BOM):** Details on components and raw materials for each product.

- **ProductCostHistory:** Historical data on product manufacturing costs.
 - **ProductInventory:** Information on product stock levels.
 - **WorkOrder:** Specific production order details.
 - **ProductRouting:** Process routes for each product.
 - **ScrapReason:** Reasons for product or component scrap.
- **ETL Process:** Develop ETL procedures to prepare data from these sources for analysis, ensuring data is cleaned, transformed, and loaded efficiently.
 - **KPIs and Reporting:** Develop a set of KPIs including Fiscal YTD - Waste, Fiscal YTD - Production, Average Production Lead Time, Fiscal YTD - Production Hours, On-Time Production, and Waste Percent. Design dashboards and reports to visually represent these KPIs for easy interpretation.

Chapter 2. Data preparation and Data modeling

2.1 Data preparation

2.1.1. Overall description of the AdventureWork dataset

This is a sample database called AdventureWorks2019, used by Microsoft to illustrate their applications and tools. It simulates a manufacturing and sales company for bicycle products.

The database comprises 8 main schemas, corresponding to different business functions such as human resources, products, manufacturing, purchasing, inventory, sales, and administration.

Each schema includes several tables related to its function. For example, the HumanResources schema has tables for employees, departments, pay history, job candidates, etc. The Production schema has tables for products, product categories, work orders, bill of materials, etc.

Specifically, the table count per schema is:

1. Production: 14 tables
2. Person: 10 tables
3. Sales: 14 tables
4. Purchasing: 5 tables
5. HumanResources: 8 tables
6. dbo: 3 tables

2.1.2. Data collection

The data is collected from the Manufacturing dataset of AdventureWorks by Microsoft between 2011 and 2014.

2.1.3. Data description and data understanding

- a. Data description

In the production subsystem, the connection between data tables is shown in the figure below:

Manufacturing

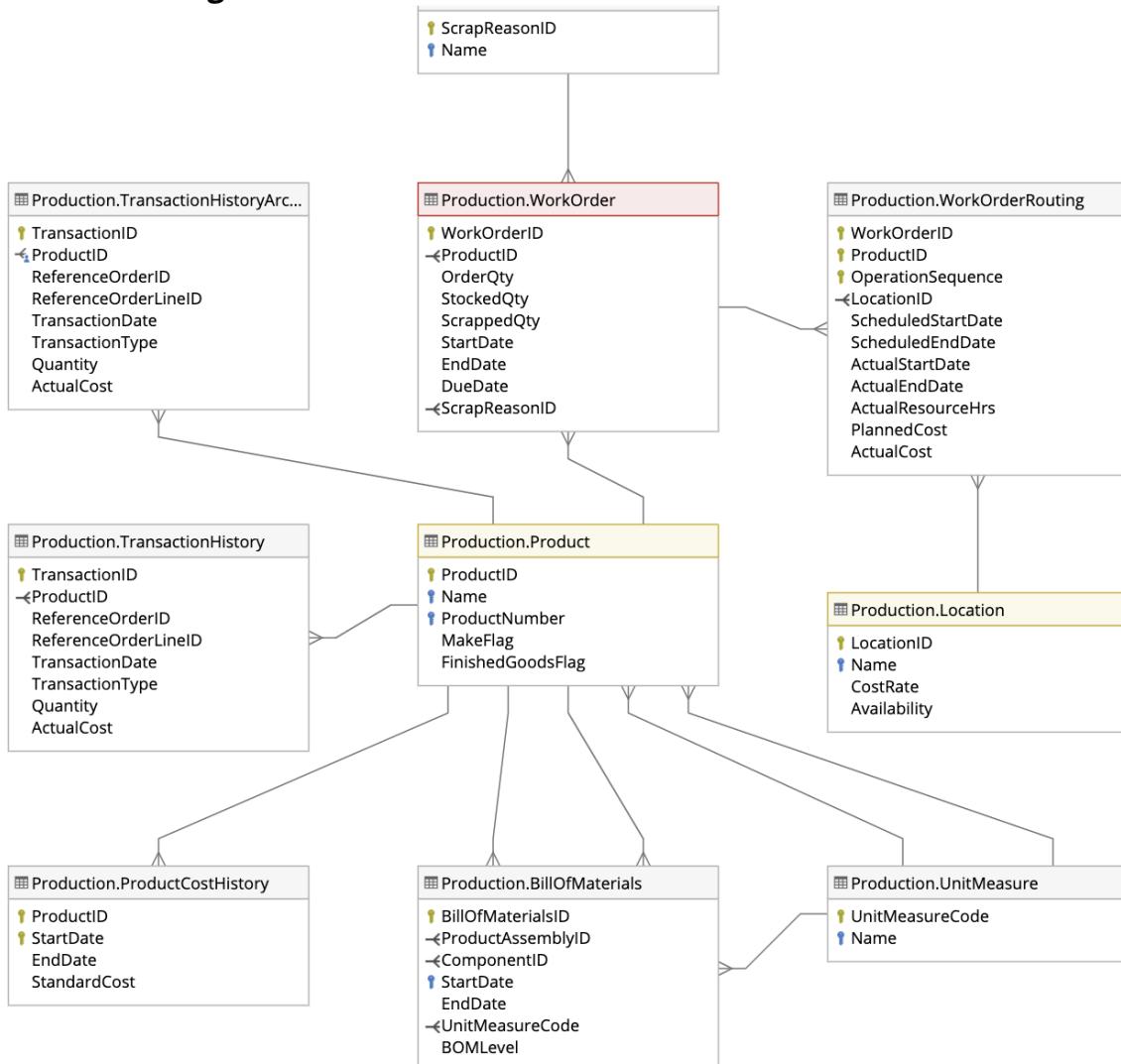


Figure 2.1: ERD of Manufacturing process management module

Table 2.1: Description of Manufacturing Schema

Table Name	Description
Production.BillOfMaterials	This table stores the bill of materials information, including the bill of materials ID, product assembly ID, component ID, start and end dates, unit measure code, and BOM level.

Production.ProductCostHistory	This table maintains the historical standard cost information for products, including product ID, start and end dates, and standard cost.
Production.ProductListPriceHistory	This table maintains the list price information for products, including product ID, start and end dates, and list price.
Production.ScrapReason	This table shows the reasons why the product was defective, corresponding to each production order.
Production.TransactionHistory	This table contains details of production transactions, including transaction ID, product ID, reference order information, transaction date, type, quantity, and actual cost.
Production.TransactionHistoryArchive	This table likely stores archived transaction history records for auditing or historical analysis purposes.
Production.WorkOrder	This table stores information about work orders, such as work order ID, product ID, order quantity, scrapped quantity, start and end dates, due date, and associated scrap reason ID.
Production.WorkOrderRouting	This table defines the routing or sequence of operations required to complete a work order, including operation sequence, location ID, scheduled start and end dates, actual start and end dates, actual resource hours, planned cost, and actual cost.
Production.Product	This table contains details about products, such as product ID, name, product number, make flag, and finished goods flag.
Production.Location	This table contains information about production locations, including location ID, name, cost rate, and availability.

Production.UnitMeasure	This table stores the unit of measure codes and their corresponding names.
------------------------	--

This dataset appears to be focused on managing various aspects of manufacturing processes, including transaction history, work orders, product information, cost tracking, bill of materials, and production locations. It provides a comprehensive view of the production cycle, from materials and components to finished goods, work order routing, and cost analysis.

b. Data understanding

Table 2.2: Description of Production.BillOfMaterials

Column	Description
Bill of Materials ID	This is a unique identifier for each record in the table, typically used for referencing and managing specific information of the bill of materials.
Product Assembly ID	This code is linked to the product or assembly to which this bill of materials applies, helping to determine the assembly structure of the product.
Component ID	This is the identifier for each part or component used in the product, allowing tracking and managing of specific components.
Start and End Dates	These dates indicate the start and end time of validity of the bill of materials, helping to determine the time frame during which the information is accurate and applicable.
Unit Measure Code	This code indicates the unit of measurement used for the components, such as meters, kilograms, or pieces, helping to standardize the tracking and management of quantities.
BOM Level	The Bill of Materials (BOM) level determines the position of the component or assembly in the overall structure of the product, from the highest level to the lowest level.

Table 2.3: Description of Production.ScrapReason

Column	Description
Production Order ID	A unique identifier for each production order.
Defect Reason	The specific reason or cause behind the product defect.
Timestamp	The date and time when the defect was recorded or detected.
Description	Additional information or notes related to the defect reason, providing context or details for analysis and corrective action.

Table 2.4: Description of Production.WorkOrder

Column	Description
Work Order ID	A unique identifier for each work order.
Product ID	The identifier of the product associated with the work order.
Order Quantity	The planned quantity of the product to be produced according to the work order.
Scrapped Quantity	The quantity of the product that was rejected or deemed unusable during production.
Start and End Dates	The dates indicating when the work order commenced and when it was completed.
Due Date	The deadline or target date for completing the work order.
Associated Scrap Reason ID	An identifier linking to the reason(s) for scrapping the product, providing insight into why certain quantities were rejected or scrapped during production.

Table 2.5: Description of Production.WorkOrderRouting

Column	Description
Operation Sequence	A numeric identifier indicating the order in which operations are performed.

Location ID	The identifier for the location where each operation takes place, such as a workstation or department.
Scheduled Start and End Dates	The planned dates for starting and completing each operation.
Actual Start and End Dates	The actual dates when each operation began and ended.
Actual Resource Hours	The total hours of resources (e.g., labor, machinery) consumed during each operation.
Planned Cost	The estimated cost associated with performing each operation as planned.
Actual Cost	The actual cost incurred for performing each operation, which may deviate from the planned cost due to factors like resource usage or efficiency.

Table 2.6: Description of Production.Product

Column	Description
Product ID	A unique identifier for each product.
Name	The name or description of the product.
Product Number	An identifier assigned to the product for tracking purposes.
Make Flag	A binary indicator (e.g., 0 or 1) denoting whether the product is manufactured internally (make) or obtained externally (buy).
Finished Goods Flag	A binary indicator specifying whether the product is considered a finished good (e.g., ready for sale) or an intermediate component in the production process.

Table 2.7: Description of Production.Location

Column	Description
Location ID	A unique identifier for each production location.

Name	The name or description of the production location.
Cost Rate	The rate or cost associated with using the production location, which may include factors such as rent, utilities, and maintenance expenses.
Availability	An indicator of the availability of the production location for scheduling production activities, which may include factors such as operating hours, downtime, or capacity constraints.

2.1.4. EDA

-Showing product quantity produced by year

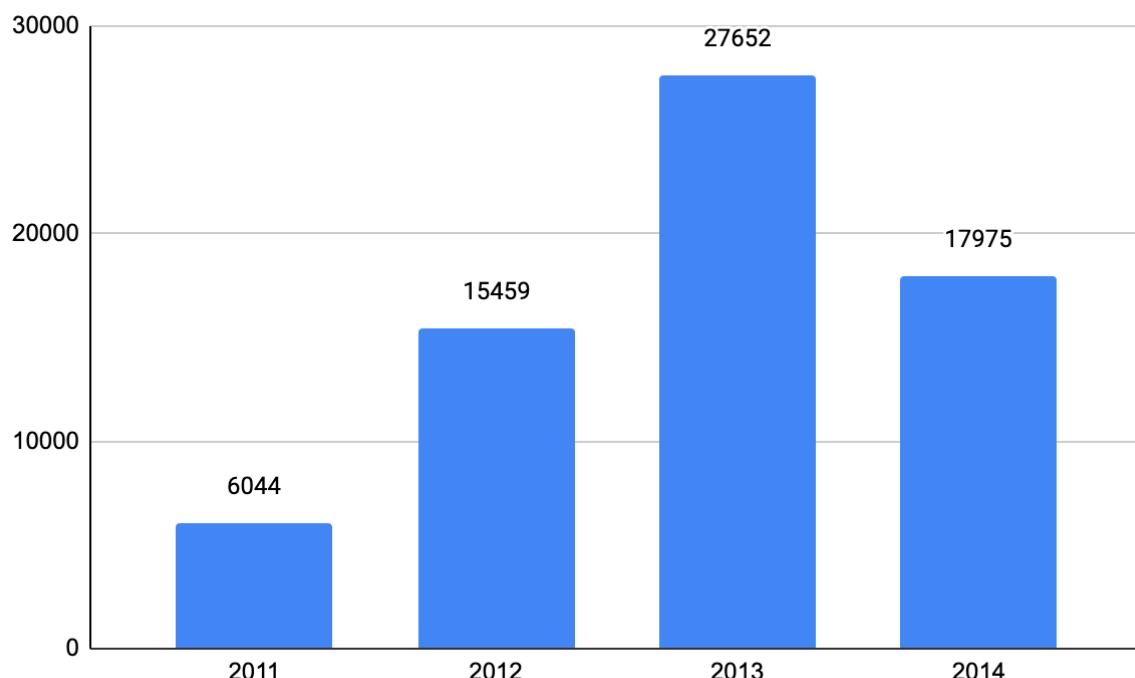


Figure 2.2: Diagram showing product quantity produced by year.

The chart illustrates the total quantity of products, primarily bicycles and accessories, produced by the company each year from 2011 to 2014, based on data from the AdventureWorks2012 database. Starting with a production quantity of 6,045 units in 2011, the company experienced a progressive increase in its yearly output, more than doubling to 15,459 units in 2012 and reaching its peak in 2013 with 27,652 units produced, making

it the most productive year during this period. However, in 2014, the production quantity declined to 17,975 units, a noticeable decrease from the previous year's high, albeit still higher than the levels observed in 2011 and 2012. The consistent yearly increase until 2013 could be attributed to factors such as increased demand, expansion of production facilities, or improved efficiency, while the subsequent decline in 2014 might have been caused by factors like a decrease in demand, supply chain disruptions, or changes in the company's production strategy. Although this analysis is based solely on the information provided in the chart, it highlights the fluctuations in the production quantity over the years, with 2013 being the peak and 2014 experiencing a decrease, potentially reflecting shifts in market conditions or operational adjustments.

Calculating total quantity in inventory across all production units.

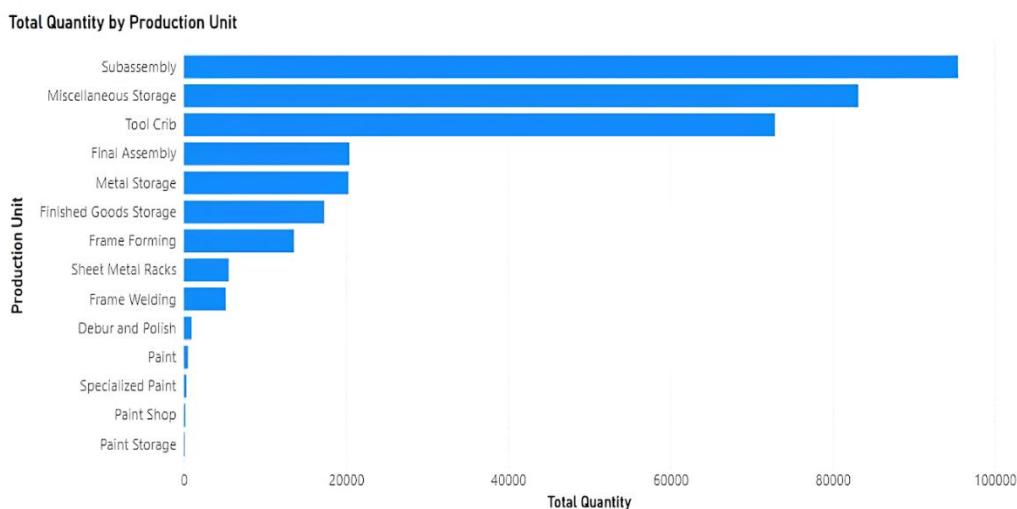


Figure 2.3: Diagram showing total quantity in inventory across all production units

Within the production department, there are fourteen (14) sub-production units with specific roles. Subassembly holds the highest production capacity, totaling 95,477 units (29%), followed by Miscellaneous Storage, accounting for 83,173 units (25%). The Tool Crib ranks third in production capacity, with a total of 72,899 units (22%).

Showing Total Days of Production and Total Days Overdue by Production Unit

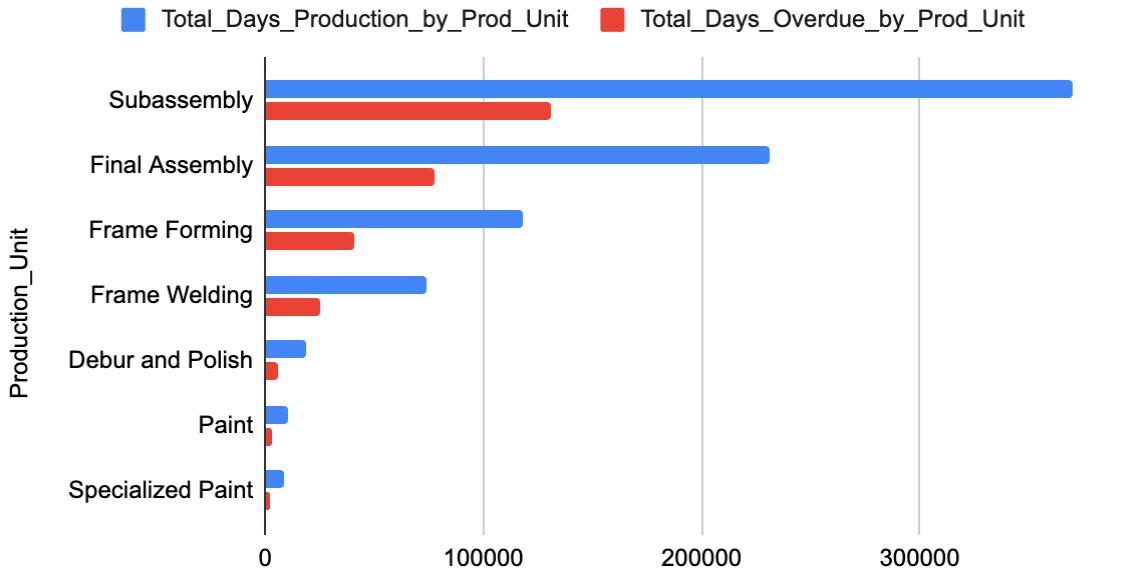


Figure 2.4: Diagram showing Total Days of Production and Total Days Overdue by Production Unit.

