UNIVERSITY OF ECONOMICS AND LAW

FACULTY OF INFORMATION SYSTEM

FINAL REPORT

Topic:

Building a Business Intelligence solution for Purchasing department of AdventureWorks Company

Lecturer: MSc. Le Ba Thien
Subject: Business Intelligence and Decision Support System
Course code: 243MI3301

Group 2

No.	Full name	Student code	Role
1	Huynh Ngoc Chau	K224060770	Member
2	Duong Mai Han	K224060782	Member
3	Nguyen Huu Loc	K224060791	Member
4	Le Thi My Tuyen	K224060823	Leader
5	Nguyen Quang Minh	K224060841	Member

Ho Chi Minh City, the 3rd of July, 2025

Acknowledgment

We would like to extend our sincere thanks to all individuals and organizations whose support and guidance contributed significantly to the completion of this project. Their assistance was invaluable throughout the research and development process.

Our deepest appreciation goes to MSc. Le Ba Thien, lecturer at the Faculty of Information Systems, University of Economics and Law – VNU HCMC. His mentorship, constructive feedbacks, and encouragement played a vital role in shaping the direction and quality of this work.

We are also thankful to the researchers and authors whose studies and publications served as important references. Their insights and data provided a solid foundation for our analysis and understanding.

While we have done our best to ensure the accuracy and depth of this project, we recognize that some limitations may remain. We welcome all feedback and suggestions for further improvement.

Once again, we express our heartfelt gratitude to everyone who supported us throughout this journey. Your contributions are deeply appreciated.

Group 2

Commitment

We hereby affirm that this project was entirely conducted by our team under the supervision of MSc. Le Ba Thien. Throughout the implementation, we independently managed all components of the research process.

This study incorporates references to prior work and documented sources where appropriate, which were essential in supporting our analysis and validating our results. The data, findings, and interpretations presented in this report are original and have not been published elsewhere.

Ho Chi Minh City, July 3rd, 2025

Group 2

CONTENTS

FIGURE LIST

TABLE LIST

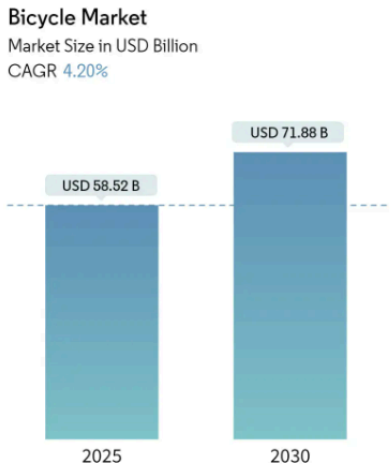
CHAPTER 1. OVERVIEW OF THESIS

1.1. Industry overview

The bicycle market size is estimated to reach USD 58.52 billion by 2025 and is projected to grow to USD 71.88 billion by 2030, with a compound annual growth rate (CAGR) of 4.2% during the forecast period 2025–2030.

As consumers increasingly choose cycling as a form of recreation, the bicycle market has grown more robust. The popularity of bicycles as a convenient means of exercise to maintain a healthy lifestyle also contributes to the market's expansion.

The bicycle industry is undergoing a major transformation driven by sustainable development initiatives and technological innovation. Manufacturers are increasingly integrating artificial intelligence (AI) to enhance product development, anticipate consumer demand trends, and optimize supply chain operations.



Market Overview	
Study Period	2019 - 2030
Market Size (2025)	USD 58.52 Billion
Market Size (2030)	USD 71.88 Billion
Growth Rate (2025 - 2030)	4.20% CAGR
Fastest Growing Market	Asia-Pacific
Largest Market	Asia-Pacific
Market Concentration	Low

Figure 1.1.1: Bicycle Market Size 2019- 2030 (Source: Mordor intelligence)

In the global bicycle market, traditional retail stores continue to dominate, accounting for approximately 81% of market share in 2024. These channels include specialty stores, supermarkets, and membership clubs, offering spacious showrooms and a wide range of models, especially electric bicycles. Consumers in the middle- and high-income segments frequently visit these stores.

At the same time, the online retail channel is emerging as the fastest-growing segment, with a projected CAGR of around 13% during the 2024–2029 period. The rise in online shopping is driven by convenience, the ability to compare products, and improvements in secure payment processes. Many manufacturers are now increasing sales through online platforms to reduce overhead and intermediary costs while boosting profit margins. The COVID-19 pandemic has further accelerated this trend, enabling the online channel to expand its market share by offering a wide selection of products from both local and international brands.

Figure 1.1.2: Bicycle Market (source: Mordor intelligence)

The global bicycle market is experiencing strong growth driven by healthy lifestyle trends, the demand for sustainable mobility, and technological advancements. North America stands out with its well-developed infrastructure and government support policies. The United States leads the region with over 80% market share, fueled by the popularity of mountain bikes and electric bicycles, while Mexico is a fast-growing market thanks to investments in bike lanes and dockless bike-sharing solutions.

Europe holds a global leadership position due to its bike-friendly transportation networks and supportive government policies. Germany is the region’s largest market, with a high adoption rate of electric bicycles, while the Netherlands records the fastest

growth rate, driven by a strong cycling culture and significant infrastructure investments.

In Asia, China leads with its massive manufacturing capacity, technological innovation, and strong domestic demand. India is emerging as a rapidly growing market, supported by increasing health awareness and urban cycling promotion policies.

Overall, all three regions play a vital role in shaping the global bicycle industry's sustainable development trends.

According to data from Statista Market Insights, the number of bicycles sold worldwide has steadily increased from 117.60 million units in 2016 to a peak of 146.30 million units in 2021. However, sales slightly declined to 140.40 million units in 2022 and are projected to stabilize at around 137–140 million units annually from 2023 to 2028, with a slight increase to 138.30 million units in 2028. This stability indicates that the market has reached a saturation point, maintaining steady demand without significant fluctuations.

Currently, the bicycle retail industry is facing several challenges, such as supply chain disruptions. Competition from other sustainable transportation options like two-wheeled electric vehicles and public transit, along with a lack of adequate cycling infrastructure in many areas, also pose barriers.

Despite these challenges, the future of the global bicycle retail market remains promising, with growth driven by the rise of electric bicycles, increased investment in cycling infrastructure, and technological advancements in bicycle design and manufacturing. The focus on environmental sustainability and healthy lifestyles will continue to fuel global demand for bicycles (Grand View Research, 2023).

1.2. Business case

AdventureWorks Cycles is a simulated company developed by Microsoft to support the testing and demonstration of the AdventureWorks sample database. The

company operates in the bicycle manufacturing industry on a multinational scale, specializing in bicycles made of metal and composite materials for markets in North America, Europe, and Asia.

In addition to bicycles as its core product, AdventureWorks also sells related items such as sports apparel, bicycle components, and accessories—including sports jerseys, chains, brakes, and bottle holders. Some of these products are sourced from external suppliers, reflecting the company's dual role as both a manufacturer and retailer. Its customer base includes individual consumers and specialized bicycle retail stores. The company adopts a hybrid sales model through both direct-to-consumer e-commerce and bulk distribution to retail partners.

Among its operations, the purchasing function plays a critical role in ensuring supply chain efficiency and cost optimization. According to Netstock (2024), over 43% of small businesses lack effective BI systems, resulting in excess inventory (15–20%), obsolete stock (10–12%), and late deliveries (25%) due to poor demand forecasting. On the other hand, McKinsey & Company (2023) reports that companies using modern BI tools can reduce inventory costs by 20–30%, increase inventory turnover by 25%, and reduce forecast errors by 50% by combining BI with advanced analytics and AI. These figures highlight the tremendous value of applying BI to purchasing and supply chain management, especially in today's fast-paced, data-driven business environment.

At AdventureWorks, the Purchasing Department is responsible for planning and executing procurement activities, placing purchase orders with vendors, tracking delivery timelines, and ensuring raw materials are available for production. The AdventureWorks database contains comprehensive information on vendors, lead times, purchase order details, pricing, and shipping methods.

This project aims to extract and analyze purchasing-related data from the AdventureWorks system using BI tools such as SSIS, SSAS, and Power BI. The goal is to support decision-making for vendor evaluation, procurement planning, cost optimization, and delivery performance tracking.

For these reasons, the team launched the project: “Business Intelligence Solutions for Decision Support in Purchasing Management at AdventureWorks Cycles” to enhance procurement efficiency, reduce inventory holding costs, and optimize the company’s inbound logistics processes—turning purchasing data into a strategic decision-making asset for sustainable growth.

1.3. Scope

Subject Scope: This project focuses on researching and proposing a decision support solution for the Purchasing subsystem of the enterprise. The solution integrates Business Intelligence (BI) and Decision Support Systems (DSS) to improve procurement effectiveness in the context of digital transformation.

Time Scope: The data used in this project is extracted from the AdventureWorks database, specifically focusing on historical purchasing and procurement records from 2011 to 2014. This ensures that sufficient information is available for analyzing purchase trends, vendor performance, and delivery patterns.

Space Scope: The study is limited to internal procurement operations at AdventureWorks’ warehouses and manufacturing facilities. Analytical scenarios are developed based on the context of a mid-sized manufacturing and distribution company operating in a domestic market, without extending into international logistics or global supply chain management.

1.4. Tools

SQL Server Management Studio (SSMS): Utilized for managing and configuring SQL Server databases, enabling efficient database administration and querying.

SQL Server Integration Services (SSIS): Employed to design and execute ETL (Extract, Transform, Load) workflows, facilitating seamless data migration and transformation.

SQL Server Analysis Services (SSAS): Create and manage OLAP cubes, provide advanced data analysis and multidimensional data modeling capabilities.

Microsoft Power BI: Visualize data and create interactive reports and dashboards, enhancing data comprehension and decision-making.

1.5. Research implications

1.5.1. The value of the project

- Gain practical knowledge in building and operating data warehouses, designing purchasing data models, and integrating procurement data from multiple sources.
- Understand the use of BI tools and applications in purchasing management, such as analyzing vendor performance, purchase order efficiency, and lead times.
- Develop a business-oriented analytical mindset through the complete BI implementation lifecycle with a focus on purchasing operations.
- Apply methodologies to evaluate KPIs such as On-time Delivery Rate, Purchase Cost Trends, and Vendor Reliability to improve procurement effectiveness.
- Strengthen real-world data analysis and decision-making skills related to supply chain sourcing and vendor management.

1.5.2. The desired outcomes of the project

- Build standardized tools and metrics to support accurate, timely decision-making in procurement activities.
- Design a real-time interactive dashboard to monitor purchase order statuses, vendor performance, and procurement KPIs.
- Detect inefficiencies such as delayed deliveries, unapproved vendors, or high-cost procurement and provide actionable recommendations.
- Categorize vendors based on delivery punctuality, frequency, and pricing consistency to improve sourcing strategy.
- Identify trends and insights from historical procurement data to support forecasting, negotiation, and vendor selection decisions.

1.5.3. Project execution and deliverables

Step 1: Planning

This initial phase includes identifying the requirements of the Purchasing department, documenting current procurement workflows, and determining critical KPIs such as Average Lead Time, Purchase Frequency, and On-time Delivery Rate.

Step 2: Data Preparation

Data from OLTP systems in AdventureWorks is extracted and consolidated into a Purchasing Data Mart. Exploratory Data Analysis (EDA) is performed to clean data, ensure consistency in vendor IDs, purchase orders, item codes, and normalize units and currencies.

Step 3: ETL (Extract, Transform, Load)

ETL processes are developed to extract, transform, and load procurement data into the data warehouse. Slowly Changing Dimensions (Type 1 & 2) are handled for vendor and product data. Lookup tables are used to ensure consistency in order statuses, shipping methods, and cost entries.

Step 4: Analytics

Using SQL Server Analysis Services (SSAS), procurement data is processed into OLAP cubes for advanced analysis. MDX queries help generate metrics like Vendor Scorecards, Average Order Value, and Rejection Rates, which support procurement planning and strategy.

Step 5: Reporting

Procurement dashboards are built with Power BI to visualize trends such as monthly purchasing volumes, vendor comparison reports, and lead time analysis. These insights enhance operational visibility and inform supplier negotiations and restocking decisions.

1.6. Structure of the project

Chapter 1: Overview of thesis

This chapter introduces the background and business context of AdventureWorks Cycles, a company specializing in bicycle manufacturing and distribution. It emphasizes the current challenges faced by the Purchasing Department, such as inefficient supplier coordination, delays in deliveries, lack of visibility into purchasing trends, and excessive procurement costs. From this context, the project sets forth objectives to apply Business Intelligence (BI) for improving procurement efficiency, supplier evaluation, and purchasing decision-making.

Chapter 2: Theoretical basis

Chapter 2 provides the theoretical foundation for Business Intelligence in the purchasing domain. It outlines the benefits of BI in procurement, including improved cost control, lead time optimization, and supplier performance analysis. The chapter discusses the ETL process for transforming purchasing data, introduces procurement KPIs (e.g., Purchase Order Accuracy, On-Time Delivery Rate, Average Lead Time), explains OLAP & MDX techniques for analyzing multidimensional purchasing data, and gives an overview of Power BI for developing procurement dashboards.

Chapter 3: Analysis of user requirements and data description

This chapter analyzes the needs of the Purchasing Department. It identifies business questions and KPIs critical to procurement, such as Order Fulfillment Rate, Delivery Timeliness, and Rejected Quantity. Use cases such as Supplier Evaluation, Purchase Cycle Monitoring, and Spending Trend Analysis are also examined. Furthermore, it describes the relevant data sources from the AdventureWorks database (e.g., Purchasing.PurchaseOrderHeader, Purchasing.PurchaseOrderDetail, Vendor, ShipMethod) and outlines the data preparation and data mart structure, with a focus on the DimVendor and FactPurchaseOrders tables.

Chapter 4: Data analysis and visualization

In this chapter, the team performs data analysis and visualization based on procurement transactions. Using SQL Server Analysis Services (SSAS), the project builds OLAP cubes to enable slicing and dicing of purchase data by vendor, time, employee, and product. These analyses are visualized in Power BI dashboards, presenting insights into key procurement metrics such as Total Purchasing Amount, Top Suppliers by Volume, Purchase Frequency, and Lead Time Trends. This chapter

demonstrates how the BI system improves transparency, control, and efficiency in the purchasing process.

Chapter 5: Conclusion

This final chapter summarizes the results of the project and reflects on the impact of the BI system in enhancing procurement decision-making. Key takeaways include improved supplier visibility, more accurate order tracking, and optimized purchasing costs. The chapter also acknowledges limitations (e.g., incomplete vendor records, inconsistent status updates) and proposes future directions such as integrating predictive analytics for demand-based ordering, adopting supplier scorecards, or moving toward cloud-based procurement intelligence platforms like Microsoft Fabric.

CHAPTER 2. THEORETICAL BASIS

2.1. Overview of Business intelligence

2.1.1. Business intelligence definition

Business intelligence (BI) refers to the integration of data analytics, data mining, visualization techniques, digital tools, and robust infrastructure to support organizations in making informed, data-driven decisions. In practical terms, a modern BI system provides a unified perspective of organizational data, enabling companies to implement changes efficiently, reduce operational inefficiencies, and respond swiftly to fluctuations in markets or supply chains.

Contemporary BI platforms emphasize user-friendly, self-service capabilities, ensure data governance on reliable systems, and empower business users to access insights rapidly—thereby accelerating the decision-making process across all levels of the organization.

2.1.2. Business Intelligence implementation steps

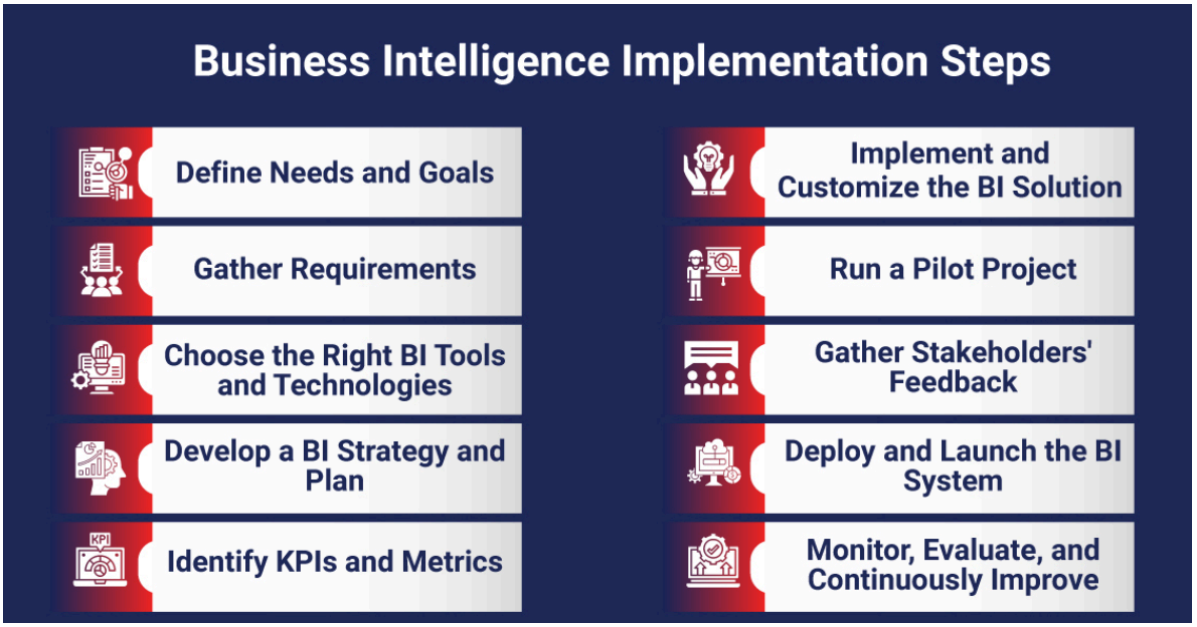


Figure 2.1.2.1: Business Intelligence implementation steps

Step 1: Define needs and goals

Business intelligence implementation starts with clearly understanding the organization's overarching business objectives, goals, risks, and expectations and how implementing BI can contribute to achieving them. The first step towards implementation is to assess your current data infrastructure, including:

- Data sources
- Reporting practices
- Existing data silos or limitations.

Work closely with stakeholders to clearly define what you aim to achieve with BI and where BI insights will be applied. This may involve improving operational efficiency, gathering customer insights, or driving sales growth.

Step 2: Gather requirements

The next BI implementation steps involve defining functional and non-functional requirements for the BI solution from all the stakeholders. The requirements can be further classified into mandatory and optional features. BI consultants play a critical role in this stage by interviewing stakeholders to collect and prioritize their needs, goals, and vision for a successful BI project implementation.

Step 3: Choose the right BI tools and technologies

The next step requires evaluating various BI tools and technologies based on factors such as:

- Scalability – Ensure the tools can accommodate your current data volume and anticipated future growth.
- Functionality – Prioritize tools that offer features relevant to your organization's specific needs (e.g., data visualization, reporting, predictive analytics).
- Integration – Choose a tool that seamlessly integrates with your existing systems and data sources.
- User-friendliness – Choose tools with an intuitive interface for users with varying technical skills.

Identify the necessary components to build a scalable BI ecosystem, including hardware resources, data storage solutions, and analytical tools to meet the evolving requirements of the organization.

Step 4: Develop a BI strategy and plan

Before delving into technical aspects, it is essential to ensure that your business intelligence (BI) implementation strategy aligns with the organization's overall business goals, priorities, and strategic direction. Equally important is convincing stakeholders of the value proposition of the BI implementation with a strong strategic plan. Without a clear plan, employees may use inaccurate data, receive conflicting guidance, and make assumptions about the meaning of various insights.

Therefore, it is necessary to create a detailed roadmap to achieve outstanding results, including timelines, milestones, resource allocation, and other processes. While developing the strategy, thoroughly answer the following three questions:

- What is our current situation?
- What are our goals?
- What resources do we need?

The BI implementation plan serves as a blueprint that provides guidance on what is needed to achieve the objectives, including scope, timeline, costs, resources, and other key elements. Project planning involves defining the scope of work, identifying project stakeholders, and establishing clear communication channels to ensure effective collaboration.

Step 5: Identify KPIs and Metrics

Identify measurable Key Performance Indicators (KPIs) to monitor the effectiveness and status of workflows. Tracking common KPIs such as user adoption rate, data quality score, and report usage metrics helps your organization monitor progress toward its goals and objectives. It also serves as a foundation for data-driven decision-making.

Step 6: Implement and customize the BI solution

This step involves developing and customizing the BI solution. It includes selecting appropriate BI tools and configuring the platform for the organization's specific data sources and infrastructure. This process covers data preparation, setting up data storage, data integration, data management, customizing the BI platform, creating user interfaces and dashboards for different departments, and performing quality assurance and optimization. This stage also involves integrating the BI solution into existing systems by automating processes with the help of data integration tools and establishing methods for Extract, Transform, and Load (ETL) of data from various sources into the BI solutions.

Step 7: Run a Pilot project

Before deploying the BI system across the entire company, it is advisable to conduct a pilot test on a smaller scale, such as within a specific department or focused group. This helps identify and mitigate risks, refine the implementation strategy, and demonstrate the feasibility, functionality, and potential benefits of the BI solution before full-scale deployment across the organization.

Step 8: Gather stakeholders' feedback

Organize regular meetings or discussions with BI stakeholders to assess the current progress of the project and propose timely changes based on feedback. A trial version can be launched to gather general feedback from end users and turn bottlenecks into opportunities for a successful BI strategy.

Step 9: Deploy and launch the BI system

The final step is to launch and deploy the BI system across the entire company. This includes rolling out the BI solution in multiple iterations, monitoring performance, and addressing any arising issues. The BI solution must be scalable to accommodate the organization's growth needs.

Step 10: Monitor, evaluate, and continuously improve

The implementation of Business Intelligence (BI) is an ongoing journey, not a one-time event. Organizations must be prepared to adapt and optimize their BI solutions based on the following:

- Evolving business needs
- Technological advancements
- User feedback

2.1.3. Benefits of Business Intelligence

Clearer reporting: BI gives organizations the ability to ask questions in plain language and get answers they can understand. Dashboards can prioritize the most important insights, saving time for both data experts and nontechnical team members.

Instead of using best guesses, staff can base decisions on what their business data is telling them whether it relates to production, supply chain, customers or market trends. The data can help answer an organization's pressing questions: Why are sales dropping in this region? Where do we have excess inventory? What are customers saying on social media?

Consolidated data: BI delivers business insights by pulling in and consolidating data from multiple sources, internal and external, for complete analysis. By providing an accurate picture of the business and market, BI provides an organization with the means to design a business strategy.

Create new efficiencies: Organizations can monitor business operations against benchmarks and fix or make improvements on an ongoing basis, all fueled by data insights. Analytics can discover and help eliminate manufacturing or supply chain bottlenecks. Managers can monitor staff performance to help pinpoint where organizational changes can be made. Supply chain management can be improved by monitoring activity up and down the line and communicating results with partners and suppliers.

Deeper data insights: BI helps organizations become more data-driven, to continually improve business performance, gain competitive advantage, and locate new customers and new opportunities. They can improve ROI by understanding their business and market, and intelligently allocating resources to meet strategic objectives. New data insights can reveal customer behavior, preferences and market trends. Those insights enable marketers to better target prospects or tailor products to changing market needs.

Faster decision making: As progress is monitored and analyzed digitally, better informed decisions can be made more quickly for faster adjustments in the marketplace.

Increase customer satisfaction: When customer service staff have access to customer data and insights, they can provide requested information and resolve issues more quickly.

Increase employee satisfaction: Self-help access to important business data can optimize workflows so that staff can do their jobs faster, with fewer added or repetitive steps.

2.1.4. Challenges of Business Intelligence

Contradictory conclusions: Self-service BI empowers multiple teams to search for the insights they need, but can also lead to divergent conclusions, which can create more friction instead of a unified plan of action. This can be especially true if human bias creeps into the analysis.

Skills shortfall: The need for data integration might be difficult, given a wide variety of sources, and integration might exceed current capabilities. Expertise in data science, engineering and architecture is required to help ensure that analysis yields insights that reflect reality.

Up-front costs: The initial costs to develop a powerful, modern BI system might appear large, but the cost savings generated by analysis will offset the investment.

2.1.5. Popular BI tools

Microsoft Power BI

Tableau

Qlik Sense / QlikView

SAP Business Objects

IBM Cognos Analytics

2.2. Overview of ETL

2.2.1. ETL definition

ETL, which stands for Extract, Transform, and Load, is a fundamental data integration process used in Business Intelligence systems. It involves extracting data from various source systems, transforming it according to defined business rules, and loading it into a centralized data warehouse. This process ensures that raw, fragmented, or inconsistent data becomes reliable, standardized, and structured for analytical purposes.

In the context of the Purchasing module, ETL allows for the unification of procurement-related data from multiple operational systems — such as vendor records, purchase order history, delivery statuses, and cost structures — into a single, analyzable repository. This standardized data is essential for generating meaningful insights through KPIs, dashboards, and data mining models that help organizations improve sourcing efficiency, monitor vendor performance, and optimize procurement strategies.

2.2.2. How has ETL evolved?

Extract, transform, and load (ETL) originated with the emergence of relational databases that stored data in the form of tables for analysis. Early ETL tools attempted to convert data from transactional data formats to relational data formats for analysis.

Traditional ETL

Historically, ETL processes were developed to bridge the gap between transactional systems (OLTP) and analytical systems (OLAP). In early database environments, data resided in flat or transactional structures — optimized for capturing real-time operations but not designed for large-scale analytics. For example, in a purchasing system, each transaction (e.g., a purchase order) could include redundant details about products, vendors, and employees

To overcome inefficiencies in querying and reporting, ETL pipelines were built to reshape this transactional data into relational schemas (e.g., star schema or snowflake schema). These transformed datasets allowed analysts to perform structured queries on normalized dimension tables (like DimVendor, DimProduct, DimEmployee) linked to fact tables (FactPurchaseOrders) to uncover trends, such as seasonal price fluctuations or vendor delivery delays.

Modern ETL

With the rise of cloud computing, big data, and distributed systems, ETL has evolved to support a broader range of data formats (structured, semi-structured, unstructured) and integration patterns. Modern ETL platforms can ingest data from APIs, streaming sources, IoT devices, and legacy databases, and load it into powerful data sinks such as:

Data warehouses (e.g., Azure Synapse, Amazon Redshift, Google BigQuery): optimized for structured querying, scalable storage, and business analytics. Data lakes (e.g., AWS S3, Azure Data Lake): designed for handling both structured and unstructured data at scale, enabling use cases in predictive analytics and machine learning.

In this project, SQL Server Integration Services (SSIS) is used to build the ETL pipeline for the Purchasing Data Mart of AdventureWorks. This involves transforming vendor, employee, product, and order information into a star schema model suitable for advanced reporting via Power BI and multidimensional analysis through SSAS.

2.2.3. How does ETL work?

Extract, transform, and load (ETL) works by moving data from the source system to the destination system at periodic intervals. The ETL process works in three steps:

- Extract the relevant data from the source database
- Transform the data so that it is better suited for analytics
- Load the data into the target database

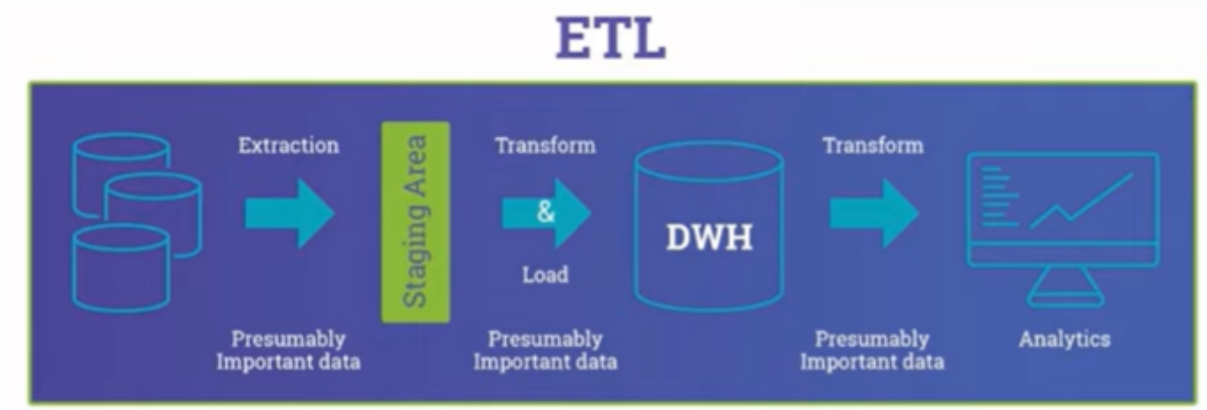


Figure 2.2.3.1: ETL process

Extract

In the ETL (Extract – Transform – Load) process, Extract is the first step, where data is retrieved from source systems such as databases, ERP applications, CRM systems, flat files, or APIs. The main goal of this step is to collect raw data from various sources and move it into a staging area for further processing. There are several methods for data extraction:

- Update Notification: The source system notifies when data changes occur.
- Incremental Extraction: Only the data that has changed within a specific time range is extracted.
- Full Extraction: All data is extracted, typically used when changes cannot be identified.

The Extract step plays a crucial role in ensuring that the collected data is complete, reliable, and suitable for processing in the subsequent stages of the ETL workflow.

Transform

In the ETL (Extract – Transform – Load) process, **Transform** is the intermediate step responsible for processing, cleaning, standardizing, and integrating raw data extracted from source systems to prepare it for loading into the target data warehouse. This stage ensures that the data is of high quality, consistent, and ready for analysis, may include the following types of data changes.

- Data cleansing: Removes errors and standardizes source data into the desired format—for example, mapping “Parent” to “P” or converting null values to 0.
- Deduplication: Identifies and removes duplicate records from the dataset.
- Format standardization: Converts data into consistent formats, such as standardizing date formats, measurement units, or character encoding—for instance, converting all weight units from kilograms to pounds for system consistency.

Load

In the ETL (Extract – Transform – Load) process, **Load** is the final step, where the transformed data is moved from the staging area to the target storage system, typically a data warehouse. This process ensures that the data is ready for analysis and reporting. The loading phase is usually automated, clearly defined, regularly scheduled, and performed in batches.

There are two methods to load data:

- Full Load: Transfers all data from the source to the data warehouse. This method is typically used during the initial load or when there are major changes in the data structure.
- Incremental Load: Loads only the data that has changed since the last load (delta data), helping to save time and system resources.

2.2.4. Popular ETL technologies and tools

Traditional tools: Informatica, Talend, Microsoft SSIS, SAP Data Services

Modern/cloud tools: Apache NiFi, AWS Glue, Google Dataflow, Azure Data Factory

Programming support: Python (Pandas), SQL scripts

2.3. Data warehouse and data mart

A Data Warehouse is a centralized repository that allows you to store and analyze large amounts of data collected from different sources. It is specifically designed to handle analytical processing and decision-making. Unlike traditional databases, which are optimized for transactional processing, data warehouses are optimized for read-heavy queries, reporting, and analysis.

It consolidates data from various sources—such as CRM systems, ERP platforms, flat files, and external APIs—into a single, consistent format. This integration process involves an ETL (Extract, Transform, Load) pipeline, where data is extracted from the source systems, cleaned and transformed to ensure uniformity, and finally loaded into the warehouse for long-term storage and analysis.

Key characteristics of a data warehouse include being **subject-oriented**, **integrated**, **time-variant**, **non-volatile**. These attributes make the data warehouse a powerful foundation for strategic reporting and business intelligence.

In contrast, Data Mart is a smaller, specialized subset of a Data Warehouse that is designed to serve the needs of a specific business unit, department, or team. While a data warehouse typically integrates data from multiple sources across the entire organization, a data mart focuses on a specific subject area or business function (such as sales, marketing, finance, or human resources).

Depending on its architecture, a data mart can take different forms. A **dependent data mart** derives its data directly from an existing enterprise data warehouse, ensuring consistency with the overall organizational data model. In contrast, an **independent data mart** is built directly from operational systems without relying on a central warehouse, often resulting in faster deployment but potentially less consistency across departments.

When it comes to designing a data warehouse, there are two widely recognized methodologies that offer contrasting perspectives on how data should be structured and integrated within an organization. These are the top-down approach proposed by Bill Inmon and the bottom-up approach advocated by Ralph Kimball.

Bill Inmon's approach favours a top-down design in which the data warehouse is the centralized data repository and the most important component of an organization's data systems. Dimensional data marts related to specific business lines can be created from the data warehouse when they are needed. In the Inmon model, data in the data warehouse is integrated, meaning the data warehouse is the source of the data that ends up in the different data marts. This ensures data integrity and consistency across the organization.

Ralph Kimball's data warehouse design starts with the most important business processes. In this approach, an organization creates data marts that aggregate relevant data around subject-specific areas. The data warehouse is the combination of the organization’s individual data marts.

In this project, the Kimball approach is adopted for designing the data warehouse to support business intelligence in inventory management at Global Bike. This methodology is chosen because it emphasizes a bottom-up, business process–oriented design, which aligns well with the focus on specific operations such as stock levels, inventory turnover, and warehouse performance. The dimensional modeling in Kimball's method allows for efficient creation of subject-specific data marts, enabling quick and effective analysis using BI tools like Power BI.

2.4. KPIs

Key Performance Indicators (KPIs) are vital tools that organizations use to assess the achievement of both strategic objectives and day-to-day operations. They offer measurable insights into performance, supporting informed decision-making and ensuring alignment with overarching organizational goals. As emphasized by Kaplan and Norton (1996), KPIs play a central role in strategic management systems such as the Balanced Scorecard, enabling continuous tracking of progress toward long-term targets and operational excellence.

By clearly defining and consistently monitoring KPIs, organizations can better understand multiple dimensions of their performance. Financial KPIs—such as revenue growth and profitability ratios—shed light on fiscal stability, while operational KPIs—like productivity rates and quality metrics—reveal how efficiently and effectively processes are functioning.

Beyond simply measuring outcomes, KPIs are also instrumental in fostering ongoing improvement. When organizations set performance benchmarks and goals using KPIs, they can pinpoint areas for development and implement focused initiatives to enhance results. This cyclical approach not only improves efficiency but also encourages innovation and responsiveness in the face of evolving market demands.

Ultimately, KPIs are indispensable components of a strategic management framework. They empower leaders to make data-driven decisions aligned with key priorities, promote accountability and transparency, and help embed a culture of high performance. Through their effective use, organizations can achieve sustainable growth and maintain a competitive edge within their industries.

2.5. MDX language and OLAP techniques

As this project utilizes SQL Server Analysis Services (SSAS) for multidimensional analysis in the Purchasing department, understanding MDX (Multidimensional Expressions) and OLAP (Online Analytical Processing) is essential. This section presents the theoretical foundation for building analytical data cubes and extracting business value using MDX.

2.5.1. Introduction to MDX Language

MDX is a query language specifically developed for OLAP databases such as SSAS cubes. While SQL is optimized for relational, two-dimensional data, MDX is designed to handle hierarchical and multidimensional data.

Unlike SQL, which processes row-by-row data, MDX operates on **tuples**, **sets**, and **hierarchies**, enabling more intuitive and deep analytical queries — for example, comparing total purchases by product category, time, or vendor.

Key MDX features:

- Tuple-based querying: Targets specific data points in a cube by defining one member from each dimension.
- Set operations: Aggregates data across groups, e.g., total purchase value by vendor or product line.
- Calculated members: Defines KPIs and dynamic calculations within the query.
- Axis structure: Defines data display along rows, columns, and filters for multidimensional comparison.

In the purchasing-focused project, MDX is used to:

- Aggregate and compare purchase amounts and quantities across time, vendors, and product categories.
- Identify suppliers with the highest rejected quantity or late deliveries.
- Analyze trends in procurement volume and spending by quarter or fiscal year.

2.5.2. OLAP techniques and cube design

OLAP enables interactive and multidimensional analysis of large datasets in the data warehouse, empowering users to discover trends, outliers, and business opportunities.

The **Purchasing cube** plays a central role in unifying data from purchasing activities and supports OLAP operations such as:

Drill-down: From total yearly purchase cost to specific product or order line.

Roll-up: Aggregating data from product level to category level or from month to quarter.

Slice-dice: Filtering or rearranging the cube to focus on certain vendors, regions, or years.

Pivot: Changing perspectives to compare data across dimensions (e.g., vendor performance over time).

This project implements MOLAP (Multidimensional OLAP) due to its advantages:

- MOLAP pre-aggregates data inside the cube, enabling high-speed query performance.
- Calculated KPIs such as total rejected quantity, average unit price, and fulfillment rates are embedded within the cube.

Additionally, the project partially adopts a HOLAP (Hybrid OLAP) model:

- HOLAP enables drill-through from summary cube data to detailed transactional data (e.g., PurchaseOrderDetail).
- Improves flexibility and scalability when analyzing high-volume purchasing records.

2.5.3. MDX Query Structure in SSAS

An MDX query has a distinct structure compared to SQL but follows a logical flow, supporting flexible, real-time data exploration.

Core components of an MDX query:

WITH: Defines calculated measures or custom sets.

SELECT: Specifies dimensions and members to be shown on rows and columns.

FROM: Identifies the cube being queried.

WHERE: Defines slicing conditions (filters), e.g., by vendor, year, or region.

Example query in this project context:

```
SELECT
  [Time].[Calendar].[Year].Members ON COLUMNS,
  [Vendor].[Vendor Name].Members ON ROWS
FROM
  [PurchasingCube]
WHERE
  ([Product].[Category].&[Accessories])
```

This query returns total purchasing values by vendor and year, limited to the Accessories product category.

Benefits of using MDX in this purchasing BI project:

- Enable ad hoc queries for analyzing purchase behavior and vendor reliability.
- Instantly identify patterns such as frequently delayed shipments or overstocked product lines.
- Seamlessly integrate with Power BI to visualize purchasing metrics via interactive dashboards.

MDX and OLAP serve as the analytical backbone for the **Purchasing BI System** at AdventureWorks. Through a well-designed cube and expressive MDX queries, users can navigate and analyze procurement data from multiple perspectives — vendor, product, time, and cost — enabling informed, timely, and strategic purchasing decisions

2.6. Visualization

The project team utilizes **Power BI** to develop interactive and insightful visualizations based on the **Purchasing Data Mart**. These visualizations transform raw procurement data into actionable insights that support decision-making in various purchasing activities such as supplier performance analysis, purchase order tracking, delivery timeliness, cost control, and procurement planning.

2.6.1. Power BI definition

Power BI is a business analytics solution developed by Microsoft. It enables users to transform data from various sources—spreadsheets, ERP systems, databases, or cloud services—into intuitive and interactive dashboards and reports. Through rich visualizations, Power BI helps uncover trends and outliers, allowing procurement managers to monitor purchase trends, vendor reliability, and cost structures effectively.

2.6.2. Core components of Power BI

Power BI comprises five key components, each contributing to a seamless data visualization and sharing experience:

Power BI Desktop

A Windows-based application that serves as the main development environment. It is used in this project to design data models and build analytical reports related to vendor ratings, purchase history, and procurement costs.

Power BI Service

A cloud-based platform where reports and dashboards are published, shared, and consumed by stakeholders such as procurement officers, warehouse managers, and finance departments.

Power BI Mobile

Mobile applications for iOS, Android, and Windows that allow real-time access to dashboards—useful for managers who need to track key purchasing metrics on the go.

Power BI Report Builder

A specialized tool for creating paginated reports that resemble traditional paper reports. It is particularly helpful for generating formal purchase summaries, vendor comparison sheets, and compliance documentation.

Power BI Report Server

An on-premises solution that enables secure report distribution within the organization—ideal for companies with sensitive procurement data or limited access to cloud services.

Such visual reports allow stakeholders to make **informed and timely purchasing decisions**, ensuring procurement efficiency, supplier accountability, and cost control throughout the organize.

CHAPTER 3. ANALYSIS OF USER REQUIREMENTS AND DATA DESCRIPTION

3.1. Purchasing department

3.1.1 Purchasing department

In the bicycle manufacturing and retail industry, the Purchasing Department of AdventureWorks plays a vital role in supply chain management and ensuring the continuous operation of production and business activities. This department is responsible for the procurement and control of all materials, components, and finished goods necessary for both the bicycle manufacturing process and the company's retail operations.

For the manufacturing segment, the Purchasing Department handles ordering and supplying raw materials such as bike frames, wheels, chains, brakes, and other related components. They also ensure the availability of tools, equipment, and specialized machinery required for the production line.

On the retail side, the Purchasing Department is responsible for ensuring that goods are always available in warehouses and stores—including finished bicycles and replacement parts—to meet customer demand in a timely manner and maintain optimal inventory levels.

One of the department's top priorities is effective inventory management. They must ensure sufficient raw materials for production and goods for retail, while also avoiding excess inventory that could negatively impact cash flow and the company's ability to invest in other important activities such as marketing or new product R&D.

The Purchasing Department also plays a crucial role in supplier evaluation and selection. In addition to cost, they consider criteria such as quality, reliability, and supplier responsiveness. This is a key factor in the bicycle industry, where product durability and quality significantly impact brand reputation.

In addition, the Purchasing Department continuously strives to optimize procurement costs through contract negotiation, sourcing new suppliers, and implementing effective purchasing strategies. This helps the company improve profit margins while maintaining high product quality.

As a central part of the supply chain, the Purchasing Department directly affects the continuity of production and business operations, cost optimization, and product quality assurance. Through these activities, they contribute to enhancing AdventureWorks' competitiveness and sustainable success in the bicycle industry.

3.1.2 Organizational structure

The Purchasing Department of AdventureWorks is organized according to a functional model with three main hierarchical roles: Purchasing Manager, Buyers, and Purchasing Assistants. Each position is assigned specific tasks to ensure that the procurement process runs efficiently, transparently, and effectively supports production and business operations.

Purchasing Manager

Role: The head of the department, responsible for the overall strategy and operations of the entire purchasing function.

Responsibilities:

- Develop and implement a comprehensive purchasing strategy for both the manufacturing and retail segments.
- Establish purchasing policies, procedures, and performance standards.
- Manage and oversee the activities of the entire purchasing team.
- Make final decisions on critical matters such as selecting strategic suppliers or signing major contracts.
- Build and maintain long-term partnerships with key domestic and international suppliers.

Buyers

Role: Procurement specialists in charge of daily purchasing transactions and managing supplier relationships.

Responsibilities:

- Search for, evaluate, and select reputable suppliers to ensure quality and reasonable pricing.
- Negotiate pricing, payment terms, and purchasing contracts.
- Coordinate with Production, Warehouse, and Sales departments to accurately determine procurement needs.
- Monitor and optimize inventory levels to minimize the risk of shortages or overstocking.
- Track supplier performance (on-time delivery, quality, cost).
- Provide data to the BI team to support procurement performance analysis.

Purchasing Assistants

Role: Provide administrative and communication support for Buyers and the Purchasing Manager.

Responsibilities:

- Create and process purchase orders in the system.
- Communicate with suppliers to confirm orders, track delivery status, and handle day-to-day issues.
- Update supplier databases and procurement history records.
- Assist in collecting and compiling data for regular purchasing reports.
- Support document verification, invoice tracking, and monitoring of delivery and warehouse receipt processes.