In this analysis, I compared total production days and overdue days by unit from 2011 to 2014. Production days were calculated by subtracting ActualStartDate from ActualEndDate, while overdue days were determined by the difference between ScheduledStartDate and ActualStartDate. Despite occasional overdue days, most production units met manufacturing timelines. If overdue days exceeded production days, it signaled operational issues. For instance, the Subassembly unit, with the highest production quantity, also had the highest production and overdue days. This trend was observed across other units, showing a correlation between production quantity, production days, and overdue days.

Showing products as finished goods ready for sale

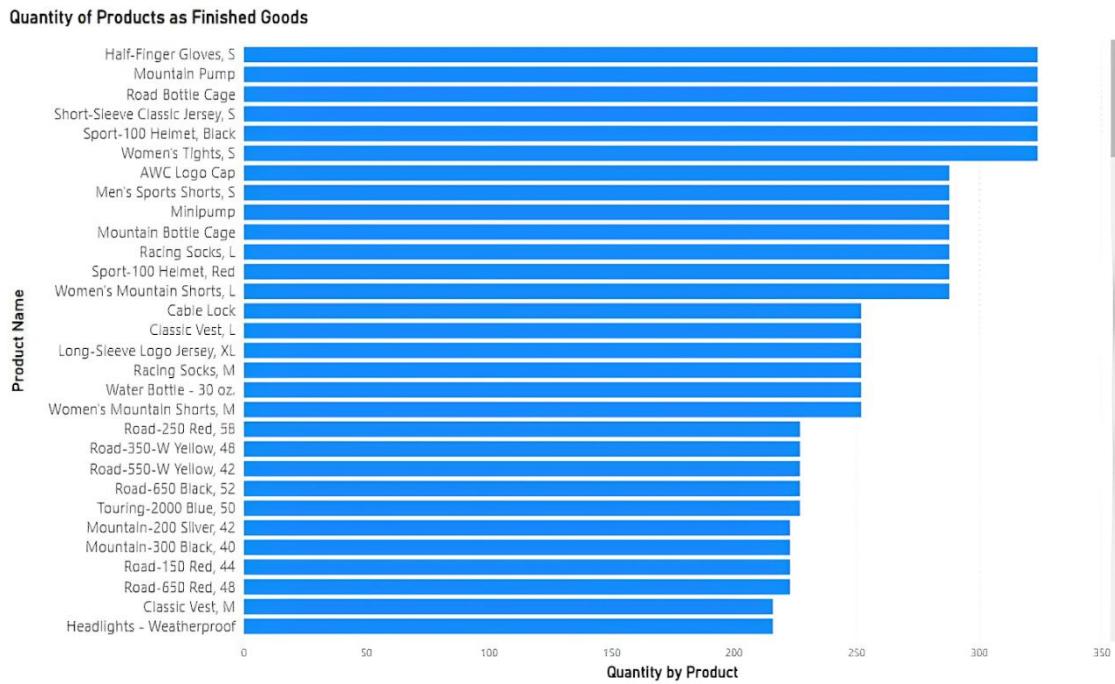


Figure 2.5: Diagram showing products as finished goods ready for sale.

The "Finished Goods Storage" unit ranks sixth in terms of production quantity, with a total of 17,319 units produced. This unit represents the final stage in the company's production process and holds 152 products that are ready for sale. Notably, among these products, "Half-Finger Glover," "Mountain Pump," "Road Bottle Cage," "Short-Sleeve Classic Jersey," "Sport-100 Helmet," and "Women's Tights" have the highest quantity ready for sale, each with 324 units available.

Overall, the analysis provides insight into the productivity and readiness of products within the company's production chain, highlighting specific items with significant quantities available for sale.

Total Production Cost per Product

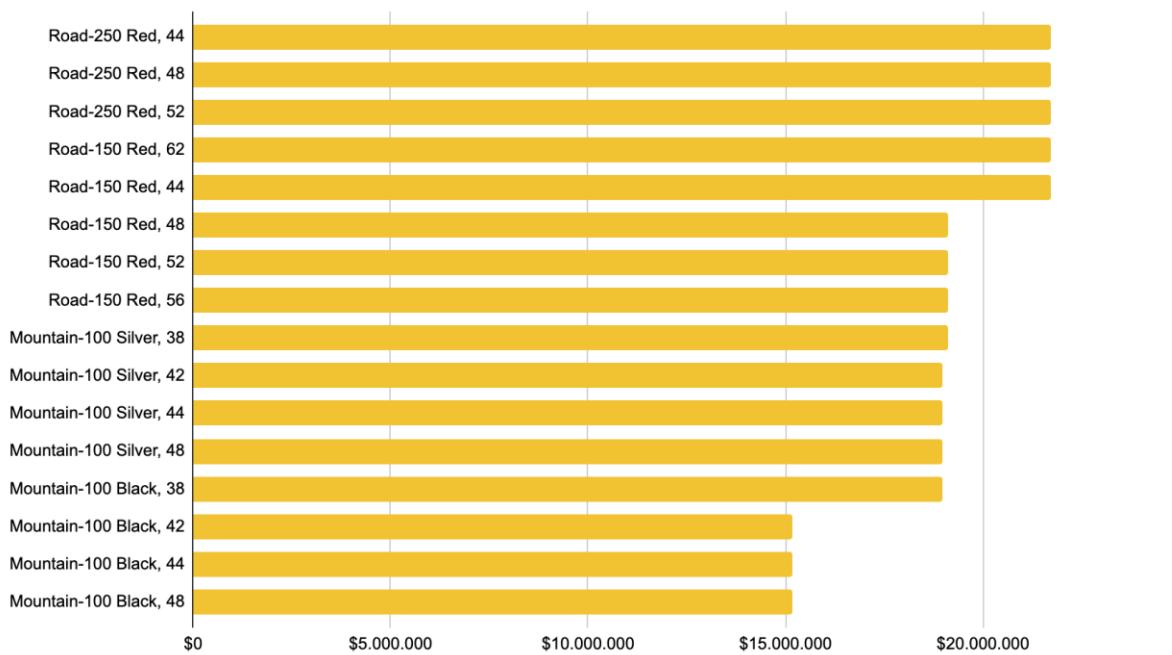


Figure 2.6: Total Production Cost per Product

Assembly Quantity Required Over Time

Assembly Quantity Required Over Time

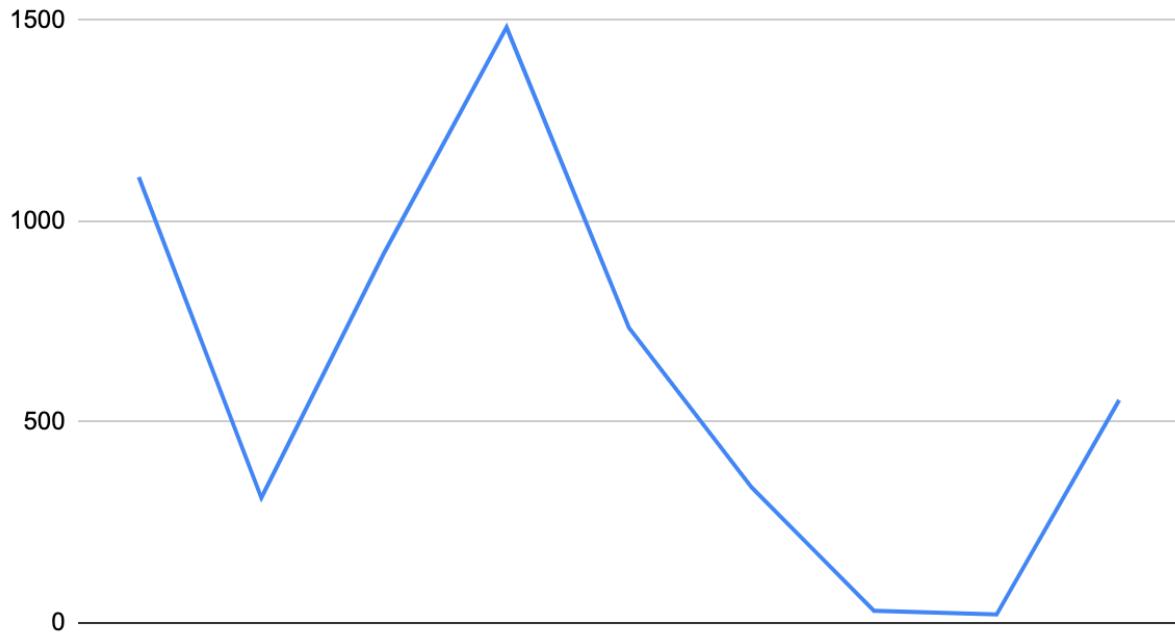


Figure 2.7: Assembly Quantity Required Over Time

This chart illustrates the quantity of assemblies needed for production over a specified period. This chart visualizes the fluctuation in assembly demand over time, providing insights into production planning and resource allocation. It may detect trends such as seasonal variations or sudden spikes in demand, helping businesses adjust their manufacturing processes effectively. Additionally, it supports setting production targets and scheduling production activities to efficiently meet demand.

Showing Number of Days of Production and Number of Days Overdue for Subassembly Production Unit

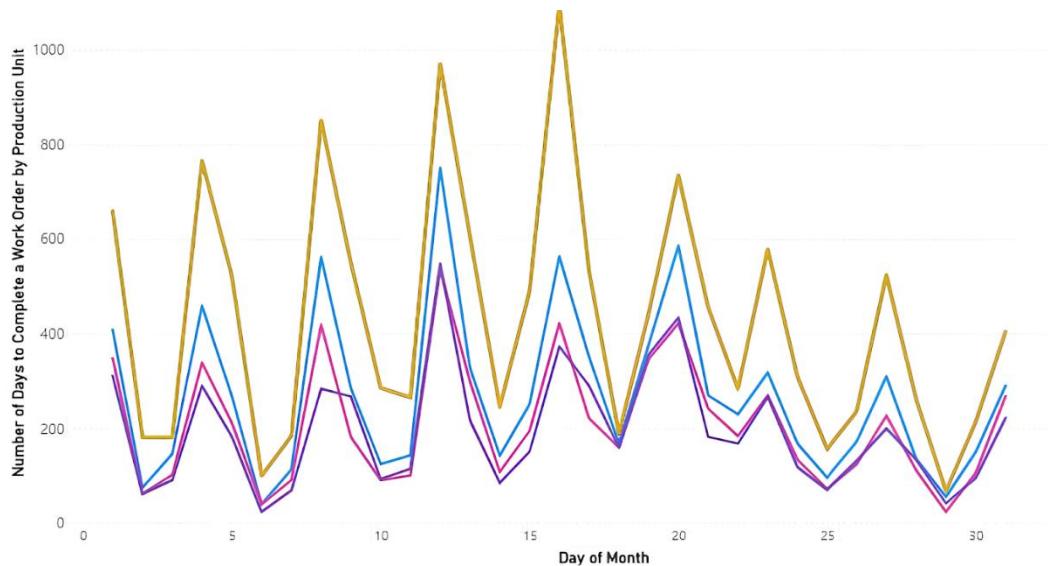


Figure 2.8: Diagram showing Number of Days to Complete a Work Order by Day and Production Unit from 2011 to 2014

In this time series analysis, we observe that the Subassembly unit consistently ranks highest in terms of the number of days required to complete a work order on a daily basis. Notably, there's a notable pattern where production activity tends to peak in the middle of each month across all production units.

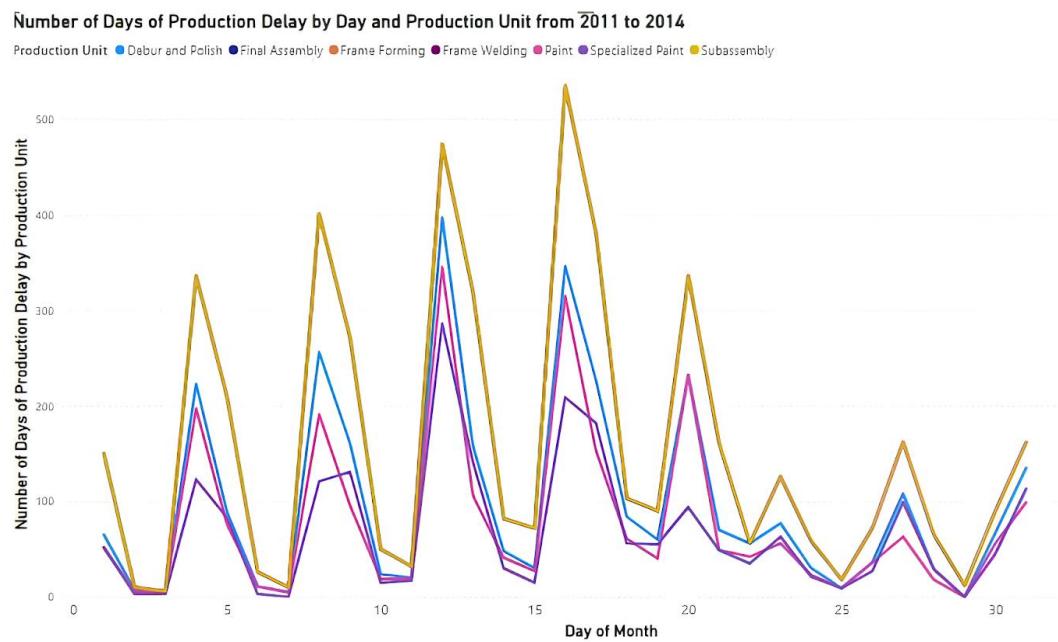


Figure 2.9: Diagram showing Number of Days of Production Delay by Day and Production Unit from 2011 to 2014.

In this section, Subassembly continues to experience the highest number of production delay days, coinciding with the middle of the month, a trend consistent across all production units. This correlation underscores a strong relationship between production days and production delay days.

Calculating total orders and sales amount by product

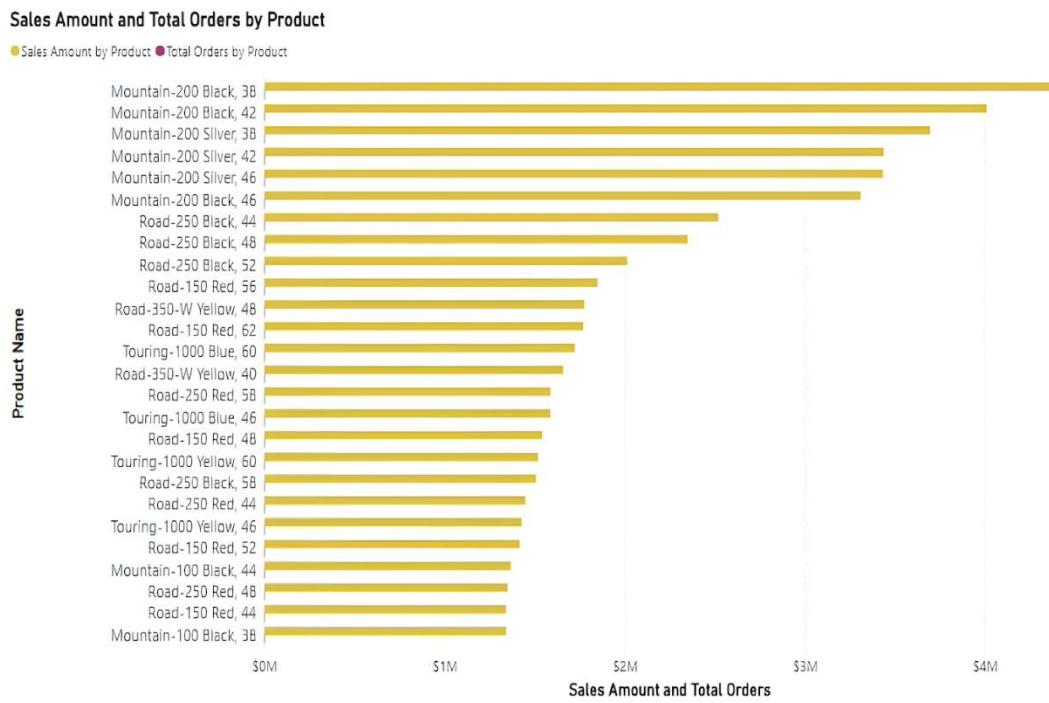


Figure 2.10: Diagram showing total orders and sales amount by product

In this section, we processed a total of 274,914 orders for 266 products, resulting in a cumulative sales amount of \$109.8 million. The product with the highest sales amount is the Mountain-200 Black, 38 variances, generating \$4.4 million in sales from 2,977 orders.

2.2. Bus matrix

A bus matrix is a valuable tool utilized in data management and business analysis, serving to visualize the connections between various dimensions and business processes. It organizes dimensions along one axis and business processes along the other, with each intersection indicating the data associated with that particular dimension and process. By

establishing standardized measures for each dimension, the bus matrix facilitates the creation of a data warehouse, allowing for seamless support of diverse business processes and effortless adaptation to evolving requirements. This tool proves instrumental in constructing flexible data models and enhancing data management systems within organizations.

Table 2.8: Bus matrix

Business Process	Dimensions			
	Date	Product	ScrapReason	Location
Manufacturing	X	X	X	
Quality				
Production	X	X		X
Category Analysis				
Inventory	X	X		X

- Master Data

Master data refers to fundamental and crucial information that an organization possesses and upholds. It comprises stable and unchanging data concerning the fundamental entities of the business, such as customers, products, suppliers, and more. This type of data tends to remain consistent over time and is shared across different departments within the organization. Master data plays a pivotal role in supporting decision-making processes, maintaining information organization, and ensuring coherence across various systems and business operations.

In our context, master data encompasses information associated with numerous objects listed in the table below:

Table 2.9: Description of master data which is built to dismission table

Object	Description
Scrap Reason	This category contains data regarding the reasons behind the generation of scrap material during Aventureworks' production processes. It includes identifiers and descriptions of failures leading to scrap material generation.
Product	This category encompasses comprehensive data concerning the products either manufactured or utilized in the production of goods by AdventureWorks. It includes product identifiers, names, categories, attributes, pricing, costs, stock limits, and other relevant details.
Product Category	This refers to the various types of products offered by AdventureWorks, including bicycles, ingredients, apparel, and accessories.
Product SubCategory	This category provides more detailed classification information about specific product types within broader product categories at AdventureWorks.
Location	This pertains to the physical sites where goods or materials are stored or manufactured within AdventureWorks. It includes details such as location IDs and descriptive information about warehouses, manufacturing plants, and other relevant facilities involved in the storage and production processes.

Transaction data

Transactional data pertains to the information concerning an organization's day-to-day business operations. It encompasses specific details regarding various transactional activities, including but not limited to orders, invoices, payments, and other events relevant to the business processes. This type of data is characterized by its frequent changes, reflecting the ongoing events and activities in the short term within the organization. Transactional data holds significant importance for businesses as it furnishes a

comprehensive record of their financial transactions and operational undertakings, enabling insights into the organization's performance and facilitating informed decision-making processes.

Table 2.10: Description of transaction data which is built to fact table

Object	Description
Work Order	Work Order data offers valuable insights into manufacturing operations, providing details such as product specifications, quantities, scrap rates, and timestamps for the manufacturing process.
Work Order Routing	Work Order Routing data delves into the specific sequence of tasks within each work order, detailing the production process at different locations. This information includes both actual and projected production times and costs, aiding in the optimization of production workflows and resource allocation.

2.3. Data modeling

2.3.1. Data model

a. Dimensions Table

Table 2.11: Mapping of Dimension Tables

AdventureWork2022			Manufacturing_DW		
Attribute	Data Type	Allow null	Attribute	Data Type	Allow null
Production.Location			Dim_Location		
LocationID (PK)	smallint		LocationID (PK)	smallint	
LocationName	nvarchar(50)		LocationName	nvarchar(50)	
CostRate	money		CostRate	money	
Availability	Decima(8,2)		Availability	Decima(8,2)	
ModifiedDate	datetime				
			StartDate	datetime	

			EndDate	datetime	x
Production.Product			Dim_Product		
ProductID	int		ProductID(PK)	int	
Name	nvarchar(50)		ProductName	nvarchar(50)	
ProductNumber	nvarchar(25)		ProductNumber	nvarchar(25)	
MakeFlag	bit		MakeFlag	bit	
FinishedGoodsFlag	bit		FinishedGoodsFlag	bit	
Color	nvarchar(15)	x	Color	nvarchar(15)	x
SafetyStockLevel	smallint		SafetyStockLevel	smallint	x
ReorderPoint	smallint		ReorderPoint	smallint	x

StandardCost	money		StandardCost	money	x
ListPrice	money		ListPrice	money	
Size	nvarchar(5)	x	Size	nvarchar(5)	x
SizeUnitMeasureCode	nchar(3)	x	SizeUnitMeasureCode	nchar(3)	x
WeightUnitMeasureCode	nchar(3)	x	WeightUnitMeasureCode	nchar(3)	x
Weight	decimal(8, 2)	x	Weight	float	x
DaysToManufacture	int		DaysToManufacture	int	x
ProductLine	nchar(2)	x	ProductLine	nchar(2)	x
Class	nchar(2)	x	Class	nchar(2)	x
Style	nchar(2)	x	Style	nchar(2)	x

ProductSubcategoryID	int	x	ProductSubcategoryID	int	x
ProductModelID	int	x	ProductModelID	int	
SellStartDate	datetime		SellStartDate	datetime	
SellEndDate	datetime	x	SellEndDate	datetime	x
DiscontinuedDate	datetime	x	DiscontinuedDate	datetime	x
rowguid	uniqueidentifier				
ModifiedDate	datetime				
			StartDate	datetime	
			EndDate	datetime	x
Production.SubCategoryProduct					

Name	nvarchar(50)		SubCategoryName	nvarchar(50)	
			CategoryID	Int	X
Production.CategoryProduct					
Name	nvarchar(50)		CategoryName	nvarchar(50)	
Production.ScrapReason			Dim_ScrapReason		
ScrapReasonID(PK)	smallint		ScrapReasonID(PK)	smallint	
ScrapReasonName	nvarchar(50)		ScrapReasonName	nvarchar(50)	
ModifiedDate	datetime				
			StartDate	datetime	
			EndDate	datetime	X

	Dim_Date		
	DateKey(PK)	int	
	FullDateAlternateKey	datetime	
	DayNumberOfWeek	tinyint	
	EnglishDayNameOfWeek	nvarchar(10)	
	SpanishDayNameOfWeek	nvarchar(10)	
	FrenchDayNameOfWeek	nvarchar(10)	
	DayNumberOfMonth	tinyint	
	DayNumberOfYear	smallint	
	WeekNumberOfYear	tinyint	

	EnglishMonthName	nvarchar(10)	
	SpanishMonthName	nvarchar(10)	
	FrenchMonthName	nvarchar(10)	
	MonthNumberOfYear	tinyint	
	CalendarQuarter	tinyint	
	CalendarYear	smallint	
	CalendarSemester	tinyint	
	FiscalQuarter	tinyint	
	FiscalYear	smallint	
	FiscalSemester	tinyint	

b. Fact Tables

A fact table in a data warehousing context typically stores quantitative data, often referred to as measures, that are used for analysis along with foreign keys referencing dimension tables. When it comes to a fact table specifically designed for manufacturing. This table serves as a repository for data related to the manufacturing process, including various metrics and attributes associated with the production of goods.

Table 2.12: Mapping of Fact Tables

AdventureWork2022			Manufacturing_DW		
Attribute	Data Type	Allow null	Attribute	Data Type	Allow null
Production.WorkOrder			Fact_Manufacturing		
WorkOrderID	int		WorkOrderID	int	
ProductID	int		ProductID(FK)	int	
OrderQty	int		OrderQty	int	
StockedQty	int		StockedQty	int	
ScrappedQty	smallint		ScrappedQty	smallint	
ScrapReasonID	smallint	x	ScrapReasonID (FK)	smallint	x
Production.WorkOrderrouting					
WorkOrderID	int				
ProductID	int				
OperationSequence	smallint		OperationSequence	smallint	
LocationID	smallint		LocationID(FK)	smallint	
ScheduledStartDate	datetime		ScheduledStartDate	datetime	
ScheduledEndDate	datetime		ScheduledEndDate	datetime	
ActualStartDate	datetime	x	ActualStartDate	datetime	x
ActualEndDate	datetime	x	ActualEndDate	datetime	x
ActualResourceHrs	decimal(9, 4)	x	ActualResourceHrs	decimal(9, 4)	x

PlannedCost	money		PlannedCost	money	x
ActualCost	money	x	ActualCost	money	

2.2.3. Data Warehouse model (Star Schema)

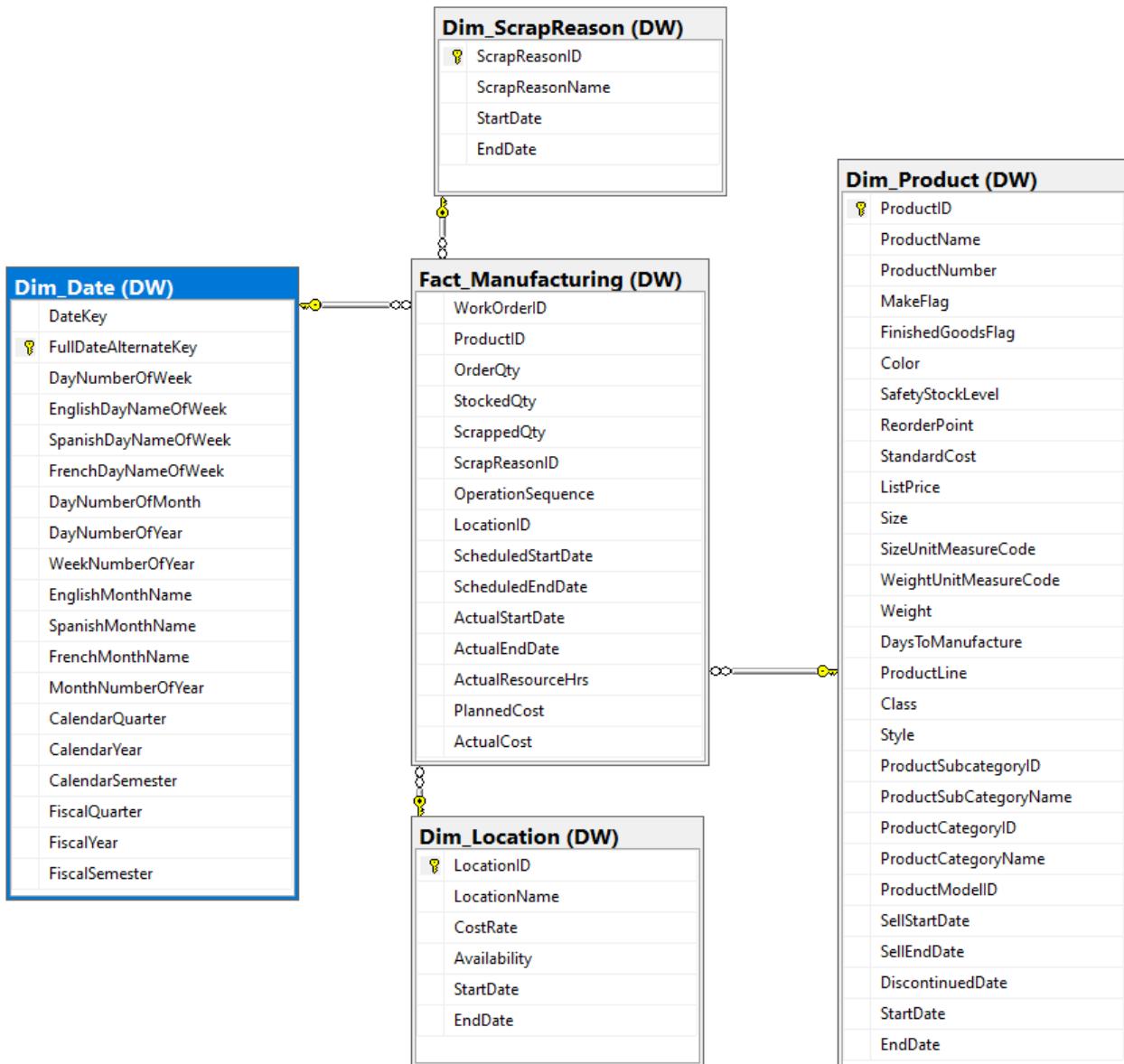


Figure 2.11: Data Warehouse Model – Star Schema (Source: Author)

A star schema is a fundamental technique in data warehousing, devised by Ralph Kimball during the 1990s. It serves as a structured and intuitive method to represent data efficiently.

By minimizing redundancy in business definitions, it facilitates quick aggregation and filtering of data within the data warehouse. The schema consists of a central fact table containing the key metrics of interest, complemented by dimension tables detailing the attributes associated with these metrics. This arrangement simplifies the visualization of multidimensional data structures, making it widely adopted in data marts. The fact table captures essential metrics like sales revenue and profit margins, with each record representing a distinct event or transaction. Meanwhile, dimension tables provide descriptive attributes such as product, customer, time, and location, enabling users to analyze data from various angles.

Chapter 3. Data Integration

3.1. Data Integration Strategy

Use the ETL Technique to integrate data creating data mark of manufacturing. Here is a diagram to describe the strategy.

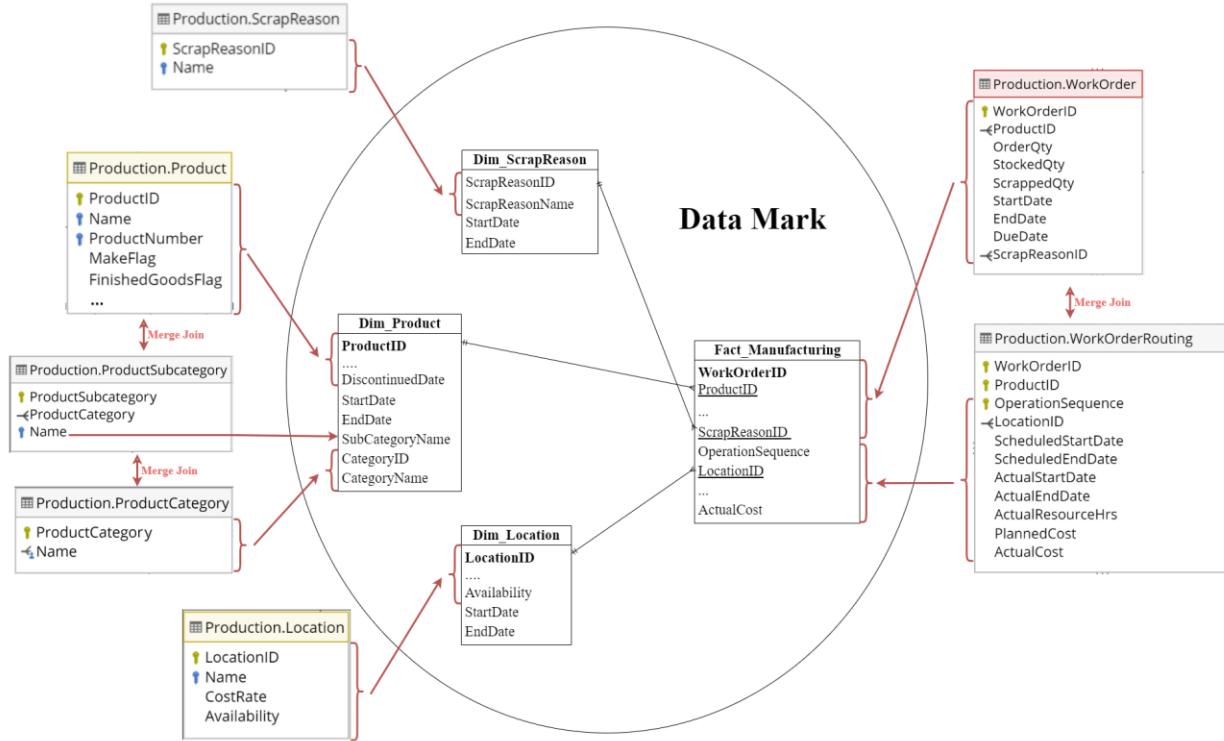


Figure 3.1. Data mapping diagram

Data Mark is made up of 4 dimension tables. In particular, the Dim_Date table will be created manually with the command so it is not shown in the image above. Dim_ScrapReason and Dim_Location is created from only one original data table, Production.ScrapReason and Production.Location, respectively. Production.Product, Production.ProductSubcategory and Production.ProductCategory are merged and joined together to form the Dim_Product table. Fact_Manufacturing retrieves data from two tables Production.WorkOrder and Product.WorkOrderRouting. This data integration process is performed using ETL techniques from the project team that identifies input data, outputs and necessary transformations.

3.2. ETL process on SSIS

To build our data warehouse for AdventureWorks2022, the project employed SQL Server Integration Services (SSIS) and Visual Studio 2019. These tools facilitated the extraction, transformation, and loading (ETL) of data from the source system into our data warehouse. The ETL tasks can be segmented into two main parts: one for handling dimension tables and another for fact tables.

Dimension Table's ETL Process

The following is the ETL process using the SSIS tool for the dimension tables in the project, including Dim_Product, Dim_ScrapReason, Dim_Location, and Dim_Date.

- **Step 1:** Open Visual Studio 2019 and create a new Integration Services Project.
- **Step 2:** Create new Connection Managers.
- **Step 3:** Generate a new SSIS package.
- **Step 4:** In SSIS packages, add Data Flow Tasks to Control Flow.⁴⁹
- **Step 5:** Select Data Flow Task, add an OLE DB Source, and configure to extract data from AdventureWorks 2022 source.
- **Step 6:** Add Sort Component to sort data ascending by primary key. Use Data Conversion to convert data type.
- **Step 7:** Use a Slowly Changing Dimension Component for transformation.
- **Step 8,** add and configure OLE DB Destination to load data into the destination.