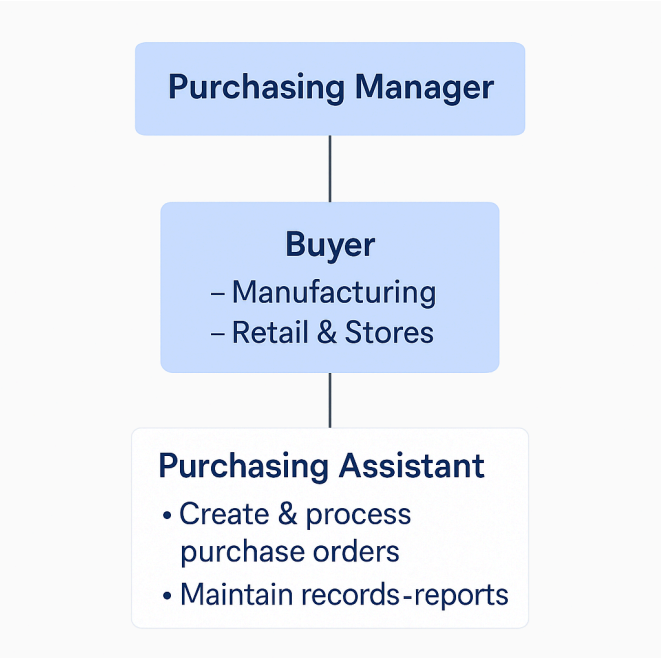


Figure 3.1.2.1: Roles hierarchy

3.2. Purchasing process

Step 1: Purchase requisition

- Departments (Production, Retail, Warehouse, Engineering) submit purchase requests based on production needs or inventory replenishment.
- The system checks current inventory levels and suggests appropriate purchase quantities.

Step 2: Verification and approval

- The Buyer reviews the request details (item, quantity, required delivery date) and checks the budget.
- The Purchasing Manager or authorized personnel approves large or critical purchase requests.

Step 3: Purchase order (PO) creation

- The Buyer creates an official Purchase Order (PO) and sends it to the selected supplier.
- The PO includes detailed information: item code, quantity, price, delivery date, and delivery location.

Step 4: Delivery tracking

- The Buyer monitors the delivery progress from the supplier.
- The Purchasing Assistant communicates regularly with the supplier to ensure on-time delivery.
- In the BI system, the order status is automatically updated at each milestone.

Step 5: Goods receipt and inspection

- When the goods arrive at the warehouse, the warehouse team inspects the quantity and quality.
- If acceptable, the goods are received into stock; if not, a return or issue resolution process is initiated.

Step 6: Payment and reconciliation

- The Finance Department reconciles the PO, delivery documents, and the supplier's invoice.
- Once verified, payment is processed according to the contract terms.

Step 7: Supplier evaluation and procurement data analysis

Buyers and the Purchasing Manager use the Power BI dashboard to:

- Monitor on-time delivery rates
- Identify delayed or quantity-mismatched orders
- Compare performance across suppliers

This data supports periodic supplier evaluations and strategic decision-making

3.3. Business requirements in purchasing department

No.	Role	What	How	Why
1	**Purchasing Manager**	-Develop and implement long-term purchasing strategies. -Establish purchasing policies and standardized procedures. -Approve high-value contracts and strategic suppliers. -Evaluate overall purchasing performance regularly. -Coordinate with other departments to define strategic sourcing needs.	-Analyze consumption reports, production demands, and market trends to propose appropriate strategies aligned with company goals. -Create clear procedures for handling purchase requisitions (PR), supplier selection, PO approval, and quality checks. -Conduct regular meetings with key suppliers to evaluate performance. -Collaborate with Finance, Warehouse, and Production to coordinate budget and delivery schedules.	-Ensure all purchasing activities are aligned with strategic company goals. -Improve cost-efficiency, risk management, and supplier relationships. -Maintain a sustainable supply chain with stable pricing and consistent quality.

2	**Buyer**	-Receive and process purchase requisitions from departments. -Select appropriate suppliers. -Create, send, and monitor purchase orders (POs). -Resolve delivery issues: delays, quantity mismatches, or product quality issues. -Update PO status on the system. -Act as liaison between suppliers and internal teams.	-Validate PR against current inventory and budget before proceeding. -Use approved supplier list, evaluate based on pricing, reliability, lead time, and quality. -Generate PO in the ERP system, send it to the supplier, and confirm order acceptance. -Monitor delivery process, coordinate with Warehouse for inspections, and resolve discrepancies. -Record supplier performance for future evaluation.	- Ensure timely and accurate procurement of materials and goods to support production and sales. -Minimize risks related to stockouts or overstocking. -Improve visibility and transparency in procurement operations.

3	**Purchasing Assistant**	-Support Buyers in administrative and data entry tasks. -Create and manage POs in the system. -Communicate with suppliers to confirm delivery dates and schedules. -Maintain and archive procurement documents: POs, invoices, delivery notes, inspection records. -Assist in report generation.	-After POs are created by Buyers, assist with printing, sending confirmations to suppliers, and updating order statuses. -Track delivery details and product conditions in the system. -Update supplier database: contacts, locations, product lists. -Compile data from various POs and suppliers to prepare weekly/monthly/quarterly reports. -Support data management and validation for Power BI dashboards and performance reviews.	- Save time for Buyers by handling routine administrative tasks. -Ensure accurate and up-to-date purchasing data to support audits, decision-making, and supplier assessments. -Improve collaboration between Purchasing, Finance, Warehouse, and BI teams.

Table 3.3.1: Business requirements

3.4. Define main key performance indicators

To support effective operational monitoring and analysis, a set of Key Performance Indicators (KPIs) has been defined and implemented within the Power BI dashboard. Each KPI was carefully designed to provide actionable insights aligned with the specific business questions of the Purchasing Department.

To support daily procurement operations, this dashboard focuses on order tracking and cycle efficiency. The following KPIs provide actionable insights for purchasing clerks and supervisors:

Total Purchase Orders

Total Purchase Orders is a key performance indicator that measures the total number of purchase orders issued over a defined period. This metric reflects the operational activity level of the procurement department and provides insight into purchasing frequency and supplier engagement.

Formula

Total Purchase Orders =DISTINCTCOUNT(FactPurchaseOrder[PurchaseOrderID])

An increase in the number of purchase orders typically indicates a rise in procurement activity, often driven by greater demand for raw materials or finished products, which may result from expanding production or sales operations. However, a sharp rise in order volume—particularly if composed of numerous small or fragmented orders—can also suggest inefficiencies in purchasing practices, such as poor order consolidation and increased administrative burden. Additionally, higher purchase order frequency may strain the supply chain by placing greater demands on suppliers, logistics partners, and internal processing systems.

Conversely, a decline in total purchase orders may reflect reduced operational activity due to lower demand, production slowdowns, or seasonal changes. In some cases, this reduction may be a positive sign of enhanced efficiency, particularly if it

stems from improved order consolidation or the implementation of automated procurement processes. Nonetheless, a sudden drop in purchase orders may also act as a warning signal, potentially indicating procurement delays, budgetary constraints, supply chain disruptions, or system-related issues.

Total Stock Quantity

This KPI represents the total number of product units currently available across all warehouses. It is essential for ensuring sufficient stock to fulfill internal requests and planned purchases.

Formula

```
Total Stock = SUM(Inventory[Quantity])
```

Out-of-Stock Items

This metric identifies how many products have no stock left. A high number of out-of-stock items may signal the need for urgent replenishment or flaws in order forecasting.

Formula

```
Out-of-Stock Item
= CALCULATE(DISTINCTCOUNT(Inventory[ProductID]),Inventory[Quantity] = 0 )
```

Vendor fulfillment rate (%)

Vendor Fulfillment Rate is a key performance indicator that measures the percentage of purchase orders or order lines that a vendor successfully fulfills as requested — in terms of quantity, quality, and delivery schedule. It reflects the reliability and effectiveness of a supplier in meeting procurement expectations.

This KPI is crucial for evaluating supplier performance, identifying potential risks in the supply chain, and ensuring that operations are not disrupted due to late or incomplete deliveries. A consistently high fulfillment rate indicates strong vendor reliability and helps build trust in long-term partnerships, while a low rate may signal issues in inventory, logistics, or coordination.

Formula

Fulfillment Rate = (Total Received Qty ÷ Total Ordered Qty) × 100

Total Order Quantity

Total Quantity Purchased is a key metric that represents the aggregate number of product units procured over a specific period. This KPI provides insights into purchasing volume and helps assess demand patterns, procurement trends, and supplier capacity. Monitoring this indicator enables procurement teams to track inventory flow, forecast future needs, and evaluate the efficiency of purchasing strategies. A sudden spike may suggest a ramp-up in production or seasonal demand, while a decline could indicate reduced operations or improved stock optimization.

Formula

Total Order Quantity = SUM(OrderQty)

Total Products

Total Products refers to the total number of distinct products managed, purchased, or available within the procurement or inventory system. This KPI reflects

the breadth of the product portfolio and provides insight into product variety, supply chain complexity, and purchasing diversity. Tracking the total number of products helps organizations manage stock levels, evaluate vendor coverage, and monitor catalog expansion or rationalization efforts. An increasing number of products may indicate business growth or diversification, while a decrease could reflect product consolidation or streamlining strategies.

Formula

```
Total Products = Distinctcount(PurchaseOrder[ProductID)
```

Total Received Quantity

Represent the total number of units that have been successfully delivered by suppliers and accepted into inventory. This KPI reflects the actual fulfillment of purchase orders and serves as a critical measure of supply chain efficiency. Monitoring received quantity over time helps assess vendor reliability and ensures that inventory levels align with operational needs.

Formula

```
CALCULATE(SUM(FactPurchaseOrder[ReceivedQty])
```

Total Rejected Quantity

Measure the number of units delivered by suppliers that were not accepted due to quality issues, incorrect specifications, or damage. A high rejection volume may indicate problems with vendor quality control or handling during transit. This KPI is essential for identifying supply chain risks, improving procurement decisions, and working with vendors to enhance compliance and product standards.

Formula

```
CALCULATE(SUM(FactPurchaseOrder[RejectedQty])
```

3.5. Functional requirements

3.5.1. BI use case

Use Case	Why / Where / How	User	Data
Automated purchase order accuracy monitoring	*Why*: To reduce mismatches between ordered and received quantities, improving procurement accuracy and minimizing follow-up costs. *Where*: Embedded in operational dashboards to detect quantity mismatches. *How*: Use DAX in Power BI to calculate quantity difference and flag anomalies.	Purchasing Manager	PurchaseOrderHeader, PurchaseOrderDetail
Supplier on-time delivery tracking	*Why*: To measure supplier reliability and improve delivery consistency. *Where*: Supplier performance section in BI dashboard. *How*: Compare ShipDate and DueDate per PO; calculate on-time rate by vendor.	Buyers, Manager	PurchaseOrderDetail (ShipDate, DueDate), Vendor

Top vendor analysis by spend	*Why*: To identify key suppliers for strategic sourcing and negotiation. *Where*: Spend overview section of Procurement Dashboard. *How*: Rank vendors using RANKX based on total LineTotal, display top 5 with bar charts.	Purchasing Manager	PurchaseOrderDetail[LineTotal], Vendor
Delayed orders by employee	*Why*: To track accountability and improve procurement staff performance. *Where*: Employee dashboard. *How*: Filter orders with ShipDate > DueDate grouped by EmployeeID.	Purchasing Manager	PurchaseOrderHeader[EmployeeID], PurchaseOrderDetail[ShipDate, DueDate]
Unit price trend by product	*Why*: To detect pricing anomalies and support cost analysis. *Where*: Product KPI dashboard. *How*:Use AVERAGE(UnitPrice) over time by product, show with line chart.	Buyers, Manager	PurchaseOrderDetail[UnitPrice, ProductID, OrderDate]
Order tracking by status	*Why*: To monitor procurement progress and react to issues in real time. *Where*: Dashboard home screen. *How*: Visualize order status distribution using cards and pie charts;	Buyers, Assistants	PurchaseOrderHeader[Status, OrderDate], PurchaseOrderDetail[DueDate, ShipDate]

Delivery lead time variance analysis	*Why*: To evaluate vendor delivery efficiency against expected benchmarks. *Where*: Delivery detail dashboard. *How*: Use DATEDIFF(OrderDate, ShipDate) to compute actual lead time, compare with OnOrderLeadTime field for each vendor-product combo.	Buyers, Warehouse Team	PurchaseOrderHeader[OrderDate, ShipDate], ProductVendor[OnOrderLeadTime]

Table 3.5.1.1: BI use case

3.5.2. Analytical process workflow and user interaction

Purchasing Manager

The Purchasing Manager utilizes the Business Intelligence (BI) system as a strategic tool to oversee all procurement activities. Through interactive dashboards, they can monitor key performance indicators (KPIs) such as total purchase spend, on-time delivery rate, and vendor performance in real time.

With data insights from BI, the manager can identify bottlenecks in the procurement process and make informed decisions—such as switching suppliers, optimizing inventory levels, or reallocating resources. BI also supports budget planning, improves contract negotiations with key vendors, and facilitates regular performance reporting to senior leadership.

Buyer

Buyers interact with BI dashboards on a daily basis to track order status, evaluate supplier performance, and support decision-making in vendor selection. KPIs such as late deliveries, on-time delivery rate, and quantity accuracy are presented in intuitive visuals.

They can filter data by date, supplier, or product category to detect irregularities and

proactively contact vendors or propose contract adjustments. BI also enables them to monitor price fluctuations, analyze purchasing trends, and retrieve accurate data for order validation and analysis.

Purchasing Assistant

Purchasing Assistants rely on BI dashboards to manage inventory and order operations efficiently. They track pending deliveries, monitor receiving progress, and receive alerts on potential delays.

Data visualization allows them to coordinate quickly with vendors or warehouse teams to ensure timely inbound logistics. Additionally, they use BI to support routine reporting, document verification, and generate low-stock alerts to recommend new purchase requisitions.

3.5.3. Analytical styles needed

Purchasing Manager

For the Purchasing Manager, analytical tools serve as a strategic instrument for controlling total procurement spending, evaluating supplier performance, and forecasting future demand. Dashboards in Power BI allow managers to quickly detect overspending trends, delayed order statuses, or declines in supplier reliability.

By leveraging descriptive and predictive analytics, the Purchasing Manager can make informed strategic decisions, such as budget reallocation, procurement policy adjustments, or restructuring the supplier base to optimize overall supply chain efficiency.

Buyer

Buyers rely on analytical tools to monitor and enhance supplier relationships. Dashboards offer deep insights into delivery timeliness, quantity accuracy, delay frequency, and supplier-specific costs.

Using diagnostic analytics, Buyers can identify root causes of issues such as late shipments, quantity mismatches, or cost overruns and take corrective action.

Additionally, BI tools enable comparative performance analysis among suppliers to support negotiations and vendor selection decisions.

Purchasing Assistant

For Purchasing Assistants, BI tools enable real-time tracking of order statuses, flag pending approvals or delayed shipments, and help manage the entire purchase order lifecycle.

By applying descriptive analytics, they can quickly respond to issues, send timely reminders, and ensure smooth operational flow.

These tools also support the preparation of routine reports and the consolidation of procurement data, facilitating efficient communication with upper management.

3.6. Data preparation

3.6.1. Data source and collection

We use the AdventureWorks2022 database as the primary data source, focusing on the analysis of tables and views related to the purchasing management module. This includes a detailed review of data related to purchase orders, product inventory, and relevant transaction records. Through the analysis of these components, we aim to gain a comprehensive understanding of the procurement processes and the associated transactional data within the system.

For the Purchasing system, we developed a Data Mart consisting of a dataset built from 12 key tables. These tables include: *HumanResources.Employee, Person.Person, Production.Product, Production.ProductInventory, Production.ProductCategory, Production.ProductSubCategory, Purchasing.PurchaseOrderDetail, Purchasing.PurchaseOrderHeader, Purchasing.Vendor, Purchasing.ShipMethod, Purchasing.ProductVendor, Production.Location*

3.6.2. Purchasing data mart

In the Inventory module, there are 12 tables including:

HumanResources.Employee

Person.Person

Production.Product

Production.ProductInventory

Production.ProductCategory

Production.ProductSubCategory

Purchasing.PurchaseOrderDetail

Purchasing.PurchaseOrderHeader

Purchasing.Vendor

Purchasing.ShipMethod

Purchasing.ProductVendor

Production.Location

a. HumanResources.Employee

Employee information such as salary, department, and title.

Key	Name	Data type	Null	Description
PK	BusinessEntityID	int		Primary key for Employee records. Foreign key to BusinessEntity.BusinessEntityID.
AK	NationalIDNumber	nvarchar(15)		Unique national identification number such as a social security number.
AK	LoginID	nvarchar(256)		Network login. Test2
	OrganizationNode	hierarchyid	X	Where the employee is located in corporate hierarchy.
	OrganizationLevel	smallint	X	The depth of the employee in the corporate hierarchy.
	JobTitle	nvarchar(50)		Work title such as Buyer or Sales Representative.
	BirthDate	date		Date of birth.
	MaritalStatus	nchar(1)		M = Married, S = Single
	Gender	nchar(1)		M = Male, F = Female

	HireDate	date		Employee hired on this date.
	SalariedFlag	bit		Job classification. 0 = Hourly, not exempt from collective bargaining. 1 = Salaried, exempt from collective bargaining.
	VacationHours	smallint		Number of available vacation hours.
	SickLeaveHours	smallint		Number of available sick leave hours.
	CurrentFlag	bit		0 = Inactive, 1 = Active
AK	rowguid	uniqueidentifier		ROWGUIDCOL number uniquely identifying the record. Used to support a merge replication sample.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.1: Column of HumanResources.Employee

Foreign table	Relationship	Primary table	Join
HumanResources.Employee		Person.Person	**HumanResources.Employee.BusinessEntityID = Person.Person.BusinessEntityID**
Purchasing.PurchaseOrderHeader		HumanResources.Employee	Purchasing.PurchaseOrderHeader.EmployeeID = HumanResources.Employee.BusinessEntityID

Table 3.6.2.2: Relation of HumanResources.Employee

b. Person.Person

Manages personal data such as names, contact information, and identity details for customers, employees, and vendors.

Key	Name	Data type	Null	Description
PK	BusinessEntityID	int		Primary key for Person records.
	PersonType	nchar(2)		Primary type of person: SC = Store Contact, IN = Individual (retail) customer, SP = Sales person, EM = Employee (non-sales), VC = Vendor contact, GC = General contact
	NameStyle	bit		0 = The data in FirstName and LastName are

				stored in western style (first name, last name) order. 1 = Eastern style (last name, first name) order.
	Title	nvarchar(8)	X	A courtesy title. For example, Mr. or Ms.
	FirstName	nvarchar(50)		First name of the person.
	MiddleName	nvarchar(50)	X	Middle name or middle initial of the person.
	LastName	nvarchar(50)		Last name of the person.
	Suffix	nvarchar(10)	X	Surname suffix. For example, Sr. or Jr.
	EmailPromotion	int		0 = Contact does not wish to receive e-mail promotions, 1 = Contact does wish to receive e-mail promotions from AdventureWorks, 2 = Contact does wish to receive e-mail promotions from AdventureWorks and selected partners.
	AdditionalContactInfo	xml	X	Additional contact information about the person stored in xml format.
	Demographics	xml	X	Personal information such as hobbies, and income collected from online shoppers. Used for sales analysis.
AK	rowguid	uniqueidentifier		ROWGUIDCOL number uniquely identifying the record. Used to support a merge replication sample.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.3: Column of Person.Person

Foreign table	Relationship	Primary table	Join
Person.Person		HumanResources.Employee	**HumanResources.Employee.BusinessEntityID = Person.Person.BusinessEntityID**

Table 3.6.2.4: Relation of Person.Person

c. Production.Product

Contains detailed information about products that are manufactured or sold, including IDs, names, and statuses.

Key	Name	Data type	Null	Description
PK	ProductID	int		Primary key for Product records.
AK	Name	nvarchar(50)		Name of the product.
AK	ProductNumber	nvarchar(25)		Unique product identification number.
	MakeFlag	bit		0 = Product is purchased, 1 = Product is manufactured in-house.
	FinishedGoodsFlag	bit		0 = Product is not a salable item. 1 = Product is salable.
	Color	nvarchar(15)	X	Product color.
	SafetyStockLevel	smallint		Minimum inventory quantity.
	ReorderPoint	smallint		Inventory level that triggers a purchase order or work order.
	StandardCost	money		Standard cost of the product.
	ListPrice	money		Selling price.
	Size	nvarchar(5)	X	Product size.
	SizeUnitMeasureCode	nchar(3)	X	Unit of measure for Size column.
	WeightUnitMeasureCode	nchar(3)	X	Unit of measure for Weight column.
	Weight	decimal(8, 2)	X	Product weight.
	DaysToManufacture	int		Number of days required to manufacture the product.
	ProductLine	nchar(2)	X	R = Road, M = Mountain, T = Touring, S = Standard
	Class	nchar(2)	X	H = High, M = Medium, L = Low
	Style	nchar(2)	X	W = Womens, M = Mens, U = Universal
FK	ProductSubcategoryID	int	X	Product is a member of this product subcategory. Foreign key to ProductSubCategory.ProductSubCategoryID.
	ProductModelID	int	X	Product is a member of this product model. Foreign key to ProductModel.ProductModelID.

	SellStartDate	datetime	X	Date the product was available for sale.
	SellEndDate	datetime	X	Date the product was no longer available for sale.
	DiscontinuedDate	datetime	X	Date the product was discontinued.
AK	rowguid	uniqueidentifier		ROWGUIDCOL number uniquely identifying the record. Used to support a merge replication sample.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.5: Column of Production.Product

Foreign table	Relation Ship	Primary table	Join
Production.Product		Production.ProductSubcategory	**Production.Product.ProductSubcategoryID = Production.ProductSubcategory.ProductSubcategoryID**
Production.ProductInventory		Production.Product	Production.ProductInventory.ProductID = Production.Product.ProductID
Purchasing.PurchaseOrderDetail		Production.Product	Purchasing.PurchaseOrderDetail.ProductID = Production.Product.ProductID
Purchasing.PurchaseOrderDetail		Production.Product	Purchasing.ProductVendor.ProductID = **Production.Product**.ProductID

Table 3.6.2.6: Relation of Production.Product

d. Production.ProductInventory

Maintains the current inventory quantity for each product at specific warehouse locations.