3.2.1. Dim_Location

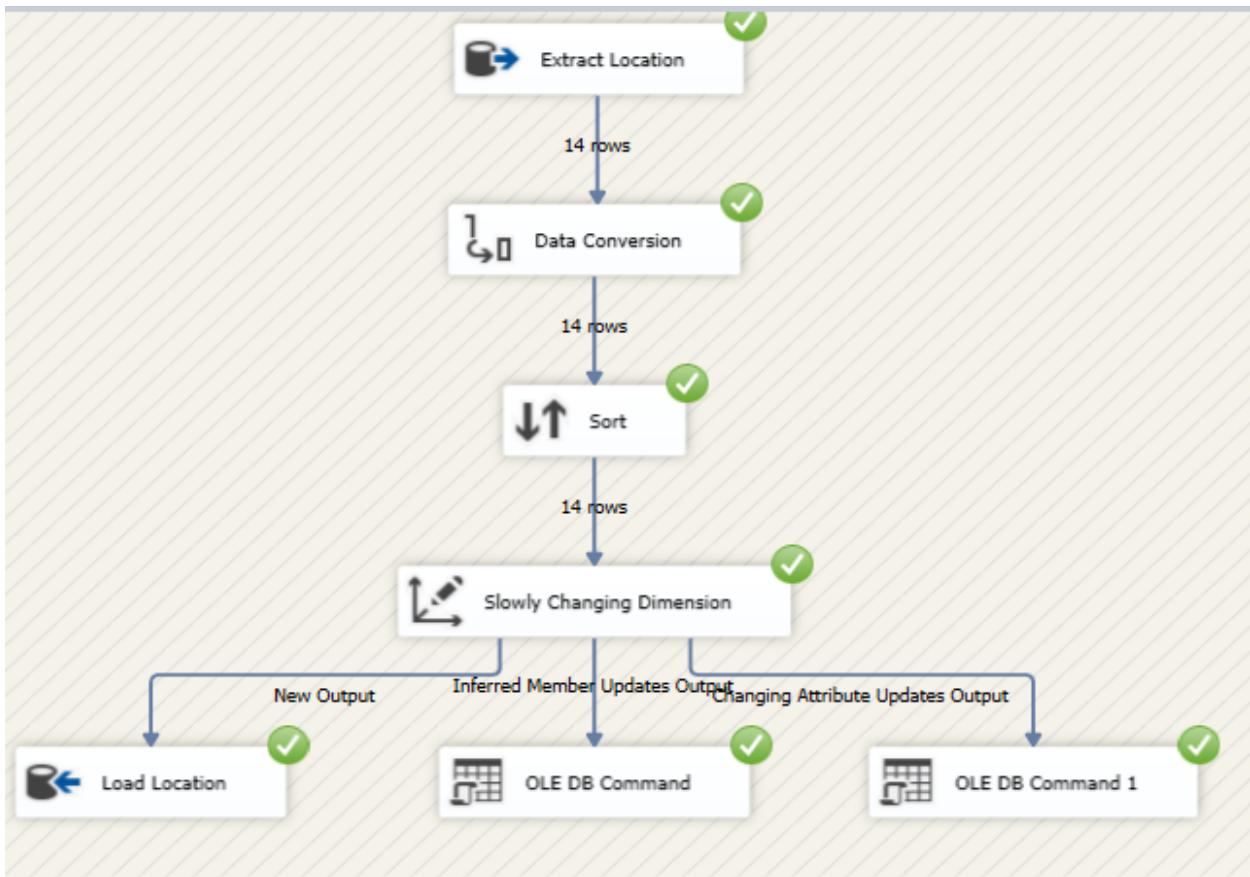


Figure 3. 2: ETL Data Flow for Dim_Locattion (Source: Authors)

The Dim_Location dimension table can only map data through a single table, Production.Location

1. Extract data from the Product.Location table
2. Convert the Availability property to the Float data type
3. Sort the data table by LocationID column
4. Use the Slowly Changing Dimension technique to load data to the Dim_Location table stored in SQL DW_Manufacturing

3.2.2. Dim_Product

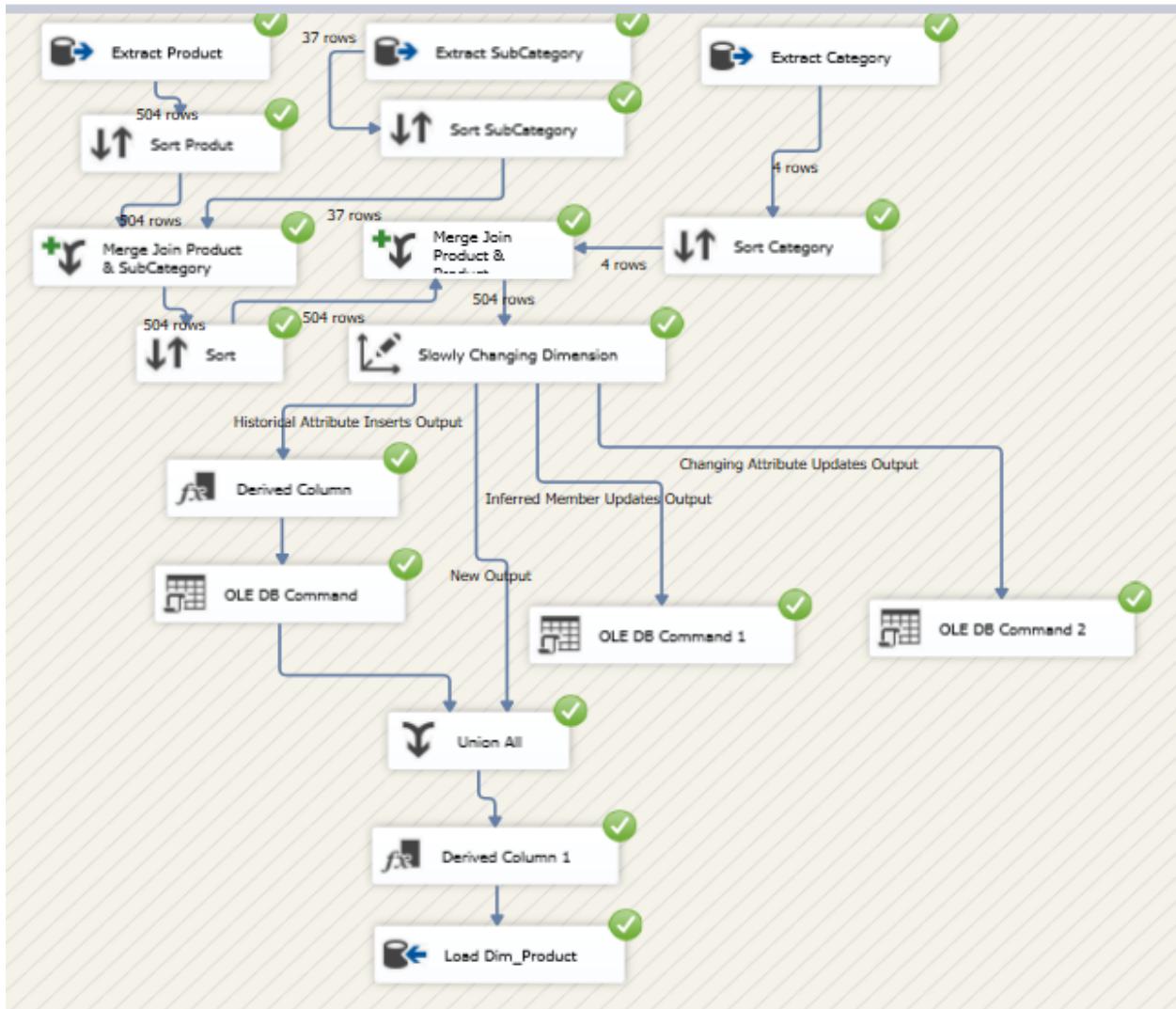


Figure 3.3: ETL Data Flow for Dim_Product (Source: Author)

Dim_Product is a combination of data from 3 source data tables: Production.Category, Production.SubCategory, Production.Product. They have a 1 - n relationship respectively

1. Extract data from 3 source data tables Production.Category, Production.SubCategory, Production.Product
2. Sort the above 3 data tables by ProductID, ProductCategoryID, ProductSubCategoryId
3. Use the Merge Join technique to combine two tables Production.SubCategory, Production.Product with a 1 - n relationship linked together through the common attribute SubCategory.ProductSubcategory - Product.ProductSubcategoryID.

4. Sort the newly created data table according to the ProductSubcategoryID attribute
5. Use the Merge Join technique to combine the newly created table and the Production.Category table with a 1 - n relationship linked together through the common attribute Category.ProductCategory - NewTable.ProductCategoryID.
6. Use the Slowly Changing Dimension technique to load data to the Dim_Product table stored in SQL DW_Manufacturing

3.3.3. Dim_ScrapReason

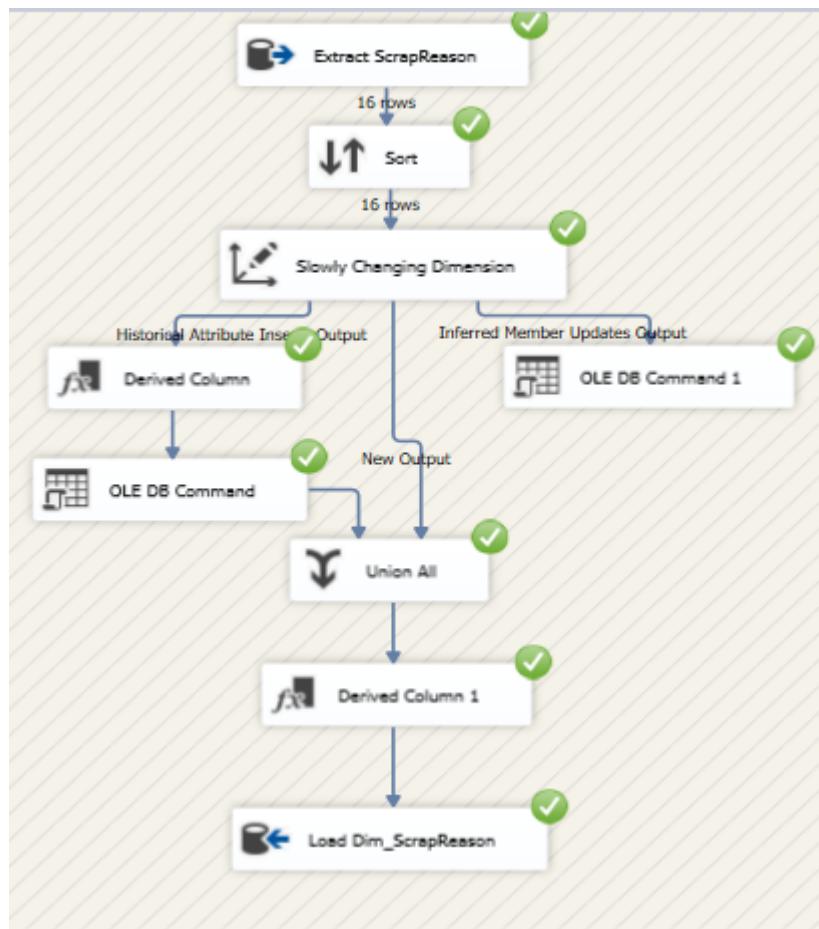


Figure 3.4. ETL Data Flow for Dim_ScrapReason (Source: Author)

The Dim_ScrapReason dimension table can only map data through a single table, Production.ScrapReason.

1. Load data from the Production.ScrapReason table
2. Sort the data table by ScrapeReasonID

3. Use the Slowly Changing Dimension technique to load data to the Dim_ScrapReason table stored in SQL DW_Manufacturing

3.2.4. Dim_Date

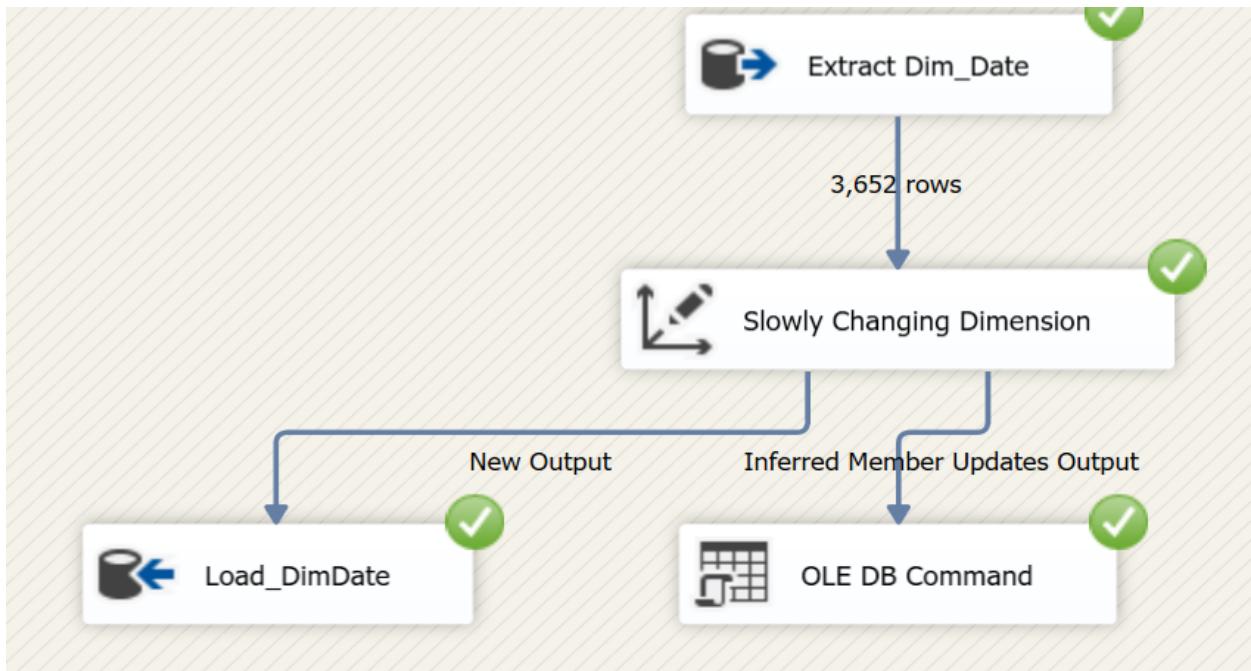


Figure 3.5. ETL Data Flow for Dim_Date (Source: Author)

The Dim_Date dimension table is a more special dimension table than the other dimension tables. It is not mapped by any source data. Instead, the Dim_Date dimension table is created with a series of statements to create a data table about the time. The command to create a timetable will be presented in the appendix

1. Extract data from the time data table created with the command.
2. Use the Slowly Changing Dimension technique to load data to the Dim_Date table stored in SQL DW_Manufacturing

3.2.5. Fact Table

To run ETL on fact tables, we will create a new SSIS Package, similar to how we did for dimension tables.

Step 1: Create a new SSIS package.

Step 2: In the Control Flow, build two Sequence Containers for Full and

IncrementalLoad. We create an Expression Task to run the Sequence Container based on our objective. We add Data Flow Tasks to the Sequence Containers.

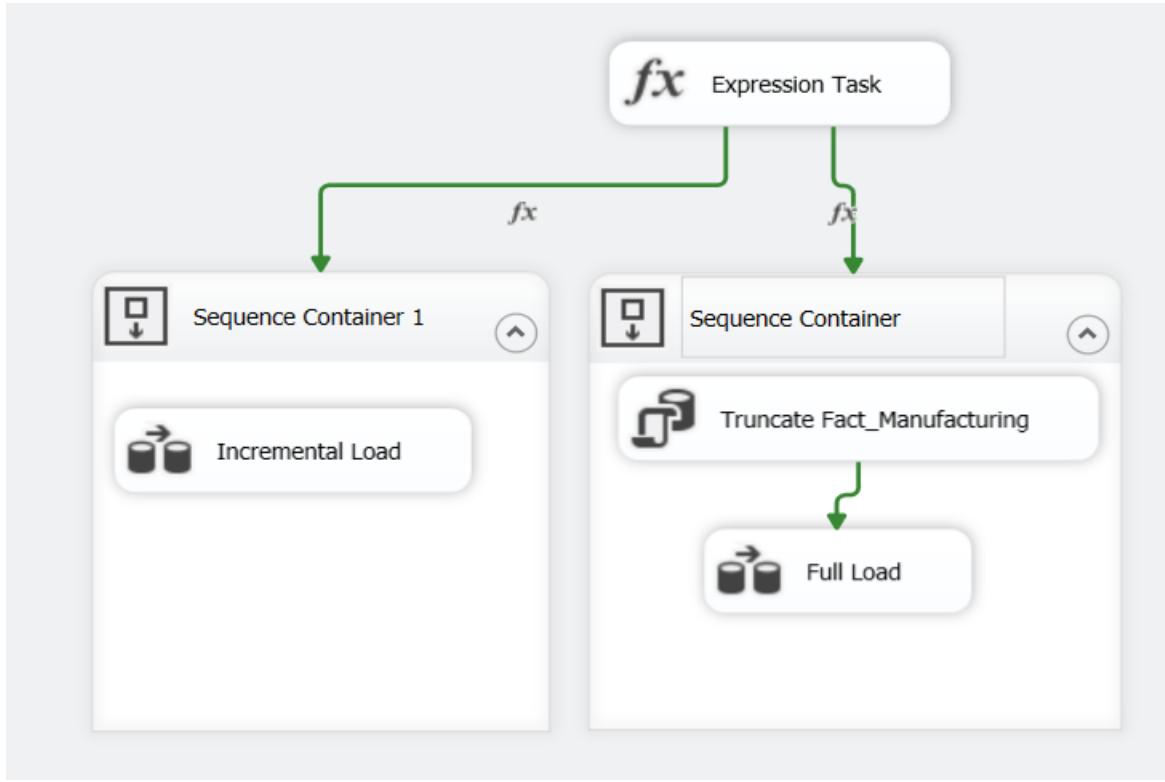


Figure 3.6: The control flow for the ETL process of the fact table (Source: Authors)

Step 3: The Fact Manufacturing table's incremental load is complicated since the destination table's data contains a large number of null values, as the data description below shows.

WorkOrderID	ProductID	OrderQty	StockedQty	ScrappedQty	ScrapReasonID	OperationSequence	LocationID	ScheduledStartDate	ScheduledEndDate	ActualStartDate	ActualEndDate	ActualResourceHrs	F	
1	19804	516	4	4	0	NULL	6	50	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	3.0000	
2	19804	516	4	4	0	NULL	7	60	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	4.0000	
3	19805	517	1	1	0	NULL	6	50	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	3.0000	
4	19805	517	1	1	0	NULL	7	60	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	4.0000	
5	19806	518	2	2	0	NULL	7	60	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	4.0000	
6	19806	518	2	2	0	NULL	6	50	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	3.0000	
7	19807	519	2	2	0	NULL	6	50	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	3.0000	
8	19807	519	2	2	0	NULL	7	60	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	4.0000	
9	19808	718	1	1	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL		
10	19809	720	1	1	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL		
11	19810	722	1	1	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL		
12	19811	739	1	1	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL		
13	19812	743	1	1	0	NULL	NULL	NULL	NULL	NULL	NULL	NULL		
14	19813	748	2	2	0	NULL	7	60	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	4.0000	
15	19813	748	2	2	0	NULL	6	50	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	3.0000	
16	19813	749	2	2	0	NULL	6	50	2012-08-11 00:00:00.000	2012-08-22 00:00:00.000	2012-08-11 00:00:00.000	2012-09-04 00:00:00.000	3.0000	

Figure 3.7: Fact Table Data Sample

To determine whether the updated data matches the data that already exists in the target table, we utilize the Lookup Component. In situations where LocationID or ScrapReasonID

are null, the Conditional Split Component is utilized to manage the situation. Lastly, we update or remove the data using the OLE DB Command.

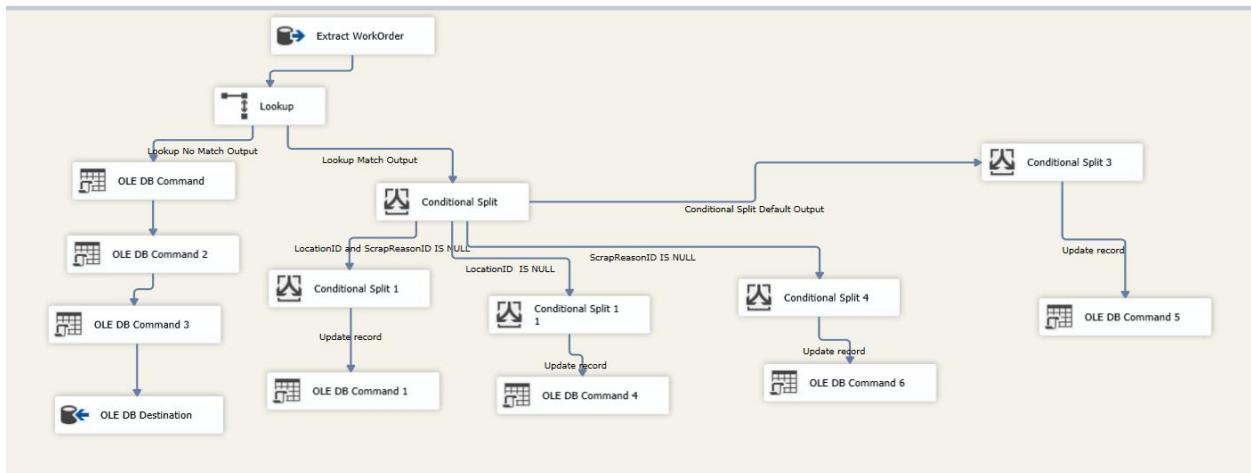


Figure 3.8. Incremental Load for Fact Manufacturing Table (Source: Authors)

Step 4: To load all data into the target table with a Full Load Container, use the perform SQL Task to perform the Truncate statement first. The Data Flow simplifies the process by merely loading data from the source to the target table.

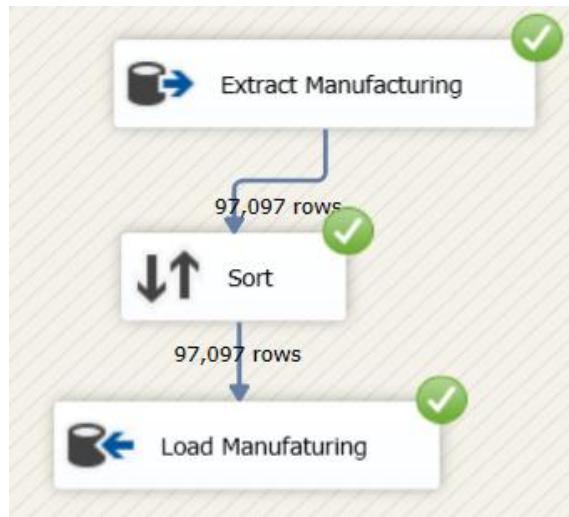


Figure 3.9: Full Load for Fact Manufacturing Table

Chapter 4. Multi-dimensional data analysis

4.1. Multidimensional data model.

4.1.1. Multi-dimensional data objectives:

- *Optimize Data Retrieval:*

For Adventure Works, a company with multiple complex database subsystems, data collection and analysis are quite intricate. Modeling dimensions will optimize the database for faster data retrieval, enabling managers to obtain necessary information promptly for effective decision-making and production process adjustments.

- *Standardize Reporting:*

Standardizing data types such as workday dates for products and others, modeling multiple dimensions will help businesses generate structured and comprehensible reports. These reports, derived from production data, can be easily shared and utilized across departments, fostering consistency and standardization in reporting. This ensures the accuracy and reliability of information, facilitating more precise decision-making.

- *Accommodate Change:*

Dimensional modeling is designed to be flexible and easy to change during data processing. If Adventure Works wants to expand or modify its production models, like adding new products or changing production processes, dimensional modeling allows for these adjustments without major disruptions to the current data structure or other departments. Its flexibility makes projects more adaptable for future expansion and responsive to the changing needs of the business.

4.1.2. Multi-dimensional data benefits:

- *Streamlined Storage and Retrieval:*

Multidimensional Databases (MDBs) operate like cuboid blocks, efficiently storing and querying data, especially with large datasets. By considering data from various dimensions, MDBs optimize storage through pre-aggregation and expedite querying using this aggregated data. MDBs prove invaluable for multidimensional sales analysis, market analysis, scientific analysis, etc., in any field requiring multi-faceted data analysis.

- *Perspective-driven Analysis:*

Multi-dimensional databases (MDBs) outshine traditional databases with their ability to analyze data from diverse perspectives. Additionally, MDBs transcend simple observation; they facilitate intricate calculations across dimensions. For instance, scrutinizing average sales by model per quarter or tracking market share fluctuations by region. MDBs, equipped with multidimensional analysis capabilities, unlock a wealth of detailed information. They empower users not only to visualize data but also to grasp the

intricate relationships within it, thus enabling effective data-driven decision-making. Consequently, users can delve deeper into detailed information derived from the same dataset.

- ***Performance Edge:***

MDBs offer superior performance compared to traditional relational database management systems (RDBMS), particularly in handling complex queries. They can swiftly process large datasets, rendering them ideal for tasks such as online analytical processing (OLAP).

MDBs are custom-built for Online Analytical Processing (OLAP), involving the analysis of large datasets from multiple perspectives. Their ability to tackle complex queries with multiple dimensions positions them perfectly for uncovering hidden trends and patterns within the data.

- ***Creation Process:***

MDBs are crafted by assembling input data in a staging area and structuring it for efficient retrieval. They are tailored for data warehousing and analytical processing applications.

4.2. Multi-dimensional Data Analysis in the Manufacturing department.

4.1.1. Multi-dimensional data analysis in Adventure Works' manufacturing.

- ***Standardization and Simplification:***

Adventure Works, as a company with multiple subsystems, prioritizes standardizing data organization to ensure easy access and consistency. Dimensional modeling aids Adventure Works in structuring data by categorizing information into clear and simple business categories, enabling the company to utilize data efficiently.

- ***Optimized Query Performance:***

In the manufacturing sector, rapid and efficient data querying plays a pivotal role in decision support and production adjustments. Applying data modeling helps minimize duplication and simplifies complex joins, thereby enhancing query performance and accelerating information retrieval.

For Adventure Works, optimizing query performance brings tangible benefits:

- Swift and efficient collection and analysis of production data.
- Timely decision support and production adjustments.

Thus, Adventure Works can increase competitiveness and improve operational efficiency in an increasingly complex manufacturing environment.

- ***Flexibility and Scalability:***

Flexibility and scalability are crucial factors in ensuring operational efficiency in an ever-changing manufacturing environment. Adopting a dimensional data modeling approach offers numerous benefits:

- Easy adaptation to new business requirements: The system can be expanded to include additional data dimensions and columns without impacting existing applications.
- Enhanced adaptability: BI systems can flexibly adjust to changes in the manufacturing environment, ensuring continuous optimization of operational performance.

Flexibility and scalability are crucial for maintaining operational efficiency in a constantly evolving manufacturing environment. Dimensional data modeling facilitates easy adaptation to new business requirements and enhances the system's ability to adjust to changes in the manufacturing environment, ensuring continuous optimization of operational performance.

4.1.2. Dimensionals analysis

Production.Location: This dimension is utilized to monitor and evaluate the effectiveness of each production location. It provides detailed information about costs, allowing tracking of production costs at each location, including material, labor, transportation, and other expenses. Tracking the availability of production resources at each location, including materials, labor, machinery, and assessing the impact of location on operational efficiency. Effectively utilizing this dimension can help businesses enhance operational efficiency, reduce costs, improve responsiveness to demand, and strengthen competitiveness in the market.

Dim_Date: This dimension enables the analysis of production data over time, providing insights into trends and fluctuations in production over time. It provides information about the calendar, time, and business cycles, aiding in optimizing planning and resource management.

Production.ScrapReason: This dimension helps understand the causes of product defects by tracking the scrap rate. Analyzing trends in product defects over time to identify emerging issues or areas for improvement. By tracking and analyzing the reasons for defects, Adventure Works can implement improvement measures to minimize waste and increase production efficiency.

Production.Product: This dimension provides detailed information about products, including physical characteristics, shapes, colors, and other attributes. Utilizing this

dimension helps businesses manage products more effectively, accurately track inventory, and develop appropriate product strategies.

Production.SubCategoryProduct and **Production.CategoryProduct**: These dimensions are used to classify products into categories and subcategories. Product classification helps organize product data logically, making it easy to retrieve and analyze. It also helps businesses gain a deeper understanding of product structure, market trends, and the operational efficiency of each product group.

4.3. Configure and Publish the Cube

To analyze data extracted from the data warehouse (DW) and generate insightful reports to aid decision-making, the thesis utilizes the SSAS (SQL Server Analysis Services) tool. SSAS is seamlessly integrated into the Business Intelligence Development Studio (BIDS), which is included with SQL Server.

The process of building the cube involves four key steps:

Step 1: Creating a Project in SSAS.

Step 2: Setting up Data Sources.

Step 3: Establishing Data Source Views along with defining Measures.

Step 4: Constructing the Cube along with defining Dimensions.

Upon completion of these steps, the outcome will enable comprehensive data analysis and reporting capabilities.

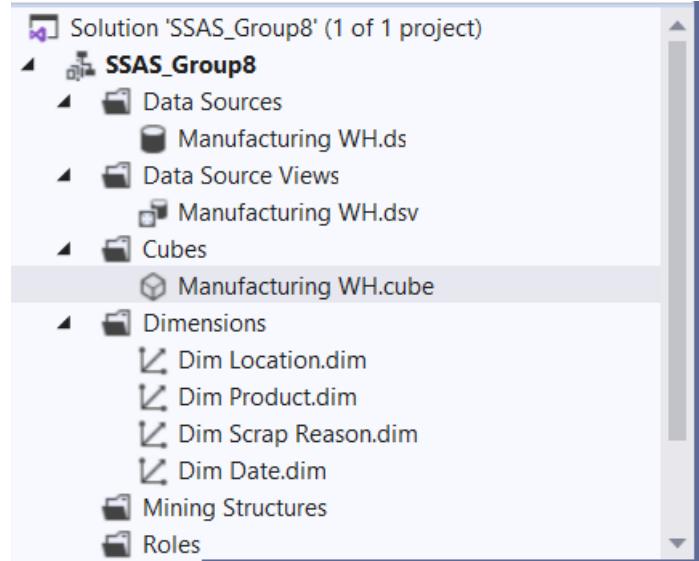


Figure 4.1: Analytic Project with SSAS (Source: Authors)

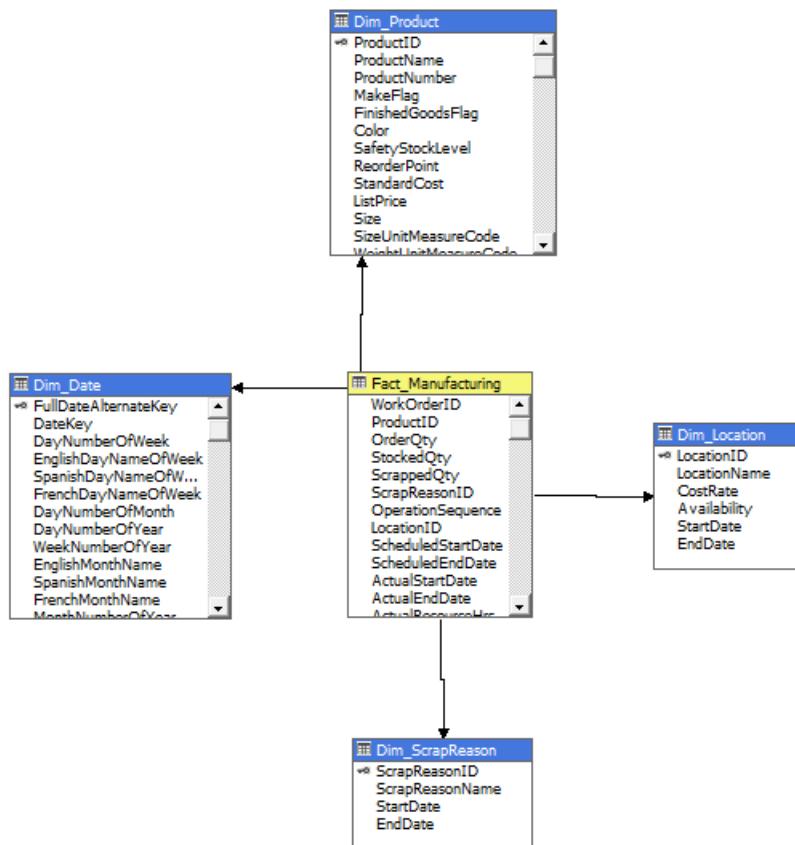


Figure 4.2: Cube Model (Source: Authors)

4.4. Analyze data blocks.

4.4.1. Product Quality Analysis

*Table 4.1: Total quantity of products removed based on each reason and location
(Source: Authors)*

- **Total quantity of products removed based on each reason and location:**

Scrapped Qty	Column Labels										Grand Total
	Debur and Polish	Final Assembly	Frame Forming	Frame Weldin	Paint	Specialize d Paint	Subassembly	Unknown	n		
Brake assembly not as ordered	2	26	81	2		2	137	316	566		
Color incorrect	1	20	31	21		1	177	300	551		
Drill pattern incorrect	3	9	37	3	3		141	615	811		
Drill size too large		54					113	374	541		

Drill size too small	1	14	13	13	1	24	789	855
Gouge in metal		19	32	32		111	445	639
Handling damage	1	20	22	1	1	127	72	244
Paint process failed		37	65	11		109	1157	1379
Primer process failed	6	8	16	16	5	1	50	691
Seat assembly not as ordered		5	25	25		122	565	742
Stress test failed		13	15	3		73	220	324
Thermofo rm temperatu re too high	1	26	61	1	1	189	196	475

Thermofo rm	1	13	28	28	1		181	683	935
temperature too low									
Trim length too long	3	15	80	19	3		232	737	1089
Trim length too short	1	21	2	2	1		94	664	785
Wheel misaligned		11	59	17			90	709	886
Unknown	0	0	0	0	0	0	0	0	0
Grand Total	20	311	567	194	14	6	1970	8533	11615

A total of 11,615 defective products were identified across 20 different reasons at 8 production locations. The most prevalent issue, "Paint process failed," resulted in 1,379 removed products. Notably, the "Unknown" location had the highest number of removed products, totaling 8,533, indicating a need for closer examination of management and control practices there. Focusing on improving processes, especially regarding common issues like "Paint process failed," can lead to enhanced product quality. Delving into specific concerns such as "Trim length too long" and "Thermoform temperature too low" is essential for pinpointing root causes and optimizing production methods.

Table 4.2: Total quantity of removed products over different time periods (Source: Authors)

- **Total quantity of removed products over different time periods:**

Row Labels	Column Labels					Grand Total
	2011	2012	2013	2014	Unknown	
Bikes						
Mountain Bikes	5	17	17	4		43
Road Bikes	5	41	34	9		89
Touring Bikes			7	9		16
Components						
Bottom Brackets	31	66	76	23		196
Cranksets	12	73	168	2		255
Derailleurs	42	131	0	280		453
Forks	44	108	52	194		398
Handlebars	48	177	174	123		522
Headsets	14	3	200	13		230
Mountain Frames	0	18	42	6	45	111

Road Frames	24	18	12	83	137
Touring Frames				36	36
Wheels	25	146	265	38	474
Unknown					
Unknown	48	30	152	56	8369
Grand Total	274	834	1205	769	8533
					11615

During the period from 2011 to 2014, 2013 recorded the highest number of removed products, reaching 1,205. Other years saw varying figures, ranging from 274 to 834 removed products. Given the peak in 2013, it's imperative to conduct a thorough analysis to identify the underlying causes and implement necessary improvements. Certain product categories like "Derailleurs," "Handlebars," and "Wheels" significantly contribute to the overall count of removed products, underscoring the importance of enhancing their manufacturing quality. Addressing the considerable number of removed products categorized as "Unknown" is particularly critical for bolstering quality management and control processes.