Key	Name	Data type	Null	Description
PK	ProductID	int		Product identification number. Foreign key to Product.ProductID.
PK	LocationID	smallint		Inventory location identification number. Foreign

				key to Location.LocationID.
	Shelf	nvarchar(10)		Storage compartment within an inventory location.
	Bin	tinyint		Storage container on a shelf in an inventory location.
	Quantity	smallint		Quantity of products in the inventory location.
	rowguid	uniqueidentifier		ROWGUIDCOL number uniquely identifying the record. Used to support a merge replication sample.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.7: Column of Production.ProductInventory

Foreign table	Relationship	Primary table	Join
Production.ProductInventory		Production.Location	**Production.ProductInventory.LocationID = Production.Location.LocationID**
Production.ProductInventory		Production.Product	**Production.ProductInventory.ProductID = Production.Product.ProductID**

Table 3.6.2.8: Relation of Production.ProductInventory

e. Production.ProductCategory

Classifies products into high-level categories such as "Bikes" or "Accessories".

Key	Name	Data type	Null	Description
PK	ProductCategoryID	int		Primary key for ProductCategory records.
AK	Name	nvarchar(50)		Category description.
AK	rowguid	uniqueidentifier		ROWGUIDCOL number uniquely identifying the record. Used to support a merge replication sample.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.9: Column of Production.ProductCategory

Foreign table	Relationship	Primary table	Join
Production.ProductSubcategory		Production.ProductCategory	Production.ProductSubcategory.ProductCategoryID = Production.ProductCategory.ProductCategoryID

Table 3.6.2.10: Relation of Production.ProductCategory

f. Production.ProductSubCategory

Provides more granular classification of products within each category for better analysis.

Key	Name	Data type	Null	Description
PK	ProductSubcategoryID	int		Primary key for ProductSubcategory records.
	ProductCategoryID	int		Product category identification number. Foreign key to ProductCategory.ProductCategoryID.
AK	Name	nvarchar(50)		Subcategory description.
AK	rowguid	uniqueidentifier		ROWGUIDCOL number uniquely identifying the record. Used to support a merge replication sample.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.11: Column of Production.ProductSubCategory

Foreign table	Relationship	Primary table	Join
Production.ProductSubcategory		Production.ProductCategory	Production.ProductSubcategory.ProductCategoryID = Production.ProductCategory.ProductCategoryID

Production.Product		Production.ProductSubcategory	Production.Product.ProductSubcategoryID = Production.ProductSubcategory.ProductSubcategoryID

Table 3.6.2.12: Relation of Production.ProductSubCategory

g. Purchasing.PurchaseOrderHeader.

Stores purchase order summaries, including vendor info, order dates, and status.

Key	Name	Data type	Null	Description
PK	PurchaseOrderID	int		Primary key.
	RevisionNumber	tinyint		Incremental number to track changes to the purchase order over time.
	Status	tinyint		Order current status. 1 = Pending; 2 = Approved; 3 = Rejected; 4 = Complete
FK	EmployeeID	int		Employee who created the purchase order. Foreign key to Employee.BusinessEntityID.
	OrderDate	datetime		Purchase order creation date.
	ShipDate	datetime	X	Estimated shipment date from the vendor.
	SubTotal	money		Purchase order subtotal. Computed as SUM(PurchaseOrderDetail.LineTotal)for the appropriate PurchaseOrderID.
	TaxAmt	money		Tax amount.
	Freight	money		Shipping cost.
	TotalDue	money		Total due to the vendor. Computed as Subtotal + TaxAmt + Freight.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.13: Column of Purchasing.PurchaseOrderHeader.

Foreign table	Relationship	Primary table	Join
Purchasing.PurchaseOrderHeader		HumanResources.Employee	**Purchasing.PurchaseOrderHeader.EmployeeID = HumanResources.Employee.BusinessEntityID**
Purchasing.PurchaseOrderDetail		Purchasing.PurchaseOrderHeader	Purchasing.PurchaseOrderDetail.PurchaseOrderID = Purchasing.PurchaseOrderHeader.PurchaseOrderID
Purchasing.PurchaseOrderHeader		Purchasing.ShipMethod	Purchasing.PurchaseOrderHeader.ShipMethodID = Purchasing.ShipMethod.ShipMethodID
Purchasing.PurchaseOrderHeader		Purchasing.Vendor	Purchasing.PurchaseOrderHeader.VendorID = Purchasing.Vendor.BusinessEntityID

Table 3.6.2.14: Relation of Purchasing.PurchaseOrderHeader

h. Purchasing.PurchaseOrderDetail

Contains item-level details of each purchase order, including quantities, prices, and products.

Key	Name	Data type	Null	Description
PK	PurchaseOrderID	int		Primary key. Foreign key to PurchaseOrderHeader.PurchaseOrderID.
PK	PurchaseOrderDetailID	int		Primary key. One line number per purchased product.
	DueDate	datetime		Date the product is expected to be received.
	OrderQty	smallint		Quantity ordered.
FK	ProductID	int		Product identification number. Foreign key to Product.ProductID.

	UnitPrice	money		Vendor's selling price of a single product.
	LineTotal	money		Per product subtotal. Computed as OrderQty * UnitPrice.
	ReceivedQty	decimal(8, 2)		Quantity actually received from the vendor.
	RejectedQty	decimal(8, 2)		Quantity rejected during inspection.
	StockedQty	decimal(9, 2)		Quantity accepted into inventory. Computed as ReceivedQty - RejectedQty.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.15: Column of Purchasing.PurchaseOrderDetail

Foreign table	Relationship	Primary table	Join
Purchasing.PurchaseOrderDetail		Production.Product	**Purchasing.PurchaseOrderDetail**.ProductID = Production.Product.ProductID
Purchasing.PurchaseOrderDetail		Purchasing.PurchaseOrderHeader	**Purchasing.PurchaseOrderDetail**.PurchaseOrderID = Purchasing.PurchaseOrderHeader.PurchaseOrderID

Table 3.6.2.16: Relation of Purchasing.PurchaseOrderDetail

i. Production.Location

Identifies physical locations in warehouses used to store raw materials or finished goods.

Key	Name	Data type	Null	Description
PK	LocationID	smallint		Primary key for Location records.
AK	Name	nvarchar(50)		Location description.
	CostRate	smallmoney		Standard hourly cost of the manufacturing location.
	Availability	decimal(8, 2)		Work capacity (in hours) of the manufacturing location.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.17: Column of Production.Location

Foreign table	Relationship	Primary table	Join
Production.ProductInventory	>—	Production.Location	Production.ProductInventory.LocationID = **Production.Location**.LocationID

Table 3.6.2.18: Relation of Production.Location

j. Purchasing.Vendor

Key	Name	Data type	Null	Description
PK	BusinessEntityID	int		Primary key for Vendor records. Foreign key to BusinessEntity.BusinessEntityID
AK	AccountNumber	nvarchar(15)		Vendor account (identification) number.

	Name	nvarchar(50)		Company name.
	CreditRating	tinyint		1 = Superior, 2 = Excellent, 3 = Above average, 4 = Average, 5 = Below average
	PreferredVendorStatus	bit		0 = Do not use if another vendor is available. 1 = Preferred over other vendors supplying the same product.
	ActiveFlag	bit		0 = Vendor no longer used. 1 = Vendor is actively used.
	PurchasingWebServiceURL	nvarchar(1024)	X	Vendor URL.
8	ModifiedDate	datetime		

Table 3.6.2.19: Column of Purchasing.Vendor

Foreign table	Relationship	Primary table	Join
Purchasing.ProductVendor		Purchasing.Vendor	Purchasing.ProductVendor.BusinessEntityID = **Purchasing.Vendor**.BusinessEntityID
Purchasing.PurchaseOrderHeader		Purchasing.Vendor	Purchasing.PurchaseOrderHeader.VendorID = **Purchasing.Vendor**.BusinessEntityID

Table 3.6.2.20: Relation of Purchasing.Vendor

k. **Purchasing.ProductVendor**

Key	Name	Data type	Null	Description

PK	ProductID	int		Primary key. Foreign key to Product.ProductID.
PK	BusinessEntityID	int		Primary key. Foreign key to Vendor.BusinessEntityID.
	AverageLeadTime	int		The average span of time (in days) between placing an order with the vendor and receiving the purchased product.
	StandardPrice	money		The vendor's usual selling price.
	LastReceiptCost	money	X	The selling price when last purchased.
	LastReceiptDate	datetime	X	Date the product was last received by the vendor.
	MinOrderQty	int		The maximum quantity that should be ordered.
	MaxOrderQty	int		The minimum quantity that should be ordered.
	OnOrderQty	int	X	The quantity currently on order.
	UnitMeasureCode	nchar(3)		The product's unit of measure.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.21: Column of Purchasing.ProductVendor

Foreign table	Relationship	Primary table	Join
Purchasing.ProductVendor		Production.Product	**Purchasing.ProductVendor**.ProductID = Production.Product.ProductID
Purchasing.ProductVendor		Purchasing.Vendor	**Purchasing.ProductVendor**.BusinessEntityID = Purchasing.Vendor.BusinessEntityID

Table 3.6.2.22: Relation of Purchasing.ProductVendor

l. Purchasing.ShipMethod

Key	Name	Data type	Null	Description
PK	ShipMethodID	int		Primary key for ShipMethod records.
AK	Name	nvarchar(50)		Shipping company name.
	ShipBase	money		Minimum shipping charge.
	ShipRate	money		Shipping charge per pound.
AK	rowguid	uniqueidentifier		ROWGUIDCOL number uniquely identifying the record. Used to support a merge replication sample.
	ModifiedDate	datetime		Date and time the record was last updated.

Table 3.6.2.23: Column of Purchasing.ShipMethod

Foreign table	Relationship	Primary table	Join

Purchasing .PurchaseO rderHeader		Purchasing.Ship Method	Purchasing.PurchaseOrderHeader.S hipMethodID = **Purchasing.ShipMethod**.ShipMet hodID

Table 3.6.2.24: Relation of Purchasing.ShipMethod

3.6.3.View

This view has detailed information about the address of a vendor

Key	Name	Data type	Null
1	BusinessEntityID	int	
2	Name	nvarchar(50)	
3	AddressType	nvarchar(50)	
4	AddressLine1	nvarchar(60)	
5	AddressLine2	nvarchar(60)	X
6	City	nvarchar(30)	
7	StateProvinceName	nvarchar(50)	
8	PostalCode	nvarchar(15)	
9	CountryRegionName	nvarchar(50)	

Table 3.6.3.1: Detailed information about the address of a vendor

3.6.4. Data understanding

Various versions of the Adventure Works Cycles (AWC) database, spanning from 2005 to 2017, have been released by Microsoft and the community for educational purposes and proof-of-concept experiments (Lim and Mafas, 2020). The

Adventure Works database suite includes two distinct Microsoft SQL Server databases:

The first is an OLTP (Online Transaction Processing) database, designed with a comprehensive structure and rich content to efficiently handle day-to-day transactional operations.

The second is a Data Warehouse, specifically developed to support OLAP (Online Analytical Processing) and data mining tasks, providing a powerful environment for complex analytical queries.

To build the Data Mart, we utilized the Python programming language to perform exploratory data analysis on selected tables. The data was extracted from the AdventureWorks2019 database, focusing on closely related subsystems: Purchasing, Production, and Human Resources. After extraction, the data tables were converted into individual CSV files. The dataset used to construct the Purchasing Data Mart covers the period from 2011 to 2014.

3.6.5 Data analysis

In the development of a Business Intelligence (BI) system for purchasing management, data analysis serves as a **foundational c**omponent for transforming raw operational data into actionable insights. This section presents the data analysis phase carried out on the AdventureWorks dataset to support the design of data models, KPI definitions, and decision-support dashboards.The focus of this analysis is on descriptive analytics, particularly exploratory data analysis (EDA). This method helps ensure the integrity of the data warehouse foundation while also guiding the development of relevant performance indicators.By examining procurement-related tables, this analysis enables a comprehensive understanding of purchasing operations.

HumanResources.Employee

The HumanResources.Employee table contains detailed information about staff members involved in purchasing operations. This dataset includes 290 records and 9

attributes, and was analyzed to understand workforce characteristics and identify data anomalies.

Missing Data: OrganizationLevel has 0.34% missing values (1 record), all others are complete.

Outliers: 6 records flagged as potential outliers in OrganizationLevel using the IQR method.

Categorical Variables Overview

Variable	Count	Unique Values	Most Frequent Value	Frequency
JobTitle	290	67	Production Technician - WC40	26
MaritalStatus	290	2	M (Married)	146
Gender	290	2	M (Male)	206
HireDate	290	164	2011-05-31	9
	1,206	Diaz	211	96.10

Table 3.6.5.1: HumanResources.Employee Categorical Variables summary

Job Title Diversity: 67 different titles suggest a wide range of employee roles; however, warehouse-related positions like *Production Technician* dominate.
Gender Distribution: Male employees represent over 70%, possibly reflecting operational workforce trends in logistics/warehouse settings.

Person.Person

To further understand the structure and characteristics of the customer and contact data in the AdventureWorks database, descriptive statistics were conducted on key fields in the Person.Person table. This helps assess the distribution and variability of categorical attributes that may influence segmentation or personalization strategies.The Person.Person table contains 19,972 records and 8 columns, providing

core information about individuals involved in business transactions, including employees, vendors, and customers.

High missing rates were found in the following fields:

- Title: 94.95%
- MiddleName: 42.55%
- Suffix: 99.73%

These columns are likely optional personal attributes and may not be critical for analytical processes.

Production.Product

The Production.Product table serves as a central reference for all items managed in the inventory system, containing 290 records across 23 attributes.

Missing Data: Several fields contain significant proportions of missing values, particularly: Size, Style, ProductModelID, and DiscontinuedDate have **≥70% missing values**.This indicates either legacy records or products not actively maintained or manufactured.

StandardCost & ListPrice: Both distributions are highly right-skewed, with many products priced at or near zero, and a few high-cost items causing long tails

Production.ProductInventory

The ProductInventory table contains 1,069 records across 5 columns, representing inventory levels of products at different storage locations in the warehouse.

	Field	Data Type	Missing Values	Missing (%)
0	ProductID	int64	0	0.00
1	LocationID	int64	0	0.00
2	Shelf	object	290	27.13
3	Bin	int64	0	0.00
4	Quantity	int64	0	0.00
5	rowguid	object	0	0.00
6	ModifiedDate	object	0	0.00

Figure 3.6.5.1: Production.ProductInventory data information

Missing data is found in the Shelf column: 27.13%.

This may indicate unspecified or virtual locations, which could affect location-based stock analysis.

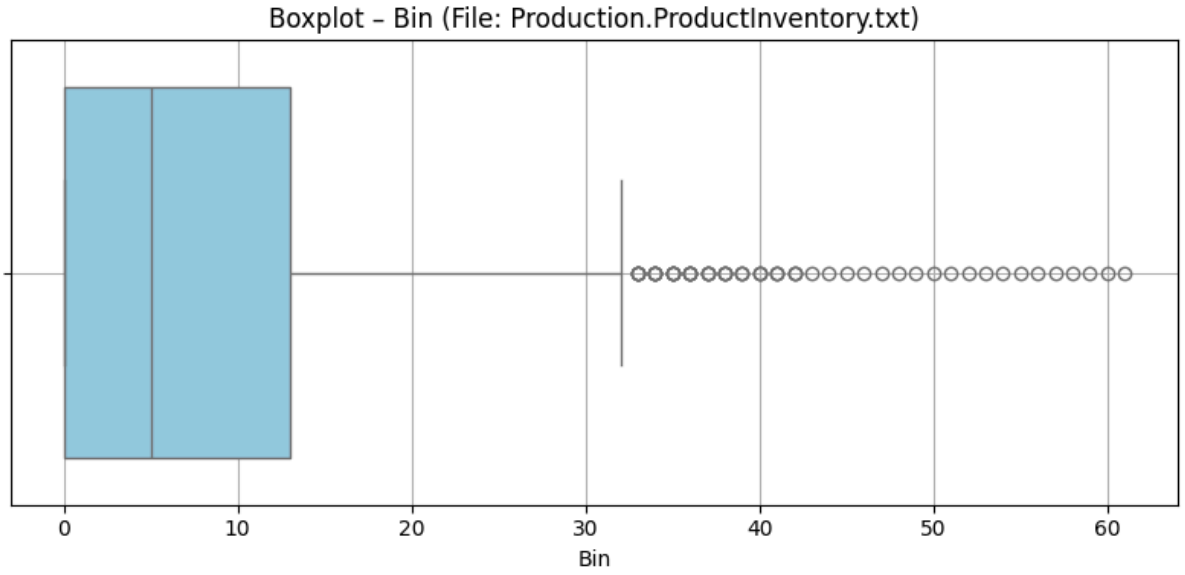


Figure 3.6.5.2: Bin boxplot

The Bin variable shows high skewness and kurtosis, indicating a long tail with higher bin values. Outlier review is recommended for stock misplacement or error.

Production.Location

The Production.Location table includes 14 records and 4 columns, representing physical storage or production areas within the manufacturing environment.

No missing values were found.

All records have complete and usable data, supporting clean integration into the warehouse location dimension.

Production.ProductSubCategory

The Production.ProductSubCategory table includes 37 records across 3 attributes, defining the intermediate product classification that links individual products to broader categories.

	Field	Data Type	Missing Values	Missing (%)
0	ProductSubcategoryID	int64	0	0.0
1	ProductCategoryID	int64	0	0.0
2	Name	object	0	0.0
3	rowguid	object	0	0.0
4	ModifiedDate	object	0	0.0

Figure 3.6.5.3: Production.ProductCategory data information

No missing values were found in the dataset, indicating clean categorical relationships.

Each Name value is unique, confirming that subcategories are distinct and properly defined.

Production.ProductCategory

The Production.ProductCategory table contains a categorical classification of all product groups available in the system. It includes 4 records and 2 columns, providing a hierarchical foundation for organizing inventory items.

✅ Số dòng: 1, Số cột: 4

📋 Bảng tổng hợp thông tin biến:

	Field	Data Type	Missing Values	Missing (%)
0	SystemInformationID	int64	0	0.0
1	Database Version	object	0	0.0
2	VersionDate	object	0	0.0
3	ModifiedDate	object	0	0.0

Figure 3.6.5.4: Production.ProductCategory data information

Variable	Count	Mean	Std Dev	Min	25%	Median	75%	Max	Skewness	Kurtosis	IQR
ProductCategory	4	2.5	1.29	1	1.75	2.5	3.25	4	0.0	-1.2	1.5

ID											

Table 3.6.5.2: Production.ProductCategory numerical summary

No outliers were detected using the IQR method due to the small number of categories.

Purchasing. ProductVendor

The ProductVendor dataset contains 460 rows and 11 columns. While most fields are complete, the OnOrderQty column has a high proportion of missing values—approximately 66.3%—which may indicate vendors with no current orders or incomplete records.

	Field	Data Type	Missing Values	Missing (%)
0	ProductID	int64	0	0.0
1	BusinessEntityID	int64	0	0.0
2	AverageLeadTime	int64	0	0.0
3	StandardPrice	float64	0	0.0
4	LastReceiptCost	float64	0	0.0
5	LastReceiptDate	object	0	0.0
6	MinOrderQty	int64	0	0.0
7	MaxOrderQty	int64	0	0.0
8	OnOrderQty	float64	305	66.3
9	UnitMeasureCode	object	0	0.0
10	ModifiedDate	object	0	0.0

Figure 3.6.5.5: Purchasing. ProductVendor data information

Additionally, several numerical fields, such as AverageLeadTime, StandardPrice, and LastReceiptCost, contain significant outliers, suggesting the presence of atypical values that may require further validation or transformation before analysis.