4.4.2. Production Performance Analysis

Table 4.3: Scrap Rate (Source: Authors)

- **Scrap Rate:**

Row Labels	Order Qty	Scrapped Qty	Scrap Rate
Bikes			
Mountain Bikes	28321	43	0.15%
Road Bikes	47196	89	0.19%
Touring Bikes	14751	16	0.11%

Components

Bottom Brackets	91189	196	0.21%
Cranksets	91375	255	0.28%
Derailleurs	272783	453	0.17%
Forks	236002	398	0.17%
Handlebars	282654	522	0.18%
Headsets	91277	230	0.25%
Mountain Frames	96802	111	0.11%
Road Frames	72144	137	0.19%
Touring Frames	18476	36	0.19%
Wheels	185809	474	0.26%
Unknown			
Unknown	3536783	8655	0.24%
Grand Total	5065562	11615	0.23%

In summary, the total Order Qty amounts to 5,065,562 products, with a Scrap Qty of 11,615 products, resulting in an overall scrap rate of 0.23%. Notably, "Cranksets" exhibit the highest scrap rate at 0.28%, highlighting the imperative for inspection and enhancement in their production process. Thus, there's a pressing need to refine the manufacturing processes, with a specific focus on "Cranksets," alongside other high-scrap-rate products like "Wheels" and "Headsets," to mitigate the overall scrap rate. Evaluating the quality of raw materials through rigorous inspections and scrutinizing the production process for products with elevated scrap rates are crucial steps toward improving overall product quality.

4.5. KPIs in SSAS

4.5.1. KPIs track the Scrap Rate

Scrap Rate is considered one of the most crucial manufacturing KPIs. This is due to the KPI offering insight into various elements that may increase or reduce the rate. For example, analyzing the scrap rate per shift may highlight management issues, whereas studying the scrap rate by machine may unearth maintenance issues that need resolving.

Formula: Scrapped Qty / Order Qty *100%.

Goal: Reduce Scrap Rate to < 0.2%.

The screenshot shows the 'Manufacturing WH.cube [Design]' window in the KPI Designer. The ribbon at the top has tabs for Cube St..., Dimensions, Calculations, KPIs (which is selected), Actions, Partitions, Aggregations, Perspectives, Translations, and Browser. Below the ribbon are standard toolbar icons. The main area is divided into sections: 'KPI Organizer' on the left listing 'ScrapRateKPI', 'CostVarianceKPI', 'UtilizationRateKPI', and 'OnTimePerformanceKPI'; 'Calculation Tools' with tabs for Metadata, Functions, Templates, and a Search Model; and 'Measure Group:' dropdown set to '<All>'. On the right, there are three main configuration panes: 'KPI' (Name: ScrapRateKPI, Associated measure group: Fact Manufacturing), 'Value Expression' ([Measures].[Scrapped Qty] / [Measures].[Order Qty], result: No issues found, Ln: 1 Ch: 51 SPC CRLF), and 'Goal Expression' (0.002, result: No issues found, Ln: 1 Ch: 6 SPC CRLF). A status pane at the bottom right shows 'Status' with a blue information icon.

Figure 4.3: Scrap Rate KPI (Source: Authors)

KPIs track the Scrap Rate				
Row Labels	Order Qty	Scrapped Qty	ScrapRate	KPI Status
+ Accessories				✓
Bikes				✓
Mountain Bikes	28321	43	0.15%	✓
Road Bikes	47196	89	0.19%	✓
Touring Bikes	14751	16	0.11%	✓
+ Clothing				✓
Components				
Bottom Brackets	91189	196	0.21%	✗
Brakes				✓
Chains				✓
Cranksets	91375	255	0.28%	✗
Derailleurs	272783	453	0.17%	✓
Forks	236002	398	0.17%	✓
Handlebars	282654	522	0.18%	✓
Headsets	91277	230	0.25%	✗
Mountain Frames	96802	111	0.11%	✓
Pedals				✓
Road Frames	72144	137	0.19%	✓
Saddles				✓
Touring Frames	18476	36	0.19%	✓
Wheels	185809	474	0.26%	✗
Unknown				
Unknown	3536783	8655	0.24%	✗
Grand Total	5065562	11615	0.23%	✗

Figure 4.4: Result Scrape rate (Source: Authors)

4.5.2. KPIs track the Cost Variance

Cost variance is a pivotal metric in manufacturing, mirroring the efficiency of production processes and resource utilization. Like the scrap rate, it provides invaluable insights into areas where costs may deviate from expectations. For instance, scrutinizing cost variance per shift can reveal managerial inefficiencies, while examining it by machine may pinpoint maintenance-related cost discrepancies.

The formula for cost variance is:

$$\text{Cost Variance} = (\text{Actual Cost}) - (\text{Planned Cost})$$

Where:

- Actual Cost represents the total cost incurred in production, including materials, labor, and overhead, taking into account scrapped quantities.

- Expected Cost denotes the projected cost based on the planned production volume and standard costs.

To align with the goal of reducing the scrap rate to below 0.2%, minimizing cost variance is paramount. This involves streamlining operations, optimizing resource allocation, and mitigating factors contributing to scrap generation and associated costs.

Efforts to reduce cost variance should encompass comprehensive analyses of production processes, quality control measures, workforce training, and maintenance schedules. By addressing cost variances effectively, manufacturing operations can enhance efficiency, reduce waste, and ultimately improve profitability.

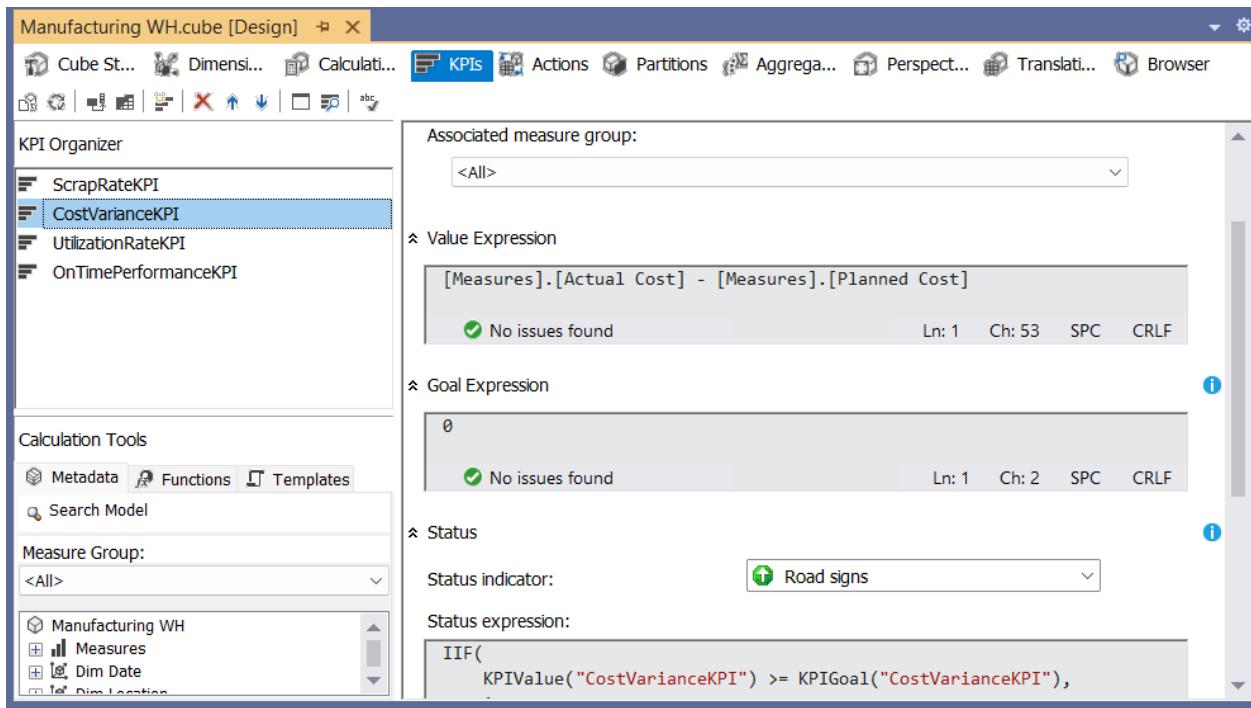


Figure 4.5: Cost Variance KPI (Source: Authors)

KPIs track the Cost Variance

Row Labels	Cost Variance	Cost Variance Goal	Cost Variance Status
	389819.5	389819.5	✓
⊕ Accessories			✓
⊕ Bikes	613382	613382	✓
⊕ Clothing			✓
⊕ Components	2484768	2484768	✓
⊖ Unknown			
Unknown			✓
Grand Total	3487969.5	3487969.5	✓

Figure 4.6: Result Cost Variance (Source: Authors)

4.5.3. KPIs track CompletionRate

Completion Rate is a significant metric used to assess the effectiveness and efficiency of various processes, projects, or tasks. It measures the proportion of tasks or activities completed within a specified timeframe or according to predefined criteria. Completion Rate provides valuable insights into the progress and performance of initiatives and helps identify areas for improvement or optimization.

The formula: StockQty/OrderQty

Goal: Stock quantity = Order quantity

The screenshot shows the KPI Organizer interface with the following details:

- KPI Organizer:** A tree view on the left showing three KPIs: ScrapRateKPI, CompletionRate (selected), and Cost Variance.
- KPI:** The main panel displays the configuration for the selected KPI.
 - Name:** CompletionRate
 - Associated measure group:** <All>
 - Value Expression:** [Stocked Qty] / [Order Qty]
 - No issues found
 - Ln: 1 Ch: 28 SPC
 - Goal Expression:** 1
 - No issues found
 - Ln: 1 Ch: 2 SPC
 - Status:** (This section is collapsed)
- Calculation Tools:** Metadata, Functions, Templates, Search Model.
- Measure Group:** <All>

Figure 4.7: Completion Rate KPI (Source: Authors)

KPIs track the Completion					
Row Labels		Stocked Qty	Order Qty	Completion Rate	Status
		3528128	3536783	99.76%	✓
+ Accessories					✗
+ Bikes					
Mountain Bikes	28278	28321	99.85%	✓	
Road Bikes	47107	47196	99.81%	✓	
Touring Bikes	14735	14751	99.89%	✓	
+ Clothing					✗
+ Components					
Bottom Brackets	90993	91189	99.79%	✓	
Brakes				✗	
Chains				✗	
Cranksets	91120	91375	99.72%	✓	
Derailleurs	272330	272783	99.83%	✓	
Forks	235604	236002	99.83%	✓	
Handlebars	282132	282654	99.82%	✓	
Headsets	91047	91277	99.75%	✓	
Mountain Frames	96691	96802	99.89%	✓	
Pedals				✗	
Road Frames	72007	72144	99.81%	✓	
Saddles				✗	
Touring Frames	18440	18476	99.81%	✓	
Wheels	185335	185809	99.74%	✓	
+ Unknown					
Unknown				✗	
Grand Total	5053947	5065562	99.77%	✓	

Figure 4.8: Result Completion Rate (Source: Authors)

Chapter 5. Visualization and Discussion

5.1 Objectives and approaches to applying BI

Supporting decision-making

Supporting decision-making in the "BI Solution for Adventure Works Manufacturing" project involves turning data from different places into important information. Business Intelligence doesn't just help companies change their own data but also combines information from outside sources like markets, customers, and industries. This makes a system where information can be changed to fit what each person or department needs.

Querying and generating reports.

The BI Solution will diversify report types, offering not only regular reports but also scheduled, automated, and on-demand ones. This facilitates swift responses to information requests from different departments within the organization and provides flexible data retrieval tools, enabling users to access and analyze data quickly and efficiently.

Statistical analysis

Utilizing statistical analysis techniques and big data, BI can predict future trends and analyze them to make strategic decisions based on reliable data. Additionally, through deeper data analysis, BI can uncover hidden incidents and risks in the manufacturing and management process, facilitating preventive measures and improvements.

Data Mining

By employing BI tools, this initiative seeks to delve into the intricacies of data to unearth complex relationships and underlying patterns. This exploration extends beyond surface-level observations, aiming to uncover latent insights that can provide valuable guidance for management decisions. Furthermore, the project aims to integrate data from diverse sources, including both structured and unstructured data sets. This holistic approach ensures a comprehensive understanding of business operations, enabling stakeholders to make informed decisions based on a rich and nuanced understanding of the organization's dynamics.

5.2 Present the dashboard

We utilized Power BI to transform data into visual representations, facilitating businesses in grasping and extracting valuable insights. Through this tool, we crafted reports and dashboards focusing on production overview, product quality control, and production performance, aligning with our team's analytical criteria.

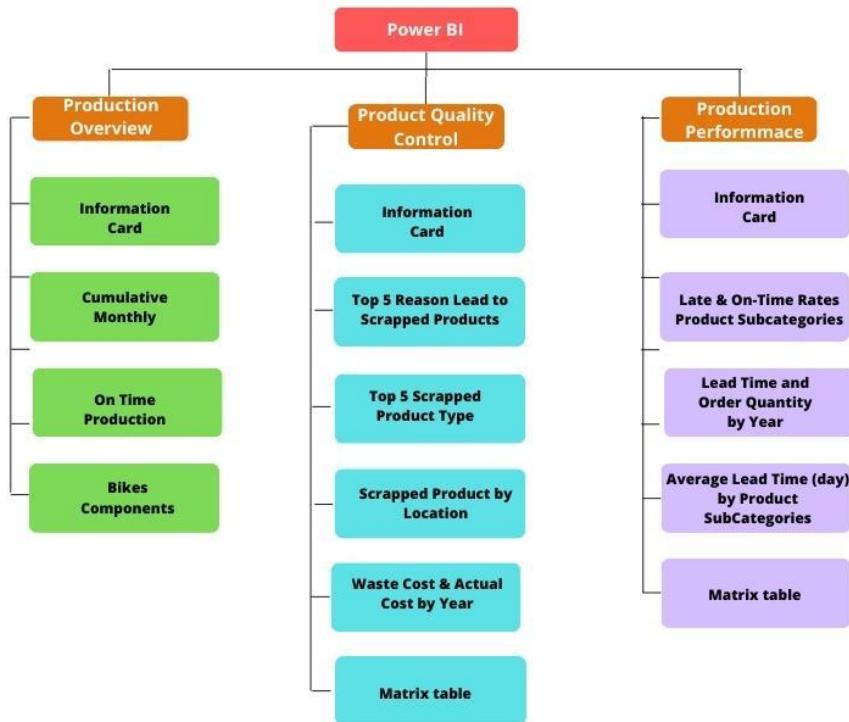


Figure 5.1: Dashboard Structure (Source: Authors)

5.2.1. Production Overview

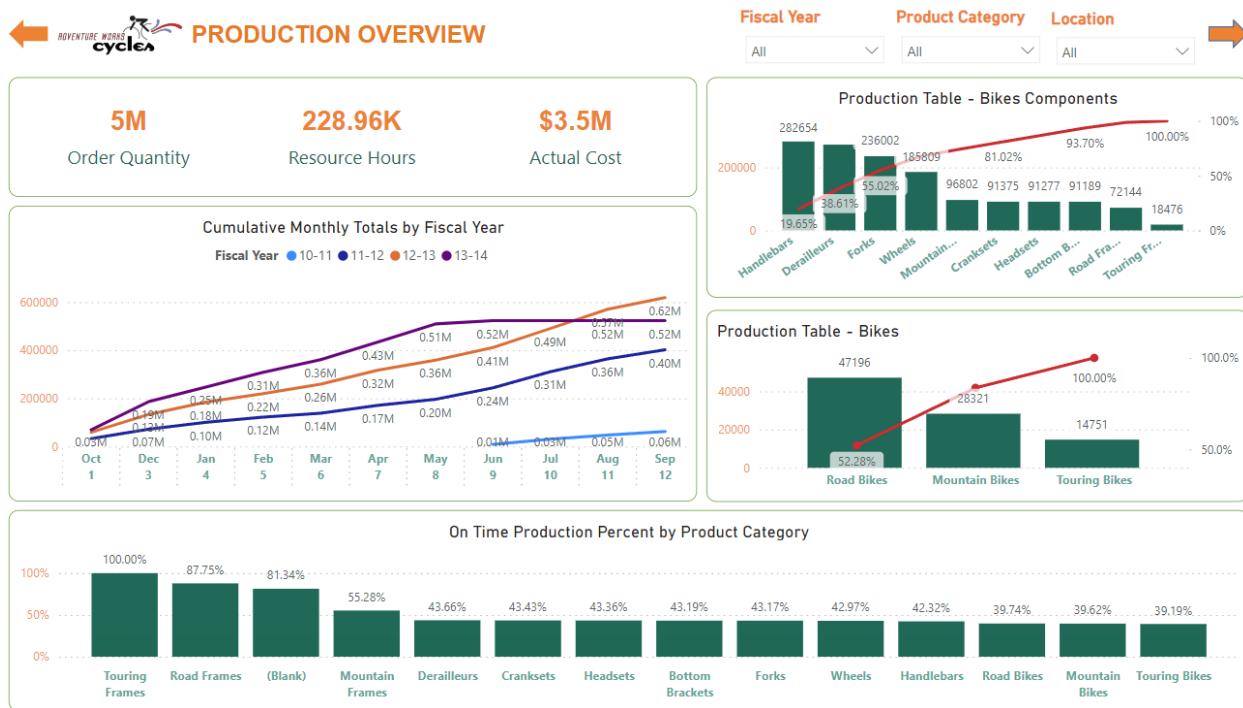


Figure 5.2: Production Overview Dashboard (Source: Authors)

The analysis of product quality performance at Adventure Works, as illustrated in Figure 5.1, provides insightful visualizations and detailed tables. The meticulously filtered dashboard by year, location name, and product category offers targeted insights into product quality, with crucial information highlighted in dashboard cards.

With over 5 million products ordered and production costs exceeding \$3.5 million, involving over 228 thousand laborers, the company's manufacturing operations appear stable. However, there are still various issues to address, as indicated by the following charts.

A Cumulative Multiline chart displaying Production totals aids in comparing fiscal year production trends and identifying manufacturing bottlenecks.

Pareto charts, resembling Bar graphs, represent frequency or cost, with longer bars indicating greater importance. The leftmost bars hold the highest significance. Overlapping lines demonstrate the percent contribution of each category towards the total, while an accumulating line depicts the cumulative percentage of significant categories. Two Pareto Charts are included: one for components necessary for bike manufacturing, highlighting

the most significant production areas, and another for finished bike products, categorizing produced bikes.