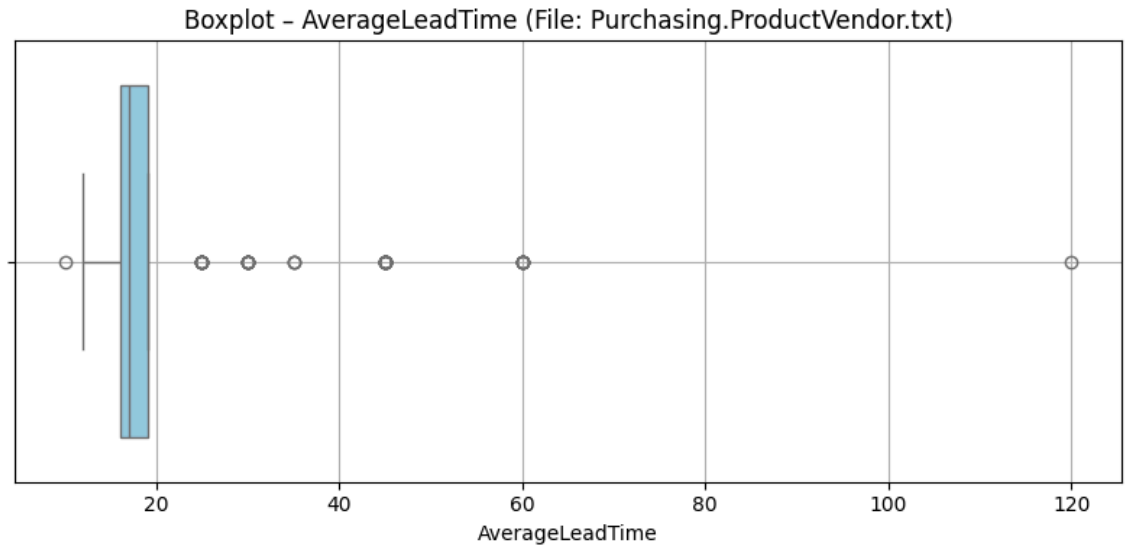


Figure 3.6.5.6: AverageLeadTime boxplot

49 outliers in 'AverageLeadTime'

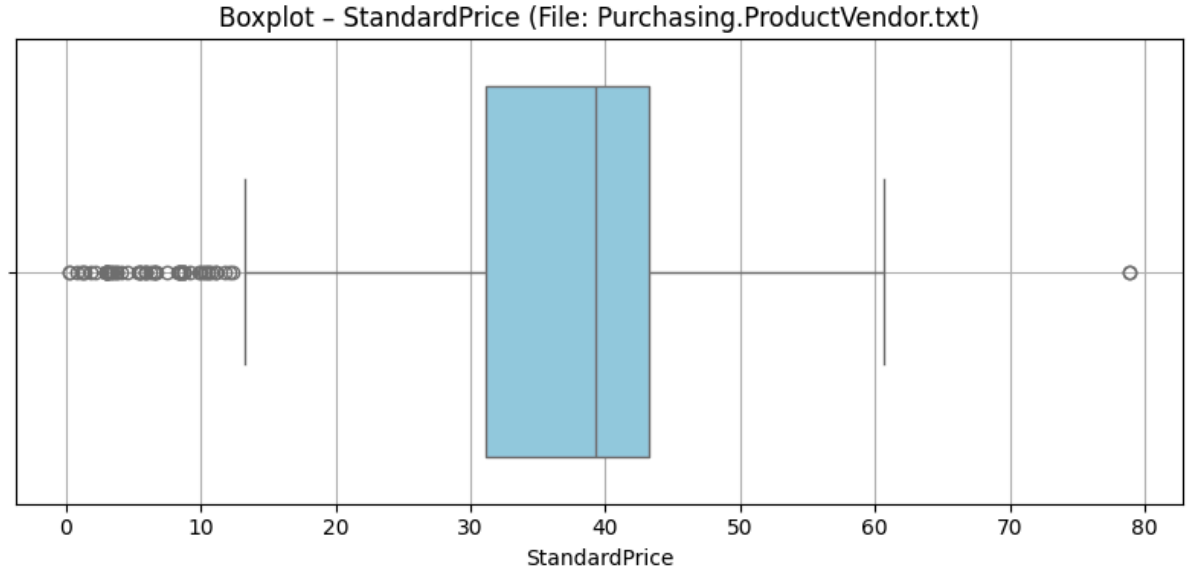


Figure 3.6.5.7: Standard price boxplot

60 outliers in 'StandardPrice'

Purchasing.ShipMethod

The ShipMethod dataset includes 5 records and 6 fields, with no missing values across any column. All fields appear structurally complete, covering essential attributes such as ShipBase, ShipRate, and method names.

	Field	Data Type	Missing Values	Missing (%)
0	ShipMethodID	int64	0	0.0
1	Name	object	0	0.0
2	ShipBase	float64	0	0.0
3	ShipRate	float64	0	0.0
4	rowguid	object	0	0.0
5	ModifiedDate	object	0	0.0

Figure 3.6.5.8: Purchasing.ShipMethod data information

Due to the small number of entries, the dataset is likely categorical in nature and primarily used for referencing shipping methods rather than detailed analysis. No outliers were detected, and data integrity appears high.

Purchasing.PurchaseOrderHeader

The PurchaseOrderHeader dataset comprises 4,012 rows and 13 fields, all of which are complete with no missing values.

	Field	Data Type	Missing Values	Missing (%)
0	PurchaseOrderID	int64	0	0.0
1	RevisionNumber	int64	0	0.0
2	Status	int64	0	0.0
3	EmployeeID	int64	0	0.0
4	VendorID	int64	0	0.0
5	ShipMethodID	int64	0	0.0
6	OrderDate	object	0	0.0
7	ShipDate	object	0	0.0
8	SubTotal	float64	0	0.0
9	TaxAmt	float64	0	0.0
10	Freight	float64	0	0.0
11	TotalDue	float64	0	0.0
12	ModifiedDate	object	0	0.0

Figure 3.6.5.9: Purchasing.PurchaseOrderHeader data information

This dataset records essential purchasing transaction metadata, including order dates, vendor IDs, employee IDs, shipping methods, and financial totals. Outlier detection reveals notable anomalies in financial-related columns such as SubTotal, TaxAmt, Freight, and TotalDue, suggesting a subset of unusually large or small purchase orders. Additional outliers in RevisionNumber and Status fields may point to uncommon update patterns or infrequent status codes that warrant closer inspection during data modeling or KPI calculation.

Purchasing.PurchaseOrderDetail

The PurchaseOrderDetail dataset consists of 8,845 records and 11 attributes, with no missing values.

	Field	Data Type	Missing Values	Missing (%)
0	PurchaseOrderID	int64	0	0.0
1	PurchaseOrderDetailID	int64	0	0.0
2	DueDate	object	0	0.0
3	OrderQty	int64	0	0.0
4	ProductID	int64	0	0.0
5	UnitPrice	float64	0	0.0
6	LineTotal	float64	0	0.0
7	ReceivedQty	float64	0	0.0
8	RejectedQty	float64	0	0.0
9	StockedQty	float64	0	0.0
10	ModifiedDate	object	0	0.0

Figure 3.6.5.10: Purchasing.PurchaseOrderDetail data information

This file provides detailed line-item data for each purchase order, including product IDs, quantities, unit prices, and fulfillment status.

Outlier analysis revealed several anomalies—particularly in ProductID (2,095 cases)

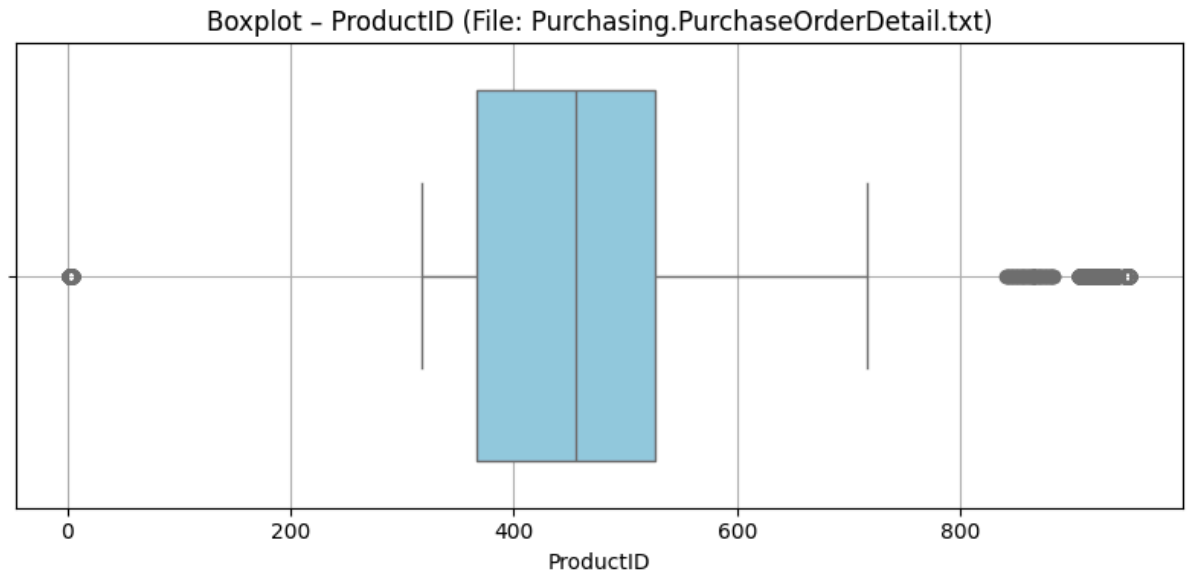


Figure 3.6.5.11: Product ID blotbox

RejectedQty, and monetary fields like UnitPrice and LineTotal—which may indicate atypical purchasing patterns, exceptional products, or errors in data entry. These outliers should be reviewed carefully, especially when analyzing procurement trends or calculating key metrics such as order fulfillment rate, total spend, or product-level performance.

Purchasing.ProductVendor

The dataset contains 460 records and 11 fields, with most columns exhibiting no missing values. However, the OnOrderQty field shows a significant 66.3% missing rate, indicating a potential issue in order tracking or vendor reporting.

	Field	Data Type	Missing Values	Missing (%)
0	ProductID	int64	0	0.0
1	BusinessEntityID	int64	0	0.0
2	AverageLeadTime	int64	0	0.0
3	StandardPrice	float64	0	0.0
4	LastReceiptCost	float64	0	0.0
5	LastReceiptDate	object	0	0.0
6	MinOrderQty	int64	0	0.0
7	MaxOrderQty	int64	0	0.0
8	OnOrderQty	float64	305	66.3
9	UnitMeasureCode	object	0	0.0
10	ModifiedDate	object	0	0.0

Figure 3.6.5.12: Purchasing.ProductVendor data information

Outlier analysis revealed unusual values across multiple numerical fields such as AverageLeadTime, StandardPrice, and ProductID, which may suggest data entry inconsistencies or genuine variability in supplier performance. These outliers and missing values warrant further investigation before proceeding to analytical modeling or integration into dashboards.

3.7. Design data warehouse

3.7.1 Bus matrix

The bus matrix for purchasing department at AdventureWorks outlines the core business processes and their connections to various dimension tables. It supports efficient analysis by integrating data warehouse components through standardized, shared dimensions. Our team developed this matrix to visualize the relationships between dimension tables, fact tables, and operational activities. By adopting the data warehouse bus architecture, we ensure consistent use of common dimensions across multiple processes, thereby improving both the accuracy and efficiency of data analysis.

Dimensions	Business Processes				
	Delivery Analysis	Purchase Order Management	Inventory management	Vendor Performance	Employee Performance
Dim Time	X	X	X	X	X
Dim Product	X	X	X	X	X

Dim Employee		X			X
Dim ProductInventory			X		
Dim Shipping	X				
Dim Vendor				X	

Table 3.7.1.1: Bus matrix

The bus matrix presented above demonstrates the connections between each business process and its related dimension tables, enabling thorough data analysis and informed decision-making within AdventureWorks' Purchasing Department. The following sections provide an overview of the key business processes relevant to the purchasing function as outlined in the matrix.

Delivery Analysis uses Dim Time, Dim Product, and Dim Shipping to evaluate delivery performance over time, by product, and by shipping method or carrier.

Purchase Order Management involves Dim Time, Dim Product, and Dim Employee to track order creation, product demand, and employee involvement in the purchasing process.

Inventory Management relies on Dim Time, Dim Product, and Dim Product Inventory to monitor stock levels, product availability, and inventory location or type over time.

Vendor Performance uses Dim Time, Dim Product, and Dim Vendor to assess supplier reliability and product quality across different time periods.

Employee Performance includes Dim Time, Dim Product, and Dim Employee to analyze individual staff contributions and performance trends related to procurement or logistics

3.7.2. Master data and transaction data

Master data refers to the fundamental and unchanging data entities that are the core of an organization's data infrastructure. It serves as the reference data for various operations and processes within the organization.

Master data is essential for ensuring consistency and accuracy across an organization's various data systems. It is used to populate dimension tables in the data warehouse, which are crucial for organizing and categorizing data in a way that supports complex analysis and reporting.

Data	Description
Product	Contains detailed information about the company's products, including attributes such as name, category, and cost.
Vendor	Stores key information about suppliers, including vendor name, contact details, account status, and preferred purchasing methods.

Table 3.7.2.1: Master data

Transactional data refers to information generated as a result of specific, individual business transactions or events.

These transactions can be a wide range of activities, such as sales, purchases, inventory movements, financial exchanges, or any event that involves the exchange or modification of data. Transactional data is inherently time-sensitive, recording the "who," "what," "when," and "where" of each transaction.

Transactional data is utilized to construct Fact tables within the Data Warehouse, which aggregate and summarize transactional information for analytical purposes.

Data	Description
Date	Comprises a list of dates used to track when sales or production events occur.
Purchasing.PurchaseOrderDetail	Records transaction data for each purchase order line, including product, quantity, unit price, and order and delivery dates.

Table 3.7.2.2: Transactional data

In essence, master data serves as the stable and consistent foundation for business processes within a data warehouse, while transactional data captures the day-to-day dynamics and operational details of the business. Both are essential pillars in building a reliable data warehouse architecture that enables thorough analysis and informed decision-making

3.8. Data model

3.8.1. Star schema structure

To support comprehensive analysis in inventory management at AdventureWorks, we adopted a Star Schema model for the data purchasing. This schema places a central fact table at the core, surrounded by dimension tables that provide context for the data. The simplicity and efficiency of this model enable fast querying and intuitive data exploration, particularly in inventory, purchasing and human resource.

The star schema leverages conformed dimensions across multiple business processes such as stock tracking, purchasing management , and vendor, shipping performance . This design facilitates consistency, data reuse, and streamlined ETL pipelines.

Star Schema Relationships

No	Relationship	Type	Description
1	DimProduct – FactPurchaseOrder	1 – n	Each product may appear in multiple Purchase orders.
2	DimEmployee – FactPurchaseOrder	1 – n	Each purchase order is taken over by an employee as a buyer.
3	DimTime – FactPurchaseOrder	1 – n	Time dimension allows analysis by date, week, month, quarter, and year.

4	DimVendor – FactPurchaseOrder	1 – n	One purchase order has a vendor, a vendor can supply for some purchase order.
5	DimProductInventory– FactPurchaseOrder	1 – n	An inventory item can have one or more records in the FactPurchaseOrders table, and each record in the FactPurchaseOrders table refers to only one inventory item.
6	DimShipmethod – FactPurchaseOrder	1 – n	One purchase order must be use one ship method but one ship method can be applied for some different purchase order.
7	DimProductvendor– FactPurchaseOrder	1-n	For a purchase order, there can be multiple products included. For each product in the order, there may be a separate evaluation for the vendor.

Table 3.8.1.1: Star schema relationship

3.8.2. Fact and dimension tables

Data Warehouse table descriptions

Table Name	Description
FactPurchaseOrder	Central fact table that stores granular records of all purchase orders. Contains metadata related purchase

	order. This also contain employee, inventory, vendor, product ship data
DimProduct	Contains product-related attributes including product name, category, subcategory, product number, safety stock level, and reorder point. SCD Type 2 is applied to track changes over time.
DimEmployee	Contain information about employees
DimTime	A classic date dimension used to analyze inventory metrics across days, weeks, months, quarters, and years.
DimVendor	Contain information about vendor.
DimInventory	This has information about inventory ò the product and the location ò this product.
DimShipMethod	Contain the information of types the ship method.
DimProductVendor	Contains information recording evaluations as well as the history of a vendor and the specific products they have supplied.

Table 3.8.2.1: Data Warehouse table descriptions

Data Warehouse Table Descriptions – Inventory Data Mart

1. DimEmployee

AdventureWorks Database	Columns	Table	Columns	Data type	SCD Type
		DimEmployee	EmployeeKey(PK)	int	0
Person.person	BusinessEntityID		EmployeeID	int	0
	FirstName		FirstName	nvarchar	2
	MiddleName		MiddleName	nvarchar	2
	LastName		LastName	nvarchar	2
HumanResources.Employee	JopTitle		JopTitle	nvarchar	2
	CurrentFlag		CurrentFlag	bit	2
	SalaryFlag		SalaryFlag	bit	2
			StarTime	datetime	
			EndTime	datetime	

Table 3.8.2.2: DimEmployee

2. DimProduct

AdventureWorks Database	Columns	Table	Columns	Data type	SCD Type
		DimProduct	ProductKey(PK)	int	0
Production.Product	ProductID		ProductID	int	0
	Name		ProductName	nvarchar(50)	2
	Color		Color	nvarchar(15)	2
	Size		Size	nvarchar(5)	2
	Weight		Weight	decimal	2
	SafetyStockLevel		SafetyStockLevel	int	2
	ProductLine		ProductLine	nchar	
	MakeFlag		MakeFlag	bit	2
	FinishedGoodFlag		FinishedGoodFlag	bit	2
Production.ProductCategory	Name		ProductCategoryName	nvarchar	2
Production.ProductSubCategory	Name		ProductSubCategoryName	nvarchar	2
			StartDate	datetime	
			EndDate	datetime	

Table 3.8.2.3: DimProduct

3. DimVendor

AdventureWorks Database	Columns	Table	Columns	Data type	SCD Type
		DimVendor	VendorKey (PK)	int	0
Purchasing.Vendor	BusinessEntityID		VendorID	int	0
	CreditRating		CreditRating	int	2
	Name		Name	nvarchar	2
	PreferredVendorStatus		PreferredVendorStatus	bit	2
	ActiveFlag		ActiveFlag	bit	2
Purchasing.vVendorWithAddresses	City		City	nvarchar	2
	StateProvinceName		StateProvinceName	nvarchar	2
	CountryRegionName		CountryRegionName	nvarchar	2
			StartDate	datetime	
			EndDate	datetime	

Table 3.8.2.4: DimVendor

4. DimTime

AdventureWorks Database	Columns	Table	Columns	Data type	SCD Type
			DateKey (PK)	datetime	0
			DateFull	date	0
			TheDay	int	0
			TheMonth	int	0
			TheQuarter	int	0
			TheYear	int	0

Table 3.8.2.5: DimTime

5. DimInventory

AdventureWorks Database	Columns	Table	Columns	Data type	SCD Type
		DimInventory	InventoryKey(PK)	int	0
Sales.SalesOrderHeader	ProductID		ProductID	int	2

Sales.SalesOrderDetail	LocationID		LocationID	int	0
	Quantity		Quantity	int	1
	Shelf		Shelf	nvarchar	2
	Bin		Bin	int	2
			StartDate	datetime	
			EndDate	datetime	

Table 3.8.2.6: DimInventory

6. DimShipMethod

AdventureWorks Database	**Columns**	**Table**	**Columns**	**Data type**	**SCD Type**
		DimShipMethod	ShipMethodKey(PK)	int	0
Purchasing.ShipMethod	ShipMethodID		ShipMethodID	int	0
	Name		Name	int	2
	ShipBase		ShipBase	int	2

	ShipRate		ShipRate	nvarchar	2
			StartDate	datetime	
			EndDate	datetime	

Table 3.8.2.7: DimShipMethod

7. DimProductVendor

AdventureWorks Database	Columns	Table	Columns	Data type	SCD Type
		DimProductVendor	ProductVendorKey (PK)	int	0
Purchasing.ProductVendor	ProductID		ProductID	int	0
	BusinessEntityID		VendorID	int	0
	MinOrderQty		MinOrderQty	int	2
	LastReceiptDate		LastReceiptDate	datetime	2
	LastReceiptCost		LastReceiptCost	money	2
	MaxOrderQty		MaxOrderQty	int	2

	AverageLeadTime		AverageLeadTime	int	2
	StandardPrice		StandardPrice	money	2
			StartDate	datetime	
			EndDate	datetime	

Table 3.8.2.8: DimProductVendor

8. FactPurchaseOrder

AdventureWorks Database	Columns	Table	Columns	Data type	SCD Type
DímhipMethod	ShipMethodKey	FactPurchaseOrder	ShipMethodKey	int	0
DimInventory	InventoryKey		InventoryKey	int	0
Purchasing.PurchaseOrderHeader	OrderDate		OrderDate	datetime	0
DimVendor	VendorKey		VendorKey	int	0

DimEmployee	EmployeeKey		EmployeeKey	int	0
DimProduct	ProductKey		ProductKey	int	0
Purchasing.PurchaseOrderHeader	Status		PurchaseOrderStatus	int	0
	Shipdate		Shipdate	datetime	0
Purchasing.PurchaseOrderDetail	PurchaseOrderID		PurchaseOrderID	int	0
	OrderQty		OrderQty	int	0
	Linetotal		Linetotal	numeric	0
	ReceivedQty		ReceivedQty	int	0
	RejectedQty		RejectedQty	int	0
	StockedQty		StockedQty	int	0
	UnitPrice		UnitPrice	money	0

Table 3.8.2.9: FactPurchaseOrder

3.9. Data warehouse building

After selecting the tables to use in the dataset and filtering the necessary columns, the team decided to build a data warehouse as shown below. The team used

T-SQL language to create dimensions and fact tables which are further explained in Appendix 1.

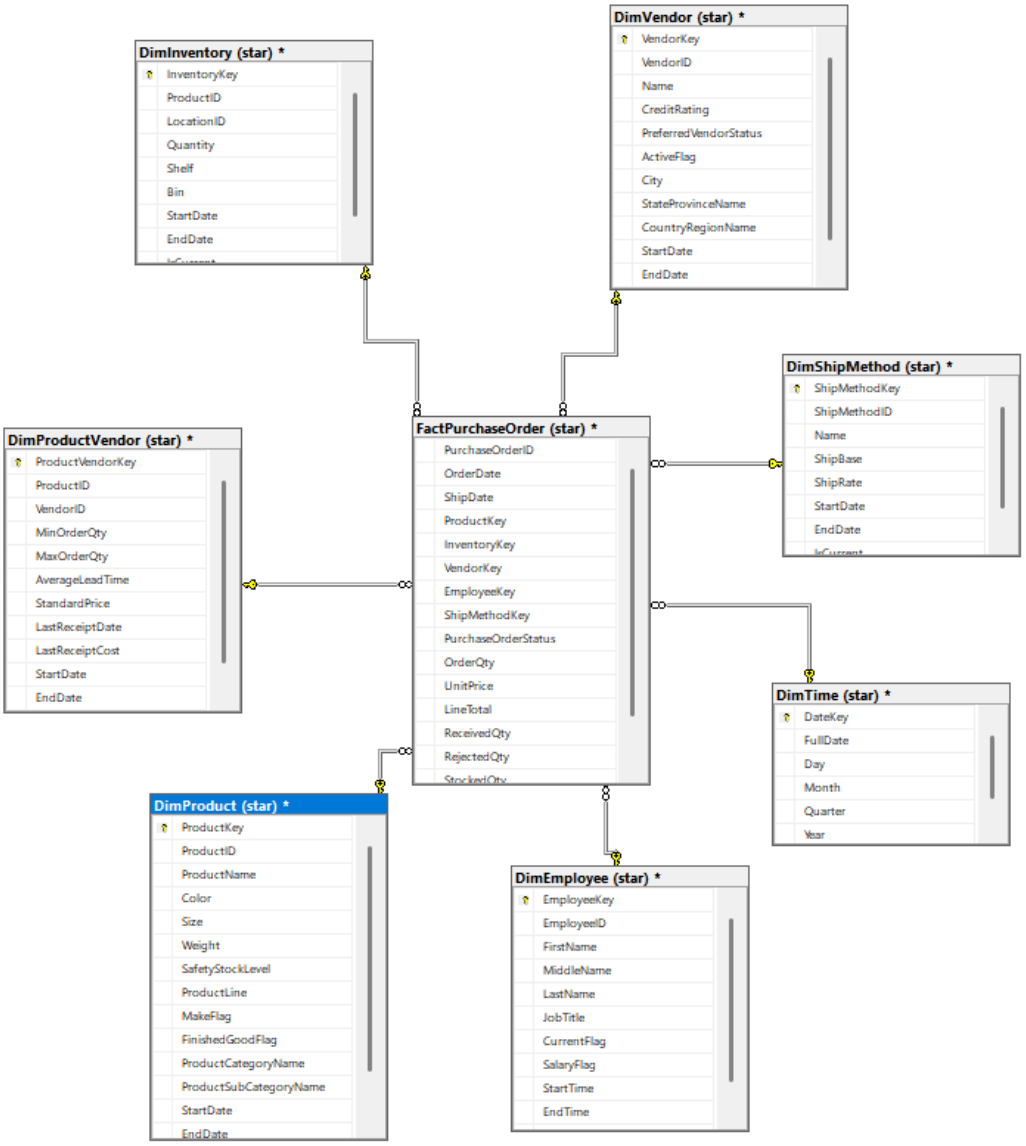


Figure 3.9.1: Data model

3.10. ETL process

3.10.1 Building a data integration framework

During the development of the DSS-BI system for the Purchasing subsystem, designing an effective data integration framework is a fundamental requirement to ensure that the input data is processed accurately, completely, and consistently before analysis. The chosen integration method is the ETL (Extract – Transform – Load) process, which plays the role of aggregating, processing, and loading data from

various sources into the data warehouse to support decision-making analysis in the DSS-BI system.

Extract:

- Data source: Extracting data from essential tables within the Purchasing subsystem, such as Purchasing.Vendor, Purchasing.ProductVendor, HumanResources.Employee, Person.Person, Production.Product, Production.ProductInventory, Production.ProductCategory, ProductSubCategory, Production.Location, Purchasing.ShipMethod, PurchaseOrderHeader, and PurchaseOrderDetails.

- Extraction criteria: Extracting crucial information including order specifics, product data, supplier details, and ordered items.

- Output format: The extracted data will be structured in table format for subsequent processing in SQL.

Transform:

- Data normalization: Standardizing data from initial formats to consistent formats within the Data Warehouse, ensuring compatibility.

- Handling historical data: Performing transformations to manage historical purchase orders and data changes, including updating historical information within the Data Warehouse.

Load:

- Loading data into data warehouse: Loading transformed data into the Data Warehouse using ETL processes in SSIS and tools.

- Data loading process control: Conducting integrity checks and managing errors during the data loading process, ensuring the accuracy and completeness of data loaded into the Data Warehouse.

- Activity logging: Logging the data loading process activities to monitor and assess the performance of the ETL process.

The Role of ETL in the DSS-BI System for Purchasing

The implementation of the ETL process brings several specific benefits to the DSS-BI system in the purchasing domain:

- Integrates data from multiple fragmented sources, creating a standardized and unified data source for analysis.
- Processes large volumes of data with complex relationships between purchase orders, products, and suppliers.
- Tracks and stores historical data, supporting trend analysis and performance evaluation over time.
- Automates the entire process, minimizing manual errors and enhancing the reliability and performance of the system.

3.10.2. End-to-end integration model

In DSS-BI systems, the ETL process plays a central role in integrating data from source systems into the data warehouse in a comprehensive and accurate manner. The end-to-end integration model illustrates the complete data flow — from initial extraction to the final loading of processed data into the analytical environment.

The process begins with extracting data from the OLTP (Online Transaction Processing) system, focusing on data fields relevant to the purchasing process, such as purchase orders, suppliers, products, and employees. Once extracted, the data is checked for existence in the data warehouse to determine the appropriate storage and transformation strategy.

- In cases where the data does not yet exist (e.g., due to a new ID or newly added records), the system loads the data directly into the warehouse.
- When duplicate or existing records are detected, the system handles them using the Slowly Changing Dimension (SCD) technique:
    - For SCD Type 1, the existing record is overwritten with the new data.
    - For SCD Type 2, the system updates the EndDate of the old record and inserts a new record with the updated information, thus preserving historical changes.

This duplicate-checking and transformation logic ensures that the data warehouse accurately reflects both current and historical information. Implementing an end-to-end integration model in the BI system significantly improves data

processing efficiency, maintains consistency, and supports more effective decision-making in the purchasing domain.

3.10.3. Practical execution of SSIS process

This part provides an overview of the ETL process for 7 tables: DimEmployee, DimVendor, DimProduct, DimInventory, DimTime, DimProductVendor and DimShipMethod. In our operational framework, we utilize the Slowly Changing Dimension (SCD) methodology to handle changing data across all these dimension tables. The specific SCD type applied depends on the inherent characteristics of each table's attributes, which will be discussed in detail in later sections. It's important to note that our data loading method follows a full load approach.

DimEmployee

The illustration shows how data from the source system is processed during the ETL procedure through three scenarios: new data, SCD Type 1, and SCD Type 2, as applied in the DimEmployee table. The process begins with extracting data and comparing it with existing records in the data warehouse to determine the appropriate handling strategy.

If the data is new, the system inserts it directly into the DimEmployee table.
In the case of changes, the system applies the SCD method:

- For SCD Type 1, the current record is updated directly.
- For SCD Type 2, a new record is created, while the old record is marked as no longer valid to preserve historical information.

In addition, certain attributes that rarely or never change are managed using SCD Type 0, meaning they remain unchanged and are not updated.

This mechanism allows the DSS-BI system to maintain a complete history of employee changes in the DimEmployee table, ensuring data accuracy and completeness for time-based analysis.

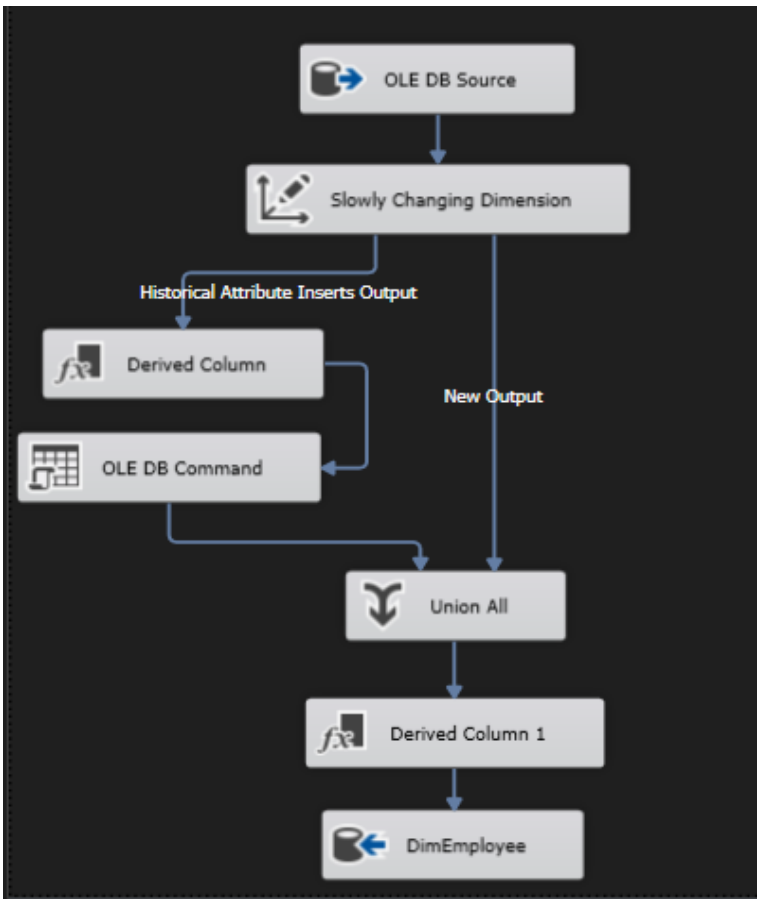


Figure 3.10.3.1: DimEmloyee ETL process

After classification, the `DimEmployee` table is updated directly. Outdated records are marked as no longer valid, and new records are added to reflect the updated information. This process ensures that the data remains accurate, complete, and capable of maintaining historical traceability.

DimInventory

During the ETL process for the DimInventory table, data is extracted from the source system and compared with existing records in the data warehouse. Based on the comparison results, the system determines whether a new record should be inserted or an existing one should be updated using the appropriate method.

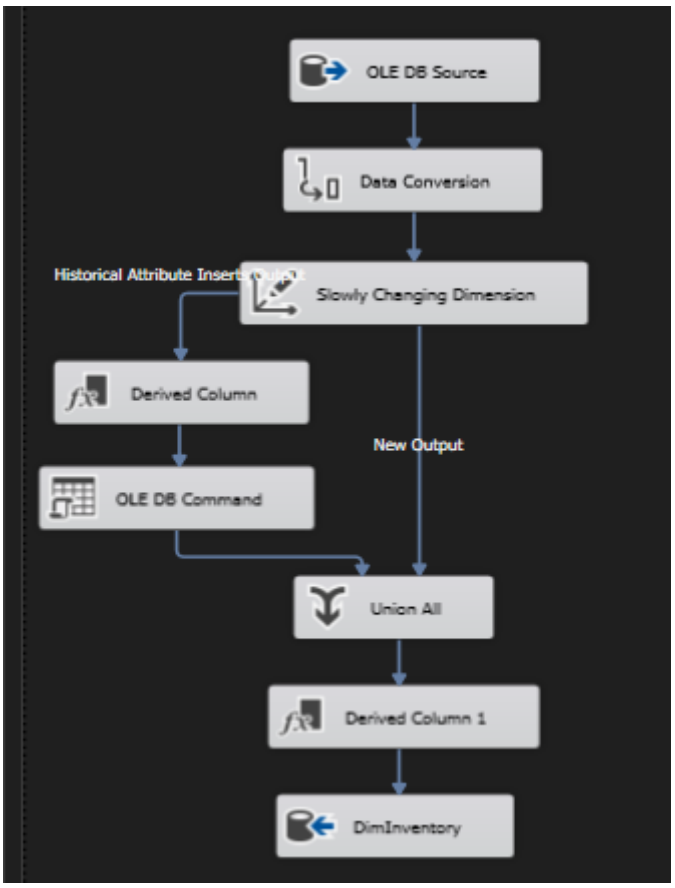


Figure 3.10.3.2: DimInventory ETL process

For `DimInventory`, the system applies a combination of different SCD types to accurately reflect inventory status. Minor changes are updated directly, while significant changes are recorded by creating new records and marking the old ones as no longer valid. This approach ensures that inventory data always reflects the actual situation at any given time and supports effective inventory analysis for planning and decision-making in warehouse management.

DimProduct

The illustration describes the data processing workflow for the `DimProduct` table, in which new records are inserted directly, while changes are mainly handled using SCD Type 2 to preserve historical data. Outdated records are marked as inactive, and new records reflect the updated information. This approach enables the system to maintain accurate product data and support time-based analysis effectively.

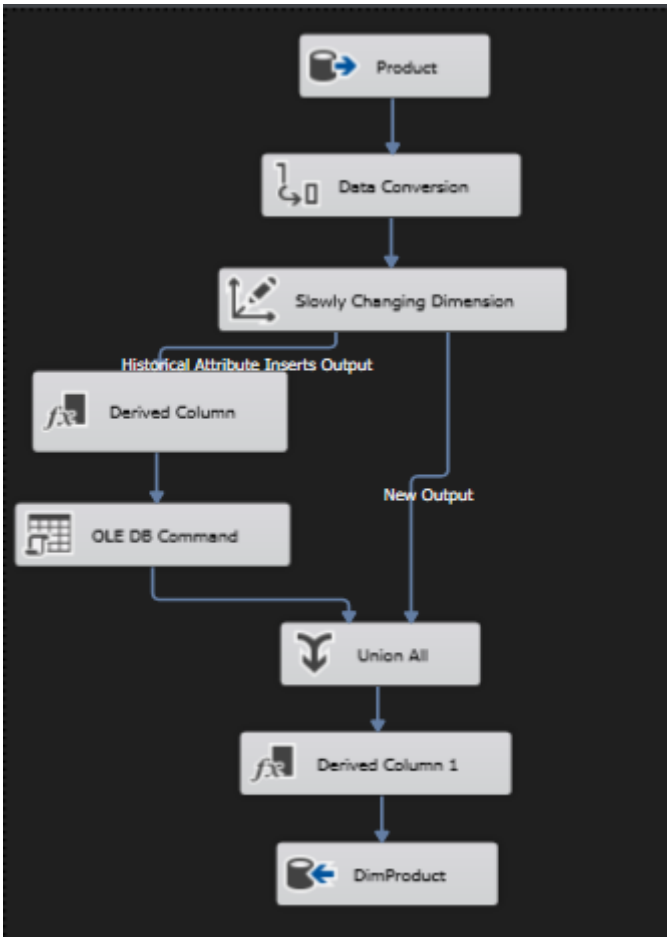


Figure 3.10.3.3: DimProduct ETL process

After data classification, the `DimProduct` table is updated directly. Records that are no longer valid are marked as expired, and new records are inserted to reflect the changes. This approach helps the system maintain accurate product data while ensuring the ability to track historical changes throughout the entire product lifecycle.

DimProductVendor

During the ETL process for the `DimProductVendor` table, data is extracted from the source system and compared with existing records in the data warehouse. The goal is to identify any changes in the relationship between products and vendors, then apply the appropriate processing strategy to ensure accuracy and up-to-date information.

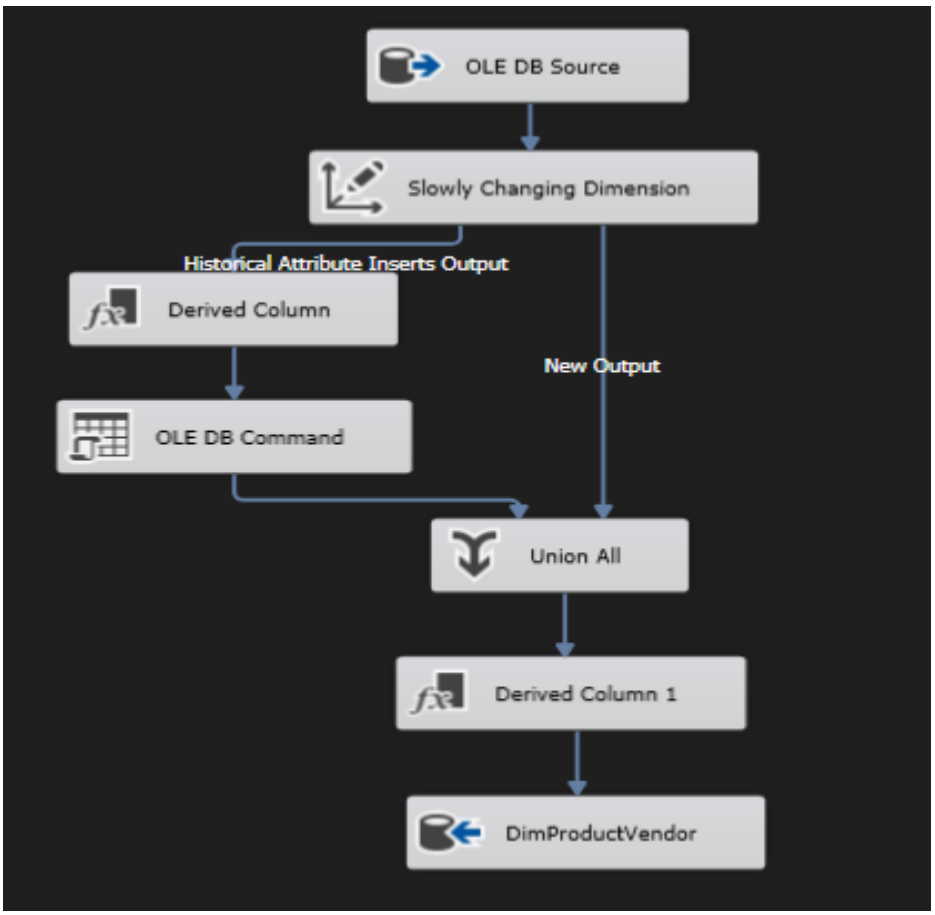


Figure 3.10.3.4: Dim ProductVendor ETL process

For the `DimProductVendor` table, changes such as the latest receipt cost (`LastReceiptCost`) or average lead time (`AverageLeadTime`) are handled using SCD Type 2 to retain historical data. When a change is detected, the current record is marked as expired, and a new record is inserted with the updated information. This approach enables the DSS-BI system to track fluctuations in purchasing relationships with vendors, supporting precise analysis of performance, cost, and lead time across different periods.

DimShipMethod

In the data integration process for the `DimShipMethod` table, data is retrieved from the source system and examined for changes against existing records in the data warehouse. Based on the comparison results, the system determines whether to treat

the record as entirely new or update an existing one, ensuring data accuracy and consistency.

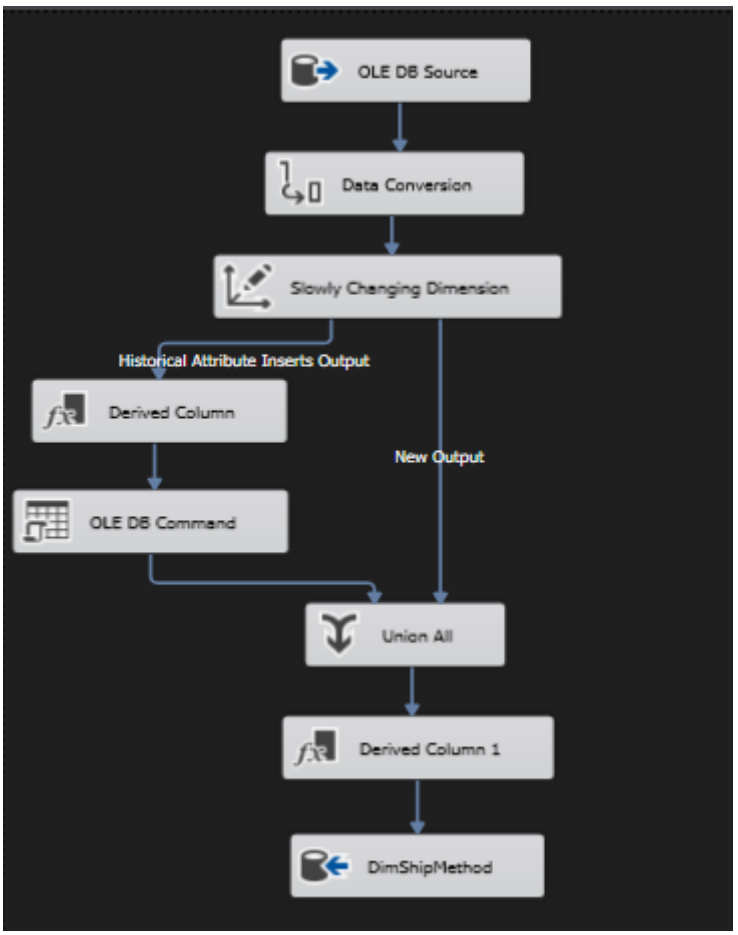


Figure 3.10.3.5: DimShipMethod ETL process

For the `DimShipMethod` table, the system prioritizes capturing changes using SCD Type 2 to maintain a complete history of shipping method variations. When a change occurs, the existing record is marked as expired, and a new record is inserted to reflect the current information. This enables detailed and accurate tracking of shipping costs, delivery performance, and policy changes over time, supporting comprehensive transportation analysis.

DimVendor

The illustration shows how data from the source system is processed during the ETL procedure for the `DimVendor` table. After extraction, the data is compared with existing records in the data warehouse to determine whether it is new or has

undergone changes. Depending on the case, the system applies the appropriate update method based on the defined SCD types.