A bar chart illustrates the timeliness of product category production, providing insights into on-time production rates.

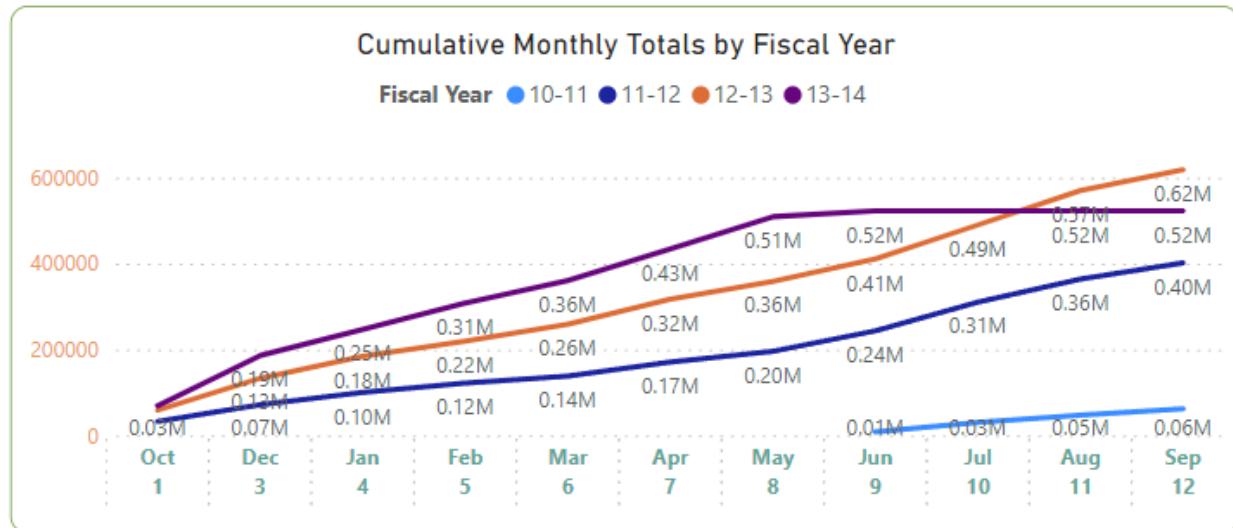


Figure 5.3: Cumulative Monthly Totals by Fiscal Year

Chart 5.2 shows a consistent increase in production quantity over the years. However, examining June, the ninth month of the fiscal year, reveals that in 2014, it only reached 1.26 compared to the same period in the previous year, whereas in 2012-2013, it rose to 1.7 compared to the same period. This indicates that although the number of orders remains significantly higher compared to the same period the previous year, the growth rate has slowed down, suggesting a slowdown in production compared to the period of 2012-2013, when the growth rate was extremely strong.

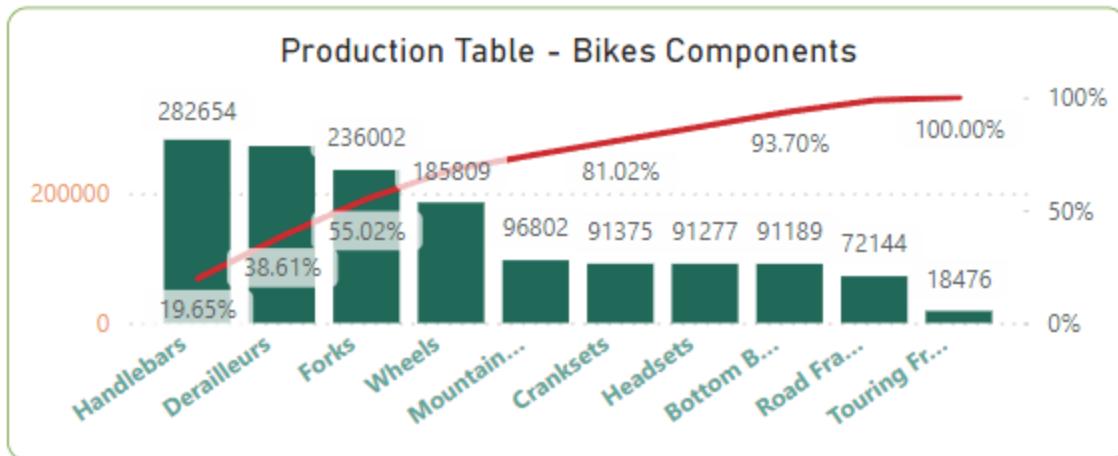


Figure 5.4: Product Component Quantity Component Pareto

The data in the Pareto chart shows the cumulative quantity of bicycle component subcategories manufactured by Adventure Works, along with the percentage of the total quantity that each subcategory represents.

Wheels are the most common component manufactured by Adventure Works. They account for nearly 28% of the total quantity of components produced.

The top four categories (Wheels, Frames, Derailleurs, and Handle bars) account for nearly 75% of the total quantity of components produced. This suggests that focusing on efficiency and cost-savings in these areas could have a significant impact on Adventure Works' overall manufacturing process.

The remaining subcategories (Forks, Cranksets, Headsets, Bottom Brackets, Touring Frames, and Road Frames) account for the remaining 25% of the total quantity of components produced. These components may be good candidates for outsourcing or evaluating alternative suppliers, as they likely have a lower impact on overall manufacturing efficiency.

Production Table - Bikes

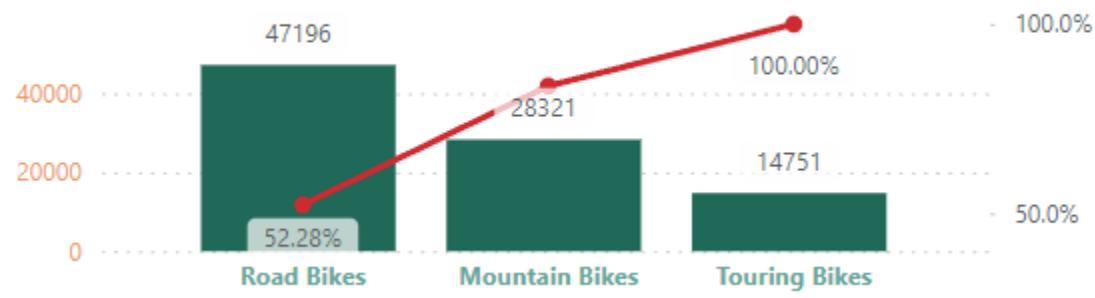


Figure 5.5: Bike Quantity Component Pareto

The difference in the number of products produced in 3 types of bicycles. Road Bikes account for more than 50% of the total number. The road bikes makeup 84% of the total bicycle production at Adventure Works, with a quantity of 47,000 units. This is compared to mountain bikes (28,000 units) and touring bikes (15,000 units), which constitute the remaining 16% of production.

The possible reason for this is that it was produced first, before the other two types of bicycles. To eliminate this factor, it is necessary to add a time dimension to consider the output over the years.

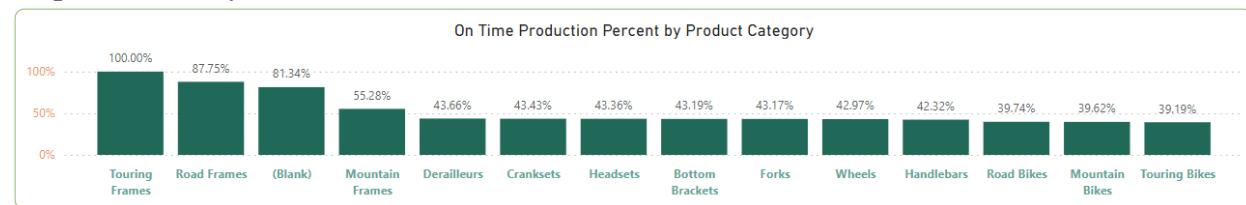


Figure 5.6: On Time Production

Overall, eight out of thirteen subcategories have on-time production percentages above 70%. The highest on time production percentage is for Touring Frames at 100%.

Three subcategories have a concerningly low on-time production percentage: Derailleurs (7.25%), Bottom Brackets (7.23%) and Cranksets (7.21%). These subcategories all relate to the drivetrain of the bicycles.

There could be a number of reasons why these subcategories have such low on-time production percentages. Perhaps there is a shortage of a particular material needed for these parts, or there may be quality control problems that are causing production delays. Another

possibility is that these parts are outsourced to a different manufacturer who is having production issues.

It would be important for Adventure Works to investigate the reasons for these low on-time production percentages and take steps to improve them. Delays in these parts could slow down the production of bicycles and lead to lost sales.

5.2.2. Production Quality Control



Figure 5.7: Production Quality Control

The analysis of product quality performance at AdventureWorks, as depicted in Figure 5.5, offers valuable insights through visual charts and detailed tables. The dashboard has been meticulously filtered by year, location name, and product category to provide targeted insights into product quality. The cards within the dashboard offer crucial insights into the production process.

The Scrapped Quantity of 12,000 units indicates a significant number of products discarded due to defects or errors, highlighting potential challenges in quality control. Although the removal rate is relatively low at 0.23%, there is still room for improvement to minimize

this rate further. However, the substantial Waste Cost of \$464,000 underscores the economic impact of scrapped products.

The Reason Leading to Scrapped Product clustered bar chart sheds light on prevalent issues within the company, guiding targeted interventions for improved quality control. The Waste Cost vs. Actual Cost Trend line chart evaluates cost-reduction strategies over time.

The Scrapped Quantity by Location column chart visually communicates scrap rates across production locations, aiding in the evaluation of scrapped product problems at each location. The Detailed Product Subcategory Analysis table breaks down quality at the subcategory level, identifying specific areas for improvement.

The effective visual representation facilitates easy comprehension of the data and supports informed decision-making for the betterment of the company. Overall, the dashboard serves as a comprehensive tool for monitoring and improving the company's product quality control measures.

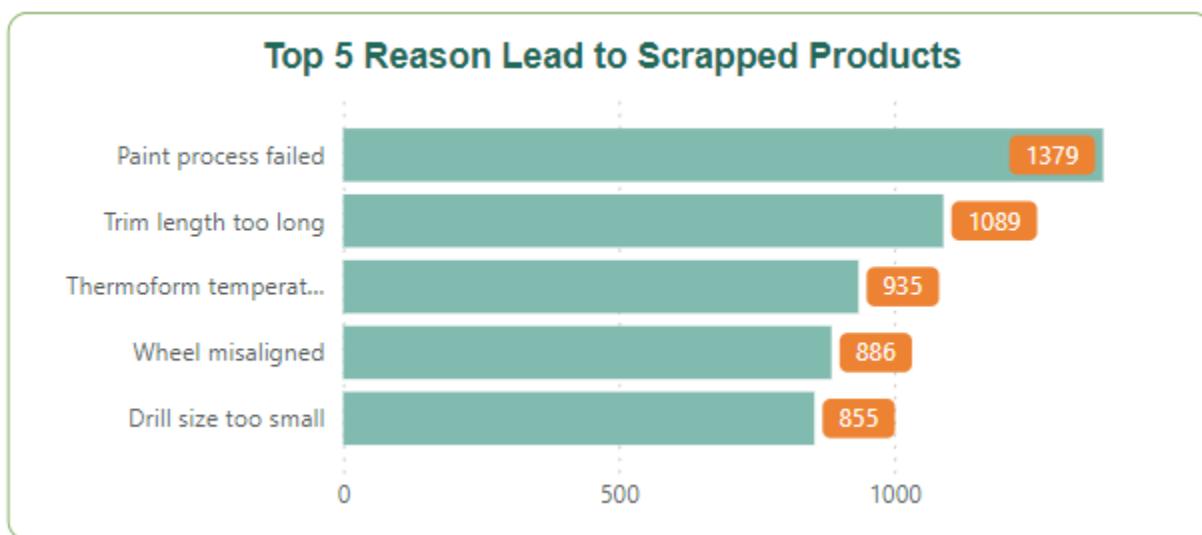


Figure 5. 8: Top 5 Reason Lead to Scrapped Products

The figure 5.6 illustrates the primary manufacturing issues contributing to the quantity of defective products, with the paint process failure being the most prevalent, resulting in a significant 1379 products being scrapped, accounting for 11.5% of the total. Following closely is the problem of overly long trim length, leading to the disposal of 1123 products, constituting 9.4% of the total. The remaining causes, ranging from 855 to 921 products, show similar levels of impact. In third place is the inadequate thermoform temperature, followed by wheel misalignment as the fourth most common issue, resulting in the

discarding of 892 products. The least common cause within the top five is the use of a drill size that is too small, contributing to the disposal of 855 products.

To address the high number of defective products stemming from these manufacturing issues, several potential solutions can be implemented. These include maintaining stringent quality standards such as using high-quality paint, ensuring meticulous surface preparation, controlling temperature settings, and utilizing precise alignment tools. Following manufacturer specifications, inspecting wheels for defects, selecting appropriate drill bits, employing proper drilling techniques, and regular maintenance of drill bits can also mitigate the problem. Strengthening quality control measures, closely adhering to manufacturing processes, and providing comprehensive training to employees on production procedures and product quality assurance are also essential steps to enhance overall skills and minimize defects.

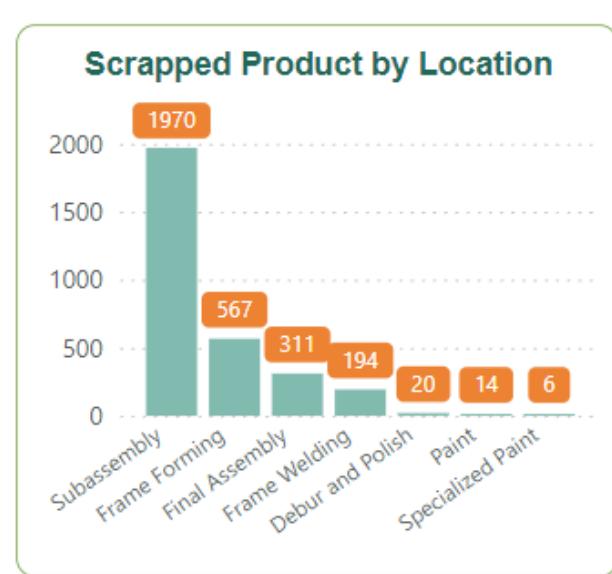
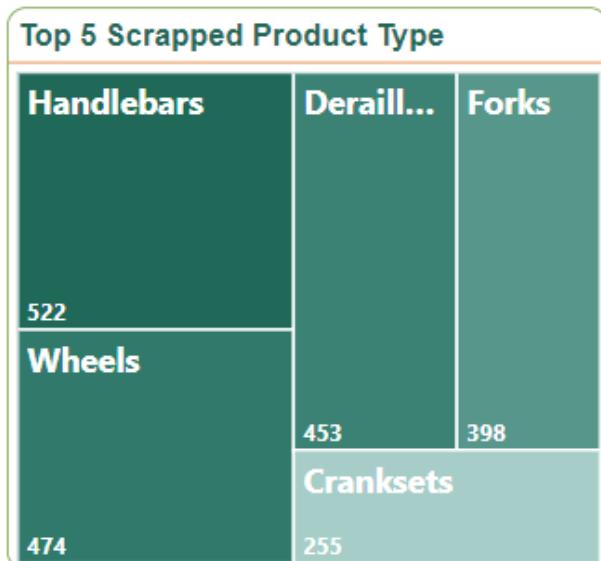


Figure 5.9: Top 5 Scrapped Product Type Figure 5. 10: Scrapped Product by Location

The bar chart in figure 5.8 provides an overview of the quantity of scrapped products across various locations in the manufacturing process, with Subassembly contributing the most waste at 1970 units, followed by Frame Forming, Final Assembly, and Frame Welding with less than 600 units each. Deburr and Polish, Paint, and Specialized Paint have notably lower waste rates, each producing less than 20 units of scrapped products. This visualization allows for easy comparison of performance between different locations, highlighting areas requiring improvement.

Adjacent to the bar chart is a Treemap chart displaying the top 5 scrapped product types. Handlebars lead with 522 units, followed by Wheels with 474 units, and Derailleurs with 453 units. Forks and Cranksets account for 398 and 255 scrapped units, respectively. Notably, all scrapped Wheels and Cranksets originate from the Subassembly location. This correlation between scrapped products and specific locations indicates potential quality issues requiring attention.

To address the high number of defective products, our team suggests focusing on improving the Subassembly location, implementing measures such as enhanced quality control, adherence to manufacturing processes, and employee training. Additionally, technical enhancements to equipment or processes could minimize errors and defects, ultimately reducing waste and improving overall product quality.



Figure 5.11: Waste Cost and Actual Cost by Year

Figure illustrates the trends of Waste Cost and Actual Cost from 2011 to 2014. It reveals a substantial increase in Waste Cost alongside a slight decrease in Actual Cost. Both costs steadily rose from 2011 to 2013, reaching peak values during that year. Waste Cost surged from \$30.6K in 2011 to \$170K in 2013, marking a nearly 450% increase. Actual Cost also notably rose from \$312K in 2011 to \$1.4M in 2013, representing about a 360% increase. However, in 2014, both costs sharply declined, dropping to \$69.3K and \$931M respectively.

Overall, the graph highlights the company's consistently high level of Waste Cost compared to Actual Cost each year, with significant fluctuations over the four-year period. It's imperative for the company to investigate the factors influencing both costs and the sudden decline in 2014. This analysis could lead to implementing measures to enhance

production efficiency, reduce resource consumption, and optimize production costs. Strategies such as improving the supply chain, negotiating better terms with suppliers, and trimming overhead expenses could help achieve cost efficiency and sustainability in the long term. Additionally, implementing stringent quality control measures throughout the production process can aid in waste reduction and ensure product quality meets or exceeds customer expectations, thereby reducing returns or recalls.