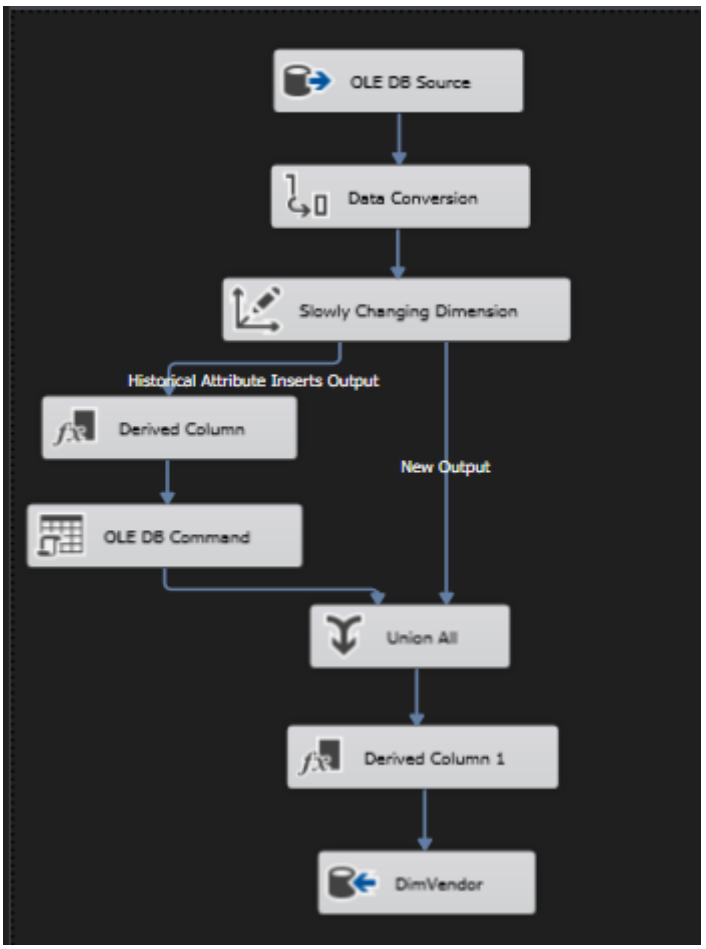


Figure 3.10.3.6: DimVendor ETL process

The illustration shows how data from the source system is processed during the ETL procedure for the `DimVendor` table. After extraction, the data is compared with existing records in the data warehouse to determine whether it is new or has undergone changes. Depending on the case, the system applies the appropriate update method based on the defined SCD types.

FactPurchaseOrder

In the data integration process, the FactPurchaseOrder table plays the role of recording purchasing transactions as they occur at specific points in time. Data is extracted from operational tables in the source system, then standardized and mapped

to the corresponding foreign keys from the dimension tables to ensure tight relationships between entities.

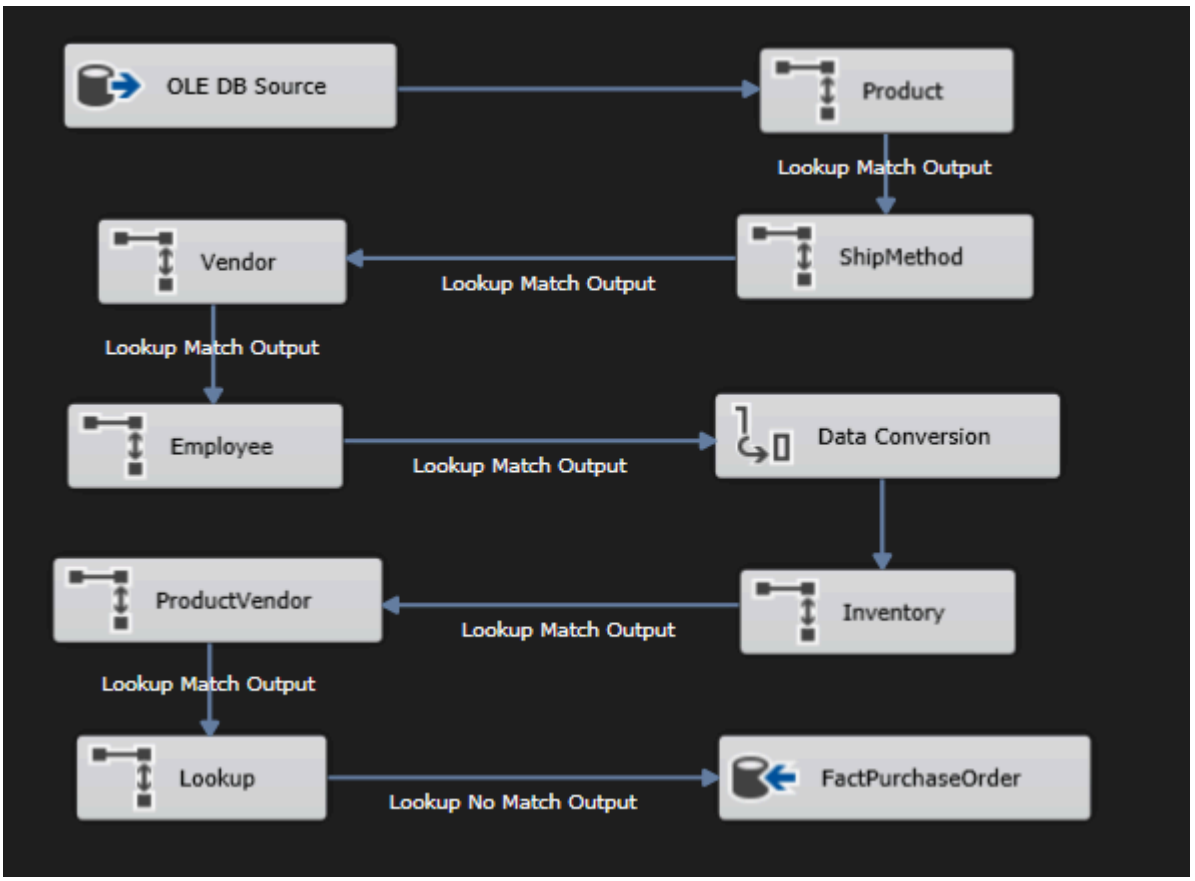


Figure 3.10.3.7: FactPurchaseOrder ETL process

Unlike dimension tables that store descriptive information, the FactPurchaseOrder table focuses on capturing actual events such as order quantity, unit price, line total, received quantity, and rejected quantity. The data is handled in a non-SCD model, with each row representing a single purchase transaction detail. By linking to dimensions such as product, vendor, employee, shipping method, and time, this fact table provides the quantitative foundation needed for analyzing purchasing costs, performance, and supply chain management within the DSS-BI system.

Once the keys have been retrieved from the dimension tables and the FactPurchaseOrders table has been populated with the necessary data, execute the master pipeline to initiate the dynamic ETL process. The master pipeline will manage the execution of child pipelines, coordinate each step of the data processing workflow, and automate the overall ETL operations to ensure accuracy and consistency.

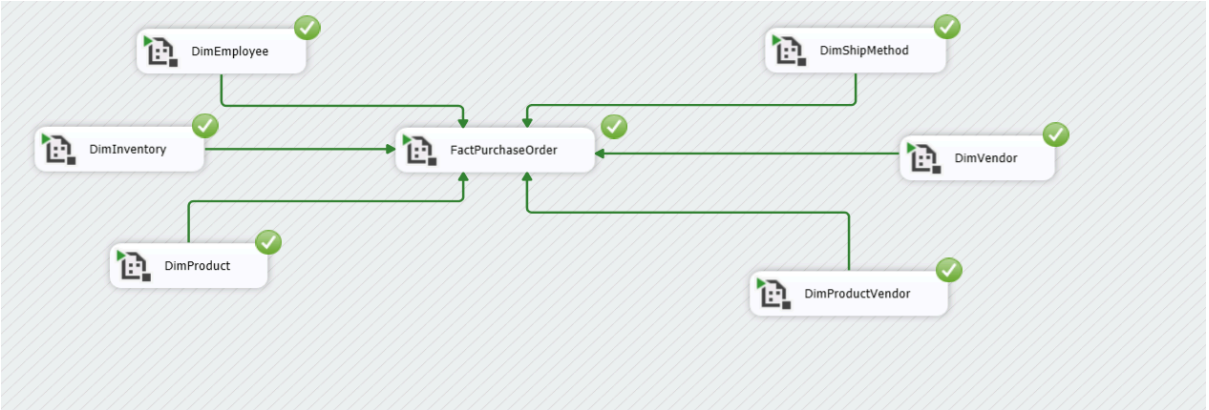


Figure 3.10.3.8: Master pipeline

After the ETL process, data is loaded into tables. The results are shown in the figures below.

	EmployeeKey	EmployeeID	FirstName	MiddleName	LastName	JobTitle	CurrentFlag	SalaryFlag	StartTime	EndTime	IsCurrent
1	1	205	Lori	A	Kane	Production Supervisor - WC45	1	0	2025-06-25 22:22:44.000	NULL	1
2	2	206	Stuart	V	Munson	Production Technician - WC45	1	0	2025-06-25 22:22:44.000	NULL	1
3	3	207	Greg	F	Alderson	Production Technician - WC45	1	0	2025-06-25 22:22:44.000	NULL	1
4	4	208	Scott	R	Gode	Production Technician - WC45	1	0	2025-06-25 22:22:44.000	NULL	1
5	5	209	Kathie	E	Flood	Production Technician - WC45	1	0	2025-06-25 22:22:44.000	NULL	1
6	6	210	Belinda	M	Newman	Production Technician - WC45	1	0	2025-06-25 22:22:44.000	NULL	1
7	7	211	Hazem	E	Abolrous	Quality Assurance Manager	1	1	2025-06-25 22:22:44.000	NULL	1
8	8	212	Peng	J	Wu	Quality Assurance Supervisor	1	1	2025-06-25 22:22:44.000	NULL	1
9	9	213	Sootha	T	Charncherngkha	Quality Assurance Technician	1	0	2025-06-25 22:22:44.000	NULL	1
10	10	214	Andreas	T	Berglund	Quality Assurance Technician	1	0	2025-06-25 22:22:44.000	NULL	1
11	11	215	Mark	L	Harrington	Quality Assurance Technician	1	0	2025-06-25 22:22:44.000	NULL	1
12	12	216	Sean	P	Alexander	Quality Assurance Technician	1	0	2025-06-25 22:22:44.000	NULL	1
13	13	217	Zainal	T	Arifin	Document Control Manager	1	0	2025-06-25 22:22:44.000	NULL	1
14	14	218	Tengiz	N	Kharatishvili	Control Specialist	1	0	2025-06-25 22:22:44.000	NULL	1
15	15	219	Sean	N	Chai	Document Control Assistant	1	0	2025-06-25 22:22:44.000	NULL	1
16	16	220	Karen	R	Berge	Document Control Assistant	1	0	2025-06-25 22:22:44.000	NULL	1

Figure 3.10.3.9: DimEmployee Result

	InventoryKey	ProductID	LocationID	Quantity	Shelf	Bin	StartDate	EndDate	IsCurrent
1	1	1	1	408	A	1	2025-06-25 22:44:55.000	NULL	1
2	2	1	6	324	B	5	2025-06-25 22:44:55.000	NULL	1
3	3	1	50	353	A	5	2025-06-25 22:44:55.000	NULL	1
4	4	2	1	427	A	2	2025-06-25 22:44:55.000	NULL	1
5	5	2	6	318	B	1	2025-06-25 22:44:55.000	NULL	1
6	6	2	50	364	A	6	2025-06-25 22:44:55.000	NULL	1
7	7	3	1	585	A	7	2025-06-25 22:44:55.000	NULL	1
8	8	3	6	443	B	9	2025-06-25 22:44:55.000	NULL	1
9	9	3	50	324	A	10	2025-06-25 22:44:55.000	NULL	1
10	10	4	1	512	A	6	2025-06-25 22:44:55.000	NULL	1
11	11	4	6	422	B	10	2025-06-25 22:44:55.000	NULL	1
12	12	4	50	388	A	11	2025-06-25 22:44:55.000	NULL	1
13	13	316	5	532	A	11	2025-06-25 22:44:55.000	NULL	1
14	14	316	10	388	B	1	2025-06-25 22:44:55.000	NULL	1
15	15	316	50	441	B	8	2025-06-25 22:44:55.000	NULL	1
16	16	317	1	283	C	1	2025-06-25 22:44:55.000	NULL	1

Figure 3.10.3.10: DimInventory Result

	ProductKey	ProductID	ProductName	Color	Size	Weight	SafetyStockLevel	ProductLine	MakeFlag	FinishedGoodFlag	ProductCategoryName	ProductSubCategoryName	StartDate	EndDate	IsCurr
1	1	1	Adjustable Race	NULL	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
2	2	2	Bearing Ball	NULL	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
3	3	3	BB Ball Bearing	NULL	NULL	NULL	800	NULL	1	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
4	4	4	Headset Ball Bearings	NULL	NULL	NULL	800	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
5	5	316	Blade	NULL	NULL	NULL	800	NULL	1	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
6	6	317	LL Crankarm	Black	NULL	NULL	500	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
7	7	318	ML Crankarm	Black	NULL	NULL	500	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
8	8	319	HL Crankarm	Black	NULL	NULL	500	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
9	9	320	Chainring Bolts	Silver	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
10	10	321	Chainring Nut	Silver	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
11	11	322	Chainring	Black	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
12	12	323	Crown Race	NULL	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
13	13	324	Chain Stays	NULL	NULL	NULL	1000	NULL	1	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
14	14	325	Decal 1	NULL	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1
15	15	326	Decal 2	NULL	NULL	NULL	1000	NULL	0	0	NULL	NULL	2025-06-25 22:15:34.000	NULL	1

Figure 3.10.3.11: DimProduct Result

	ProductVendorKey	ProductID	VendorID	MinOrderQty	MaxOrderQty	AverageLeadTime	StandardPrice	LastReceiptDate	LastReceiptCost	StartDate	EndDate	IsCurrent
1	1	1	1580	1	5	17	47,87	2011-08-29 00:00:00.000	50,2635	2025-06-26 11:30:10.000	NULL	1
2	2	2	1688	1	5	19	39,92	2011-08-29 00:00:00.000	41,916	2025-06-26 11:30:10.000	NULL	1
3	3	4	1650	1	5	17	54,31	2011-08-29 00:00:00.000	57,0255	2025-06-26 11:30:10.000	NULL	1
4	4	317	1578	100	1000	19	28,17	2011-08-29 00:00:00.000	29,5785	2025-06-26 11:30:10.000	NULL	1
5	5	317	1678	100	1000	17	25,77	2011-08-25 00:00:00.000	27,0585	2025-06-26 11:30:10.000	NULL	1
6	6	318	1578	100	1000	19	34,38	2011-08-29 00:00:00.000	36,099	2025-06-26 11:30:10.000	NULL	1
7	7	318	1678	100	1000	17	31,98	2011-08-25 00:00:00.000	33,579	2025-06-26 11:30:10.000	NULL	1
8	8	319	1556	100	1000	19	44,21	2011-08-29 00:00:00.000	46,4205	2025-06-26 11:30:10.000	NULL	1
9	9	319	1578	100	1000	19	46,27	2011-08-29 00:00:00.000	48,5835	2025-06-26 11:30:10.000	NULL	1
10	10	319	1678	100	1000	17	43,87	2011-08-25 00:00:00.000	46,0635	2025-06-26 11:30:10.000	NULL	1
11	11	320	1514	1	5	19	47,28	2011-08-29 00:00:00.000	49,644	2025-06-26 11:30:10.000	NULL	1
12	12	320	1602	1	5	17	45,21	2011-08-19 00:00:00.000	47,4705	2025-06-26 11:30:10.000	NULL	1
13	13	320	1604	1	5	17	43,21	2011-08-25 00:00:00.000	45,3705	2025-06-26 11:30:10.000	NULL	1
14	14	321	1514	1	5	19	42,21	2011-08-29 00:00:00.000	44,3205	2025-06-26 11:30:10.000	NULL	1
15	15	321	1602	1	5	17	40,76	2011-08-19 00:00:00.000	42,798	2025-06-26 11:30:10.000	NULL	1
16	16	321	1604	1	5	17	38,56	2011-08-25 00:00:00.000	40,488	2025-06-26 11:30:10.000	NULL	1

Figure 3.10.3.12: DimProductVendor Result

	ShipMethodKey	ShipMethodID	Name	ShipBase	ShipRate	StartDate	EndDate	IsCurrent
1	1	1	XRQ - TRUCK GROUND	4	0.99	2025-06-25 22:50:24.000	NULL	1
2	2	2	ZY - EXPRESS	10	1.99	2025-06-25 22:50:24.000	NULL	1
3	3	3	OVERSEAS - DELUXE	30	2.99	2025-06-25 22:50:24.000	NULL	1
4	4	4	OVERNIGHT J-FAST	22	1.29	2025-06-25 22:50:24.000	NULL	1
5	5	5	CARGO TRANSPORT 5	9	1.49	2025-06-25 22:50:24.000	NULL	1

Figure 3.10.3.13: DimShipMethod Result

	VendorKey	VendorID	Name	CreditRating	PreferredVendorStatus	ActiveFlag	City	StateProvinceName	CountryRegionName	StartDate	EndDate	IsCurrent
1	1	1580	Litware, Inc.	1	1	1	Santa Cruz	California	United States	2025-06-25 22:36:21.000	NULL	1
2	2	1660	Magic Cycles	1	1	1	Burlingame	California	United States	2025-06-25 22:36:21.000	NULL	1
3	3	1558	Marsh	1	1	1	Woodburn	Oregon	United States	2025-06-25 22:36:21.000	NULL	1
4	4	1550	Merit Bikes	5	1	1	Bremerton	Washington	United States	2025-06-25 22:36:21.000	NULL	1
5	5	1618	Metro Sport Equipment	1	1	1	Lebanon	Oregon	United States	2025-06-25 22:36:21.000	NULL	1
6	6	1612	Midwest Sport, Inc.	1	1	1	Detroit	Michigan	United States	2025-06-25 22:36:21.000	NULL	1
7	7	1586	Mitchell Sports	1	1	1	Everett	Washington	United States	2025-06-25 22:36:21.000	NULL	1
8	8	1500	Morgan Bike Accessories	1	1	1	Albany	New York	United States	2025-06-25 22:36:21.000	NULL	1
9	9	1656	Mountain Works	1	0	1	Everett	Washington	United States	2025-06-25 22:36:21.000	NULL	1
10	10	1572	National Bike Association	1	1	1	Sedro Woolley	Washington	United States	2025-06-25 22:36:21.000	NULL	1
11	11	1562	Norstan Bike Hut	1	1	1	Beaverton	Oregon	United States	2025-06-25 22:36:21.000	NULL	1
12	12	1662	Northern Bike Travel	3	1	1	Anacortes	Washington	United States	2025-06-25 22:36:21.000	NULL	1
13	13	1606	Northwind Traders	1	1	1	Phoenix	Arizona	United States	2025-06-25 22:36:21.000	NULL	1
14	14	1682	Premier Sport, Inc.	1	1	1	Boston	Massachusetts	United States	2025-06-25 22:36:21.000	NULL	1
15	15	1684	Professional Athletic Consultants	1	1	1	Burbank	California	United States	2025-06-25 22:36:21.000	NULL	1
16	16	1678	Proseware, Inc.	4	0	0	Lebanon	Oregon	United States	2025-06-25 22:36:21.000	NULL	1

Figure 3.10.3.14: DimVendor Result

	PurchaseOrderID	OrderDate	ShipDate	ProductKey	InventoryKey	VendorKey	EmployeeKey	ShipMethodKey	PurchaseOrderStatus	OrderQty	UnitPrice	LineTotal	ReceivedQty	RejectedQty	Stc
1	3726	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	420	2	32	42	4	4	550	30,4395	16741.73	550	0	55
2	3726	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	420	3	32	42	4	4	550	30,4395	16741.73	550	0	55
3	3726	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	420	42	32	42	4	4	550	30,4395	16741.73	550	0	55
4	3726	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	421	2	32	42	4	4	550	40,9395	22516.73	550	0	55
5	3726	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	421	3	32	42	4	4	550	40,9395	22516.73	550	0	55
6	3726	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	421	42	32	42	4	4	550	40,9395	22516.73	550	0	55
7	3727	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	198	2	31	283	1	4	550	2,3205	1276.28	550	0	55
8	3727	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	198	3	31	283	1	4	550	2,3205	1276.28	550	0	55
9	3728	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	199	2	30	285	1	4	550	3,6435	2003.93	550	0	55
10	3728	2014-07-16 00:00:00.000	2014-07-25 00:00:00.000	199	3	30	285	1	4	550	3,6435	2003.93	550	0	55
11	3729	2014-07-17 00:00:00.000	2014-07-26 00:00:00.000	413	2	29	287	2	4	550	21,0945	11601.98	550	0	55
12	3729	2014-07-17 00:00:00.000	2014-07-26 00:00:00.000	413	3	29	287	2	4	550	21,0945	11601.98	550	0	55
13	3729	2014-07-17 00:00:00.000	2014-07-26 00:00:00.000	413	42	29	287	2	4	550	21,0945	11601.98	550	0	55
14	3729	2014-07-17 00:00:00.000	2014-07-26 00:00:00.000	414	2	29	287	2	4	550	30,4395	16741.73	550	0	55
15	3729	2014-07-17 00:00:00.000	2014-07-26 00:00:00.000	414	3	29	287	2	4	550	30,4395	16741.73	550	0	55

Figure 3.10.3.15: FactPurchaseOrder Result

CHAPTER 4. DATA ANALYSIS AND VISUALIZATION

Chapter 4 presents a detailed overview of the end-to-end process for data analysis and visualization using advanced analytical tools and techniques.

It starts by examining data analytics with SQL Server Analysis Services (SSAS), including the creation of multidimensional data cubes and the analytical capabilities they enable. The chapter then moves into the design and implementation of a Key Performance Indicators (KPI) framework, which serves as the backbone of the reporting system. The process of analysis and visualization is structured in three main phases: first, transforming and loading data into the system; second, establishing model relationships among data entities; and finally, performing business intelligence operations through interactive dashboards. The chapter ends with a critical reflection on the findings and insights generated from these analytical activities.

4.1. Data analytics with SSAS technology

4.1.1. Building the cube

To enable effective data analysis, we installed and utilized SQL Server Analysis Services (SSAS). The data source we worked with is the *Project* database, which contains key information for analytical purposes. As part of the setup process, we first created the Project Data Source to connect to the original database. Then we built a Data Source View—a visual abstraction of the data structure—that includes 7 dimension tables: Dim Product, Dim Vendor, Dim Time, Dim Inventory, Dim Product Vendor, Dim Employee, Dim Ship Method and 1 fact table: Fact Purchase Order. These tables are fundamental in modeling the data and serve as the basis for all subsequent analysis.