Name	OrderQty	ScrappedQty	WastePercent	WasteCost
Components				
Mountain	96.80K	111	0.11%	\$68.61K
Wheels	185.81K	474	0.26%	\$46.77K
Road Frames	72.14K	137	0.19%	\$45.82K
Forks	236.00K	398	0.17%	\$29.44K
Cranksets	91.38K	255	0.28%	\$29.29K
Derailleurs	272.78K	453	0.17%	\$19.80K
Touring Frames	18.48K	36	0.19%	\$17.64K
Handlebars	282.65K	522	0.18%	\$17.52K
Headsets	91.28K	230	0.25%	\$9.80K
Bottom Brackets	91.19K	196	0.21%	\$7.24K
Total	5065.56K	11615	0.23%	\$463.55K

Figure 5.12: Product subcategory and related statistics

The table provides insight into waste costs attributed to specific product categories. With a total order quantity of 5,065,562, the total scrapped amount is 11,615, resulting in a Scrapped Quantity Rate. The graph emphasizes that bike manufacturing yields a significant waste quantity, especially in the component category. Component scrap rates are notably high at 24.21%, contrasting with Product scrap rates of just 1.27%. This substantial difference underscores the urgent need for improvement in component manufacturing processes. Remarkably, the Bottom product subcategory boasts the lowest Scrapped Rate at 74.52%.

Attention must be directed towards the Bottom subcategory to address the high Scrapped Rate. A thorough examination of the production process may be necessary to identify inefficiencies contributing to the high proportion of discarded products. Furthermore, the implementation of quality control procedures, such as regular testing and inspections, can aid in detecting and rectifying issues early on, thereby reducing the percentage of scrapped

products. This approach not only lowers production costs but also enhances overall product quality.

5.2.3. Production Performance Control

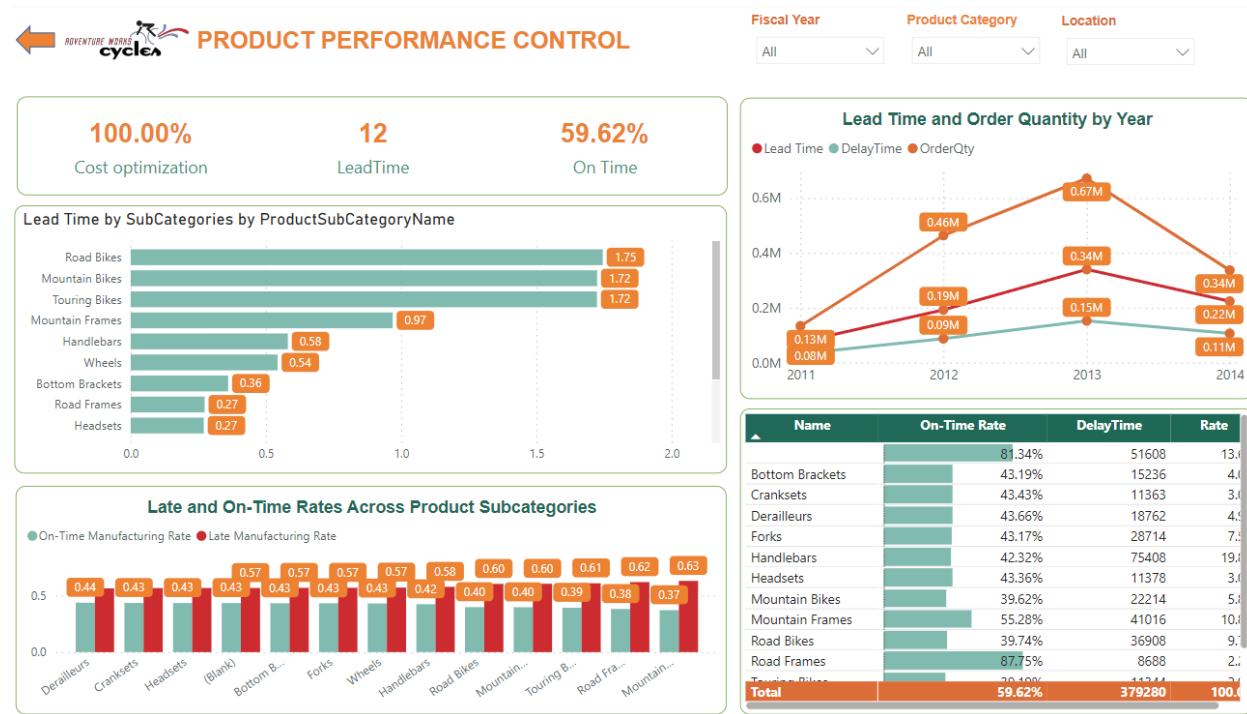


Figure 5.13: Production Performance Control

This figure will depict the product performance of countries from 2011 to 2014, focusing on fields such as Year, Quantity of Orders, Schedule Time, Actual Time, and Product Category Name.

The dashboard will offer a comprehensive overview of Production Performance, featuring key performance indicators (KPIs) represented by three corresponding cards:

1. Cost Optimization: This indicator assesses the business's capability to maintain control over production costs. It's derived from the ratio between expected and actual production costs. A Cost Optimization value of 100% indicates effective cost management, with no costs surpassing expectations. This metric offers insights into the financial health of the business and its proficiency in managing production costs efficiently.
2. Average Lead Time by Day: This metric calculates the average waiting time for an order, measured in days, indicating the duration from the beginning to the

completion of the production process. It provides a holistic view of the current production capacity of the business.

3. On-Time Production Rate: This rate is determined by the variance between expected and actual completion dates. Presently, the business maintains an average on-time production rate of 59.62%. This underscores the necessity for improvement. Identifying the root causes of scheduling issues is paramount for enhancing overall performance and realizing additional business advantages.

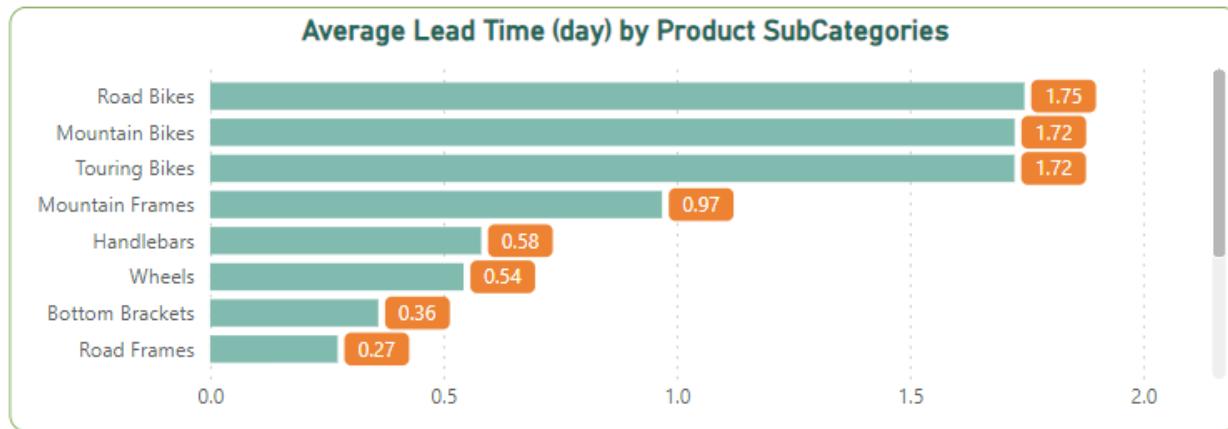


Figure 5.14: Average Lead Time (day) by Product Sub-Categories

The bar chart in the "Lead Time by Product Sub-Categories" Figure illustrates the production time across various product subcategories. This metric represents the average total production time for each type of product. Such insights can aid businesses in better controlling their production schedules by forecasting production times and implementing measures to reduce overall production time. Moreover, it enables businesses to pinpoint subcategories with longer production times, prioritizing efforts to optimize processes for those specific subcategories.

In particular, the chart highlights several top-selling products with production times ranging from 1 to 2 days, including road bikes, mountain bikes, touring bikes, and mountain frames. Notably, road bikes, mountain bikes, and mountain frames exhibit consistently high production times alongside substantial order quantities. On the other hand, touring bikes, despite starting to receive orders in 2013 with a quantity of 8.4 thousand, display an increasing trend in 2014.

To enhance revenue generation and cost savings, businesses should reassess and enhance the production processes for their top-selling products. Leveraging historical data, they can estimate production times for each order, enabling them to commit to more accurate and reliable delivery times. This, in turn, enhances competitiveness in the market by meeting customer expectations effectively.

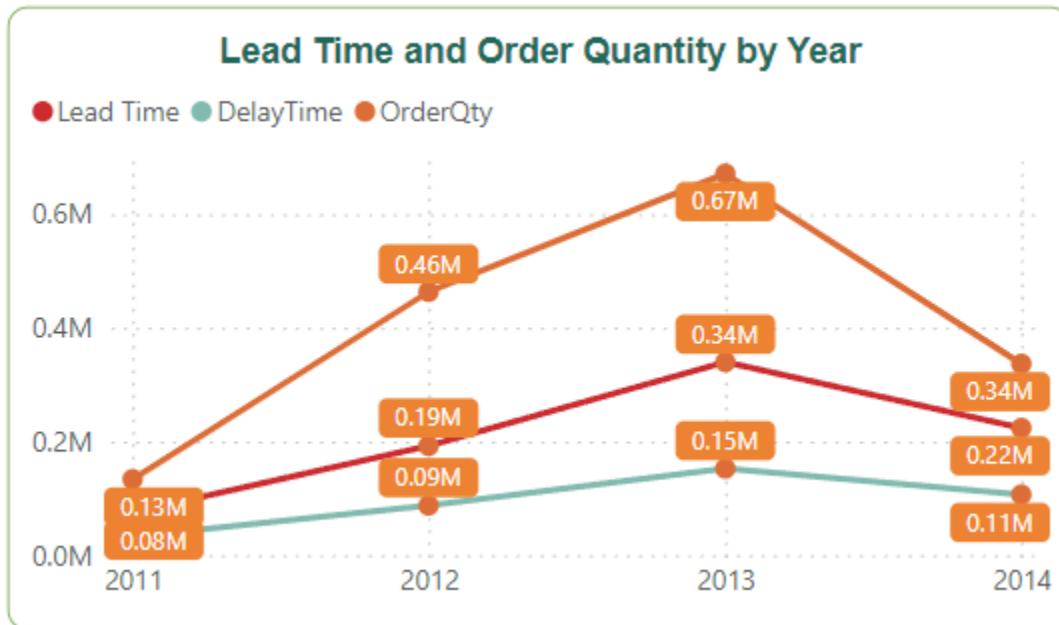


Figure 5.15: Lead Time and Order Quantity by Year

The chart will present the total quantity of products and the lead time for products by year for each country, aiding businesses in monitoring production performance, identifying years with varying product lead times, and detecting trends in the production timeline.

In the provided example, the total number of orders showed a gradual increase from 2011, peaking in 2013, followed by a sharp decline in 2014. Upon closer examination, it was discovered that the decrease in figures was attributed to the data only extending to the second quarter of 2014. However, based on the prevailing trend, it is anticipated that production time will continue to increase until the end of 2014.

Furthermore, analyzing four years of statistics for three production metrics reveals a proportional correlation among them. As preparation time increases, delay time also extends due to prolonged production and delivery processes. Simultaneously, an uptick in

the number of orders prolongs both lead and delay times, as processing and production of a large volume require additional time and effort.

To optimize production efficiency, businesses should prioritize enhancing processes, accurately forecasting demand, and upgrading transportation systems. These measures will contribute to streamlining operations, reducing lead times, and improving overall business performance.

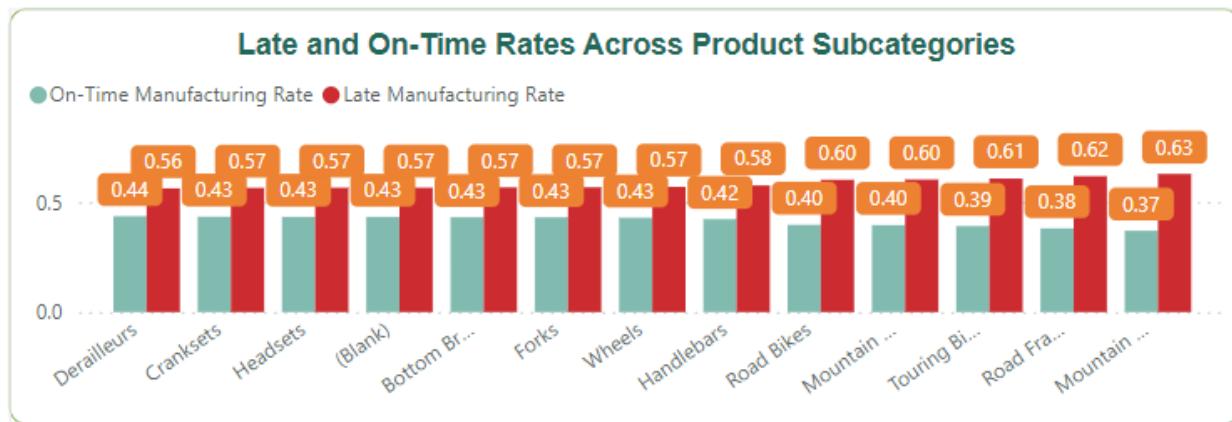


Figure 5.16: Late and On-Time Rates Across Product Subcategories

The chart illustrates the On-Time Manufacturing Rate and Late Manufacturing Rate for each product. Overall, there isn't a significant disparity between these two values, indicating efficient manufacturing activities within the business. Although the On-Time Manufacturing Rate may not be exceedingly high, the consistency in ratios across products suggests that product characteristics are not the primary cause of production delays.

To enhance the On-Time Manufacturing Rate for products with a high Late Manufacturing Rate, the business should focus on solutions such as reviewing the production schedule and aligning it with the manufacturing capacity and market demand. It's crucial to enhance the management of production resources to ensure meeting production needs efficiently.

Improving the On-Time Manufacturing Rate will bolster operational efficiency, trim costs, and elevate competitiveness in the market, ultimately contributing to sustained growth and success for the business.

Conclusion and Future Works

Conclusion:

In conclusion, our team's comprehensive analysis of the AdventureWorks sample data and subsequent implementation of business intelligence solutions have yielded invaluable insights into the company's operations. By constructing a robust data warehouse and formulating model KPIs, we have provided management with a holistic view of the company's general production situation. Through the utilization of BI tools such as SQL Server, SSIS, SSAS, and Power BI, we have enabled swift access to actionable insights via user-friendly dashboards, facilitating informed decision-making at all levels.

Our project, comprising 83 business intelligence solutions and data analytics techniques, has generated insightful reports and findings focused on optimizing key aspects of AdventureWorks Cycles' production processes. Specifically, we have identified common defects, analyzed production quality evaluations, and delved into inventory management to provide strategic recommendations for manufacturing and procurement.

With these tools and recommendations, management is equipped to enhance productivity, reduce expenses, and ensure the company's continued growth. By translating data into actionable insights, our project supports AdventureWorks Cycles' long-term goal of becoming competitive, smart factories in the future.

The type of bicycle that is produced the most is the road bicycle. The SubProducts most likely to produce errors are handlebars and wheels. The financial year with the most production is 2013. Production volume over the years follows a pattern of increasing from October and then sharply declining when reaching the next October. The following year tends to see a higher increase in production volume compared to the previous year. Regarding the guarantee of production, while production costs are typically assured within the plan, timing is not always guaranteed in advance.

Future Works

Moving forward, the project aims to expand its scope and scale by focusing on several key areas. Firstly, it will broaden the analysis of the production process to gather insights from a wider range of operational data sources and performance indicators. Secondly, a rigorous evaluation criteria framework will be established to define metrics and Key Performance Indicators aligning with strategic business objectives. Thirdly, the project will transition from descriptive reporting to developing prescriptive solutions, directly addressing current

production issues. This shift will move the project from diagnosis to remedy, enhancing its effectiveness. Additionally, staying abreast of emerging data technologies, such as cloud-based solutions, will be crucial to scaling analytics across diverse datasets in real-time production environments. Overall, the project's future aspirations center on making it more impactful, comprehensive, and technology-driven. By expanding its scale, adopting solution-oriented approaches, leveraging advanced tools, and building skills in state-of-the-art analytical methods, the project aims to support the company's growth and establish a presence in both domestic and foreign markets.

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Appendix

Lesson Learned

No	Issue / what did not work well	What the team should have done instead?	Lesson Learned
1	Not carefully analyzing and identifying business requirements from the beginning	The KPI and dashboard sections have very little insight to draw and design strategies	In the early stages of the project, it takes time to learn and gather opinions together
2	Not understanding the strengths and weaknesses of members to effectively utilize human resources	The product produced is of lower quality than the team can deliver	Have a discussion about each individual's abilities, work perspective and goals before implementing the project
3	Flow learns about operations that are not suitable for the project's situation. Go from the market to the product	Due to poor market analysis ability, it leads to the inability to provide timely and appropriate requirements when analyzing and creating BI solution strategies.	The reality is different, but in the project when the data is given right before the company's background, it is necessary to learn from what comes before.
4	Failure to document changes that occur throughout the project	Difficulty in reviewing the project's development or drawing lessons from future work	Use the project diary board throughout the project's implementation process.
5	Don't wait until the end of the hard deadline to start doing your homework. Do not estimate the time required to complete the job	When there are shortcomings when completing work, there is not enough time to review and fix them, so they must be added in later stages of the project, causing work backlog in later stages.	Tasks need to be broken down into small pieces with completion times evenly spaced throughout the implementation phase.

6	Detect backlog of work near the end of the project	Completing those tasks in a short time does not ensure quality and consistency with related content	List all the work of the entire project right from the planning stage
7	Detect content inconsistencies throughout the entire report	Efforts have been made to detect inconsistencies in content but may still be missed or not completed in time	Manage how changes to content will affect other parts, to provide timely synchronization