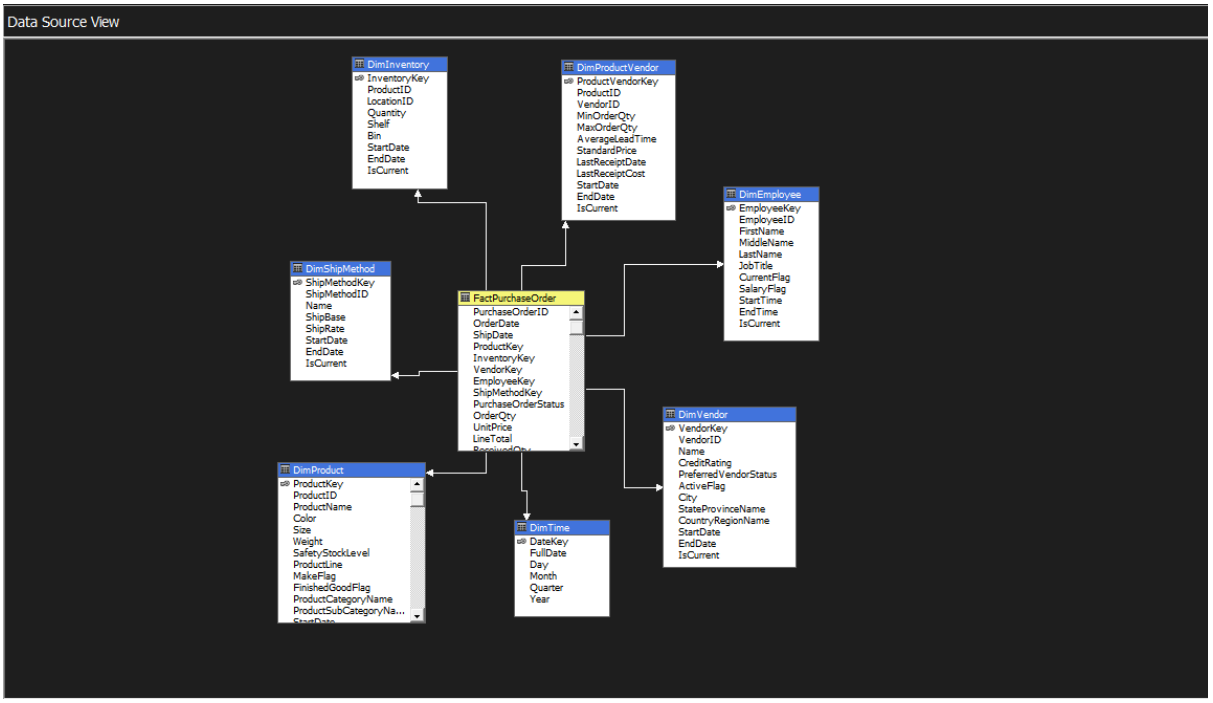


Figure 4.1.1.1: SSAS cube

4.1.2. Analysis with SSAS

	Order Qty
HL Crankarm	71500
Decal 1	62500
Decal 2	62500
HL Spindle/Axle	56100
LL Mountain Pedal	56100
LL Mountain Rim	56100
LL Spindle/Axle	56100
ML Mountain Pedal	56100
ML Mountain Rim	56100
Touring Rim	55550

Figure 4.1.2.1: Top 10 Product by Order Qty

The dataset reveals that customer purchasing behavior is heavily concentrated on core components and personalized items. Dominating the list is the HL Crankarm, with a remarkable 71,500 orders, significantly outpacing the lowest-ranked item, Touring Rim, which recorded 55,550 orders — a substantial difference of 15,950 units, or over 28.7%.

Notably, Decal 1 and Decal 2 each accumulated 62,500 orders, surpassing Touring Rim by about 7,000 orders. This indicates a strong market interest in personalized accessories, reflecting how customization continues to appeal to consumers.

Meanwhile, commonly used components such as the Spindle, Pedal, and Mountain Rim cluster around 56,100 to 56,300 orders, only slightly above the lowest-performing products by 500 to 800 units. This narrow gap suggests a steady and consistent demand across these essential items.

The dataset of the Top 20 vendors, ranked by total order value (Line Total) and average unit price, offers a broad strategic perspective—revealing not only consumption trends but also potential procurement strategies.

	Line Total	Average Unit Price
Superior Bicycles	4555898	82.8345090909091
Professional Athletic Consultants	3058775.66	39.1648612035852
Chicago City Saddles	3029109.67	30.7680007110208
Jackson Authority	2553243.6	38.685509090909
Vision Cycles, Inc.	2513742.4	38.0870060606061
Sport Fan Co.	2421619.59	37.6320060606061
Proseware, Inc.	2347422.4	35.5670060606061
Crowley Sport	2237801.46	39.8895090909091
Greenwood Athletic Company	2237801.46	39.8895090909091
Mitchell Sports	2193923	39.8895090909091
First Rate Bicycles	2085278.04	30.8245090909091
Signature Cycles	2023560.5	36.7920090909091
Electronic Bike Repair & Supplies	1950021.35	29.0614210134128
Vista Road Bikes	1892179	34.4032545454546
Victory Bikes	1857171.24	23.4491318181818
Bicycle Specialists	1766855.73	62.9895090909091
Inline Accessories	1766855.73	62.9895090909091
Compete Enterprises, Inc	1567115.76	22.613503030303
Hill's Bicycle Service	1445529.21	25.7670090909091
Competition Bike Training Systems	1443173.01	25.7250090909091

Figure 4.1.2.2: Top 20 vendor by line total

Superior Bicycles stands at the top with an impressive 4.56 million in total order value and the highest average unit price of 82.83. Leading in both total value

and unit price suggests this vendor supplies premium products or plays a strategic role in key product categories. Notably, its lead of nearly 1.5 million over the second-ranked vendor—a gap exceeding 49%—highlights its exceptional significance in the supply chain.

A different pattern emerges with vendors like Inline Accessories and Bicycle Specialists, whose average unit prices exceed 63.0, but total order values remain around 1.7 to 1.8 million. This suggests they may cater to a niche or premium segment with limited market reach, or that their higher-priced offerings have not yet achieved broad adoption.

	Order Qty	Order Qty Growth Rate
All	2344887	(null)
2011	15977	(null)
2012	140890	781.83%
2013	763758	442.10%
2014	1424262	86.48%

Figure 4.1.2.3: Growth Rate by Order Quantity from 2011 to 2014

From 2011 to 2014, the company experienced remarkable growth in order volume, rising from just 15,977 to over 1.42 million orders—a total increase of 2.34 million orders in four years. The most dramatic jump occurred in 2012 (+781.83%), followed by continued growth in 2013 (+442.10%) and 2014 (+86.48%). Though the growth rate slowed, the scale kept expanding, reflecting strong market demand, a rapidly evolving supply chain, and a clear strategic shift that positioned the company for long-term success.

4.2. Building the KPIs system

Once the cube is built, the next step is to create calculations that effectively capture the key performance indicators (KPIs). The example below illustrates this process: team members select attributes from the Measure Group, define a name for the calculation, and adjust formatting options in the Additional Properties section. This approach is consistently used for all similar calculations throughout the project.

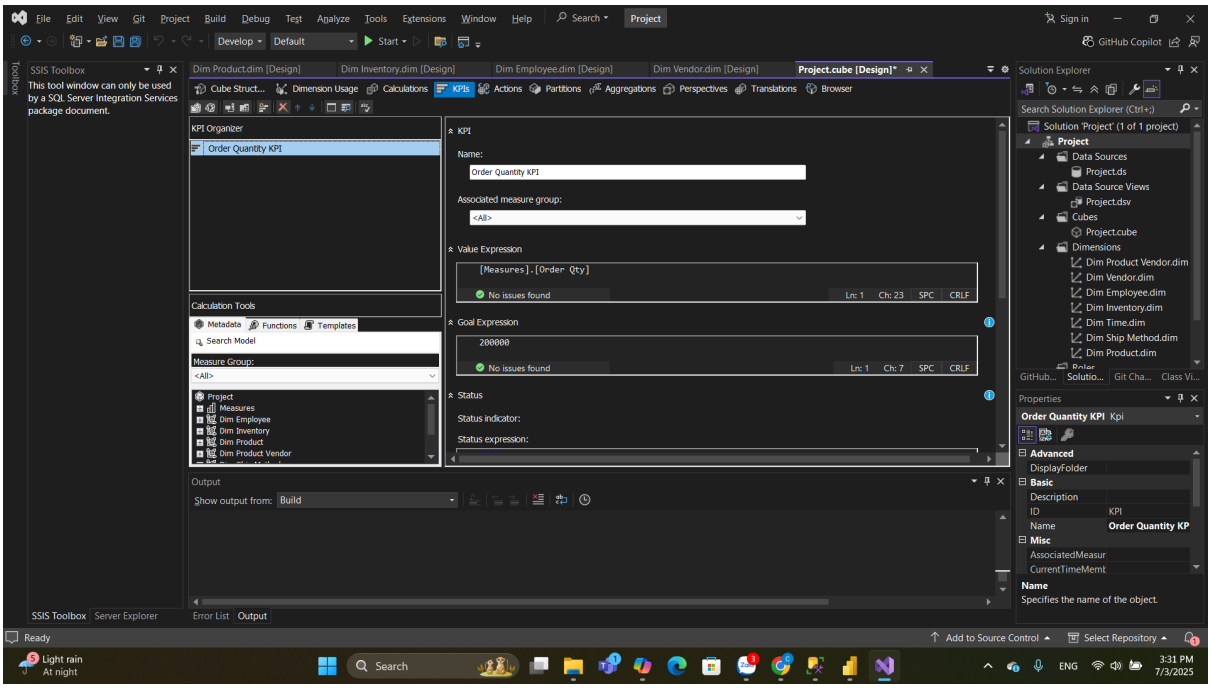


Figure 4.2.1: Build KPI Order Quantity

The KPI results for OrderQuantity are displayed in Excel:

Row Labels	Order Qty	Order Quantity KPI Status	Order Quantity KPI Trend
2010		○	→
2011	15977	○	→
2012	140890	●	↑
2013	763758	●	↑
2014	1424262	●	↑
2015		○	→
Grand Total	**2344887**	●	→

Figure 4.2.2: Order Quantity KPI by Year in Excel

Data from 2010 to 2015 reveals a clear cyclical pattern in order volume. Orders rose from 118,277 in 2010 to 140,628 in 2011, then dropped sharply during 2012–2013 to 74,278, before recovering to 140,628 in 2014. However, 2015 saw another decline back to 74,278, repeating the previous low.

With a total of 2.34 million orders across six years, the trend highlights volatile demand, suggesting a need for deeper analysis of seasonal patterns and inventory policy. While KPI trends indicate a strong recovery capability, they also point to instability and inconsistency in demand.

We also established a KPI for **Fulfillment Rate** to measure delivery performance. It tracks how much of the ordered quantity was successfully received

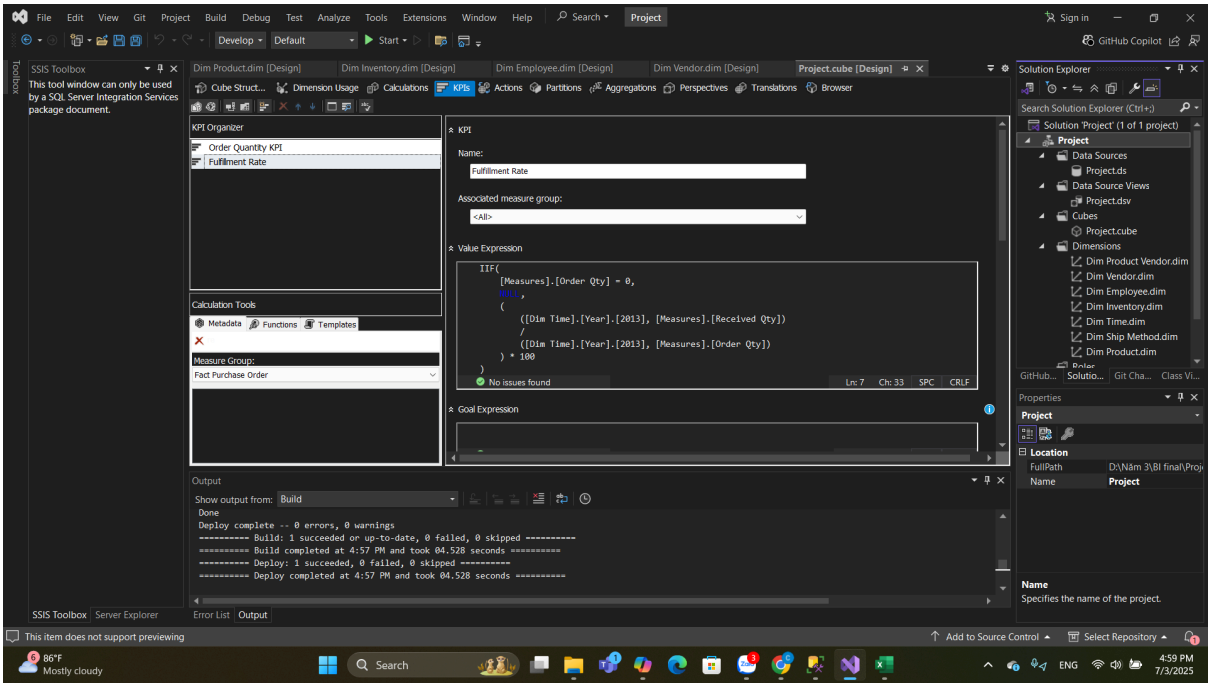


Figure 4.2.3: Build Fulfillment Rate KPI

The KPI results for Fulfillment Rate by Year are displayed in Excel:

Row Labels	Fulfillment Rate	Fulfillment Rate Status	Fulfillment Rate Trend
2010		○	→
2011	99.3052513	●	→
2012	99.00276812	●	↓
2013	99.12092574	●	↑
2014	99.07966371	●	↓
2015		○	→
Grand Total	**99.09002012**	●	→

Figure 4.2.4: Fulfill Rate by Year

The KPI results for Fulfillment Rate by Vendor in 2013 are displayed in Excel:

Row Labels	Fulfillment Rate	Fulfillment Rate Status
A. Datum Corporation		○
Advanced Bicycles	100	●
Allenson Cycles	98.2459893	●
American Bicycles and Wheels	100	●
American Bikes	99.12299465	●
Anderson's Custom Bikes	98.2459893	●
Aurora Bike Center	100	●
Australia Bike Retailer	100	●
Beaumont Bikes	98.86363636	●
Bergeron Off-Roads	100	●
Bicycle Specialists	97.36898396	●
Bike Satellite Inc.	100	●
Bloomington Multisport	100	●
Burnett Road Warriors	100	●
Business Equipment Center	100	●
Capital Road Cycles	100	●
Carlson Specialties	99.8	●
Chicago City Saddles	99.25214408	●
Chicago Rent-All	98.23529412	●
Circuit Cycles	98.58441558	●
Comfort Road Bicycles	98.39572193	●
Compete Enterprises, Inc	99.11919192	●
Compete, Inc.	99.15667311	●
Competition Bike Training Systems	98.91477273	●
Consumer Cycles	100	●

Figure 4.2.5: Fulfillment Rate by Vendor in 2013

The 2013 data shows most vendors achieved a Fulfillment Rate close to or at 100%, indicating strong reliability in order delivery across the board.

4.3. Introduction to the structure of the reporting system

4.3.1. Report highlights.

- Cover page
- Report summary

- Dashboard 1: Purchasing Dashboard
- Dashboard 2: Inventory Dashboard
- Dashboard 3: Vendor Performance dashboard
- Dashboard 4: Delivery Dashboard
- Dashboard 5: Product Dashboard
- Solution
- External research
- Appendix

4.3.2. Overall insight of dashboards

After completing the ETL process, the research team consolidated data from the data warehouse and presented it through five distinct dashboards, as outlined below:

Dashboard 1: Purchasing Overview

This dashboard offers a high-level summary of the organization's purchasing operations, including metrics such as total purchase orders, overall procurement costs, and receipt status. It enables stakeholders to understand the company's purchasing performance without delving into specific actor-level analyses.

Dashboard 2: Inventory Management

Displays both summary and detailed views of current inventory levels and product statuses. It supports better decision-making regarding replenishment and helps optimize inventory control.

Dashboard 3: Supplier Performance

Provides insights into the company's suppliers by tracking and evaluating their performance. This information facilitates improved supplier relationship management and more effective procurement strategies.

Dashboard 4: Delivery Monitoring

Focuses on assessing the effectiveness of the delivery process, enabling users to evaluate delivery methods and identify potential areas for improvement.

Dashboard 5: Product Insights

Offers in-depth information on individual products, including procurement trends and inventory levels. It helps organizations manage their product portfolio more strategically and efficiently.

4.4. Analyze and visualize data

4.4.1 Transform and load data

To manage data more effectively and allow offline access, the research team chose to use Import mode in Power BI. Unlike Direct Query, which keeps a live connection to databases like SQL Server, Import mode brings the data directly into Power BI and stores it there. This means users can work with the data even without an internet connection.

Import mode is especially useful when the dataset is small or does not change frequently. Because the data is already loaded into the system, reports run faster and are more responsive. This ensures a smoother experience during analysis, even in places where internet access is slow or unstable.

Another benefit of using Import mode is the simpler data refresh process. Although the data still needs to be updated regularly, the refresh schedule can be customized based on the needs of the organization. This gives more control over how often data is updated, making it easier to balance system performance with data accuracy.

In the case of AdventureWorks, Import mode is a reliable and practical choice for managing existing business data. It supports efficient reporting and analysis without the complexity of always connecting to live data sources. Overall, this approach helps the company use data more effectively to support better decision-making and improve operational performance across different departments.

4.4.2 Creating model relationship

Figure below describes the relationship model in Power BI. This model includes a star schema with a FactPurchaseOrders table and 7 dimension tables: DimProduct, DimVendor,DimProductVendor, DimInventory, DimShipMethod,

DimEmployee, and Dim Time. All relationships in the model are one-many, with dimension tables on the one side and FactPurchaseOrders tables on the many sides.

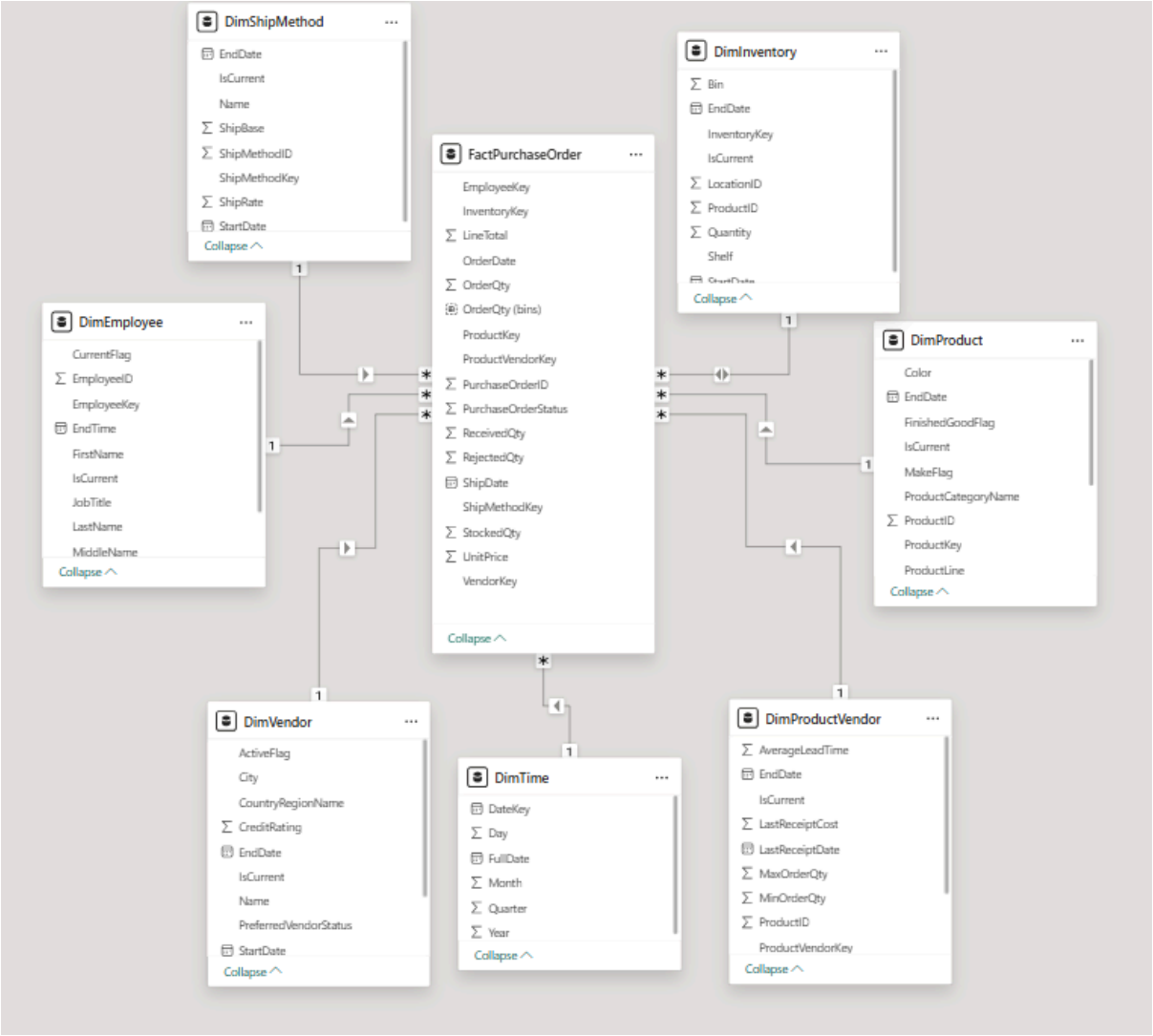


Figure 4.4.2.1: Model relationships

4.4.3.Business analysis

[GROUP 2 's POWER BI PROJECT PUBLISED]

a. Cover page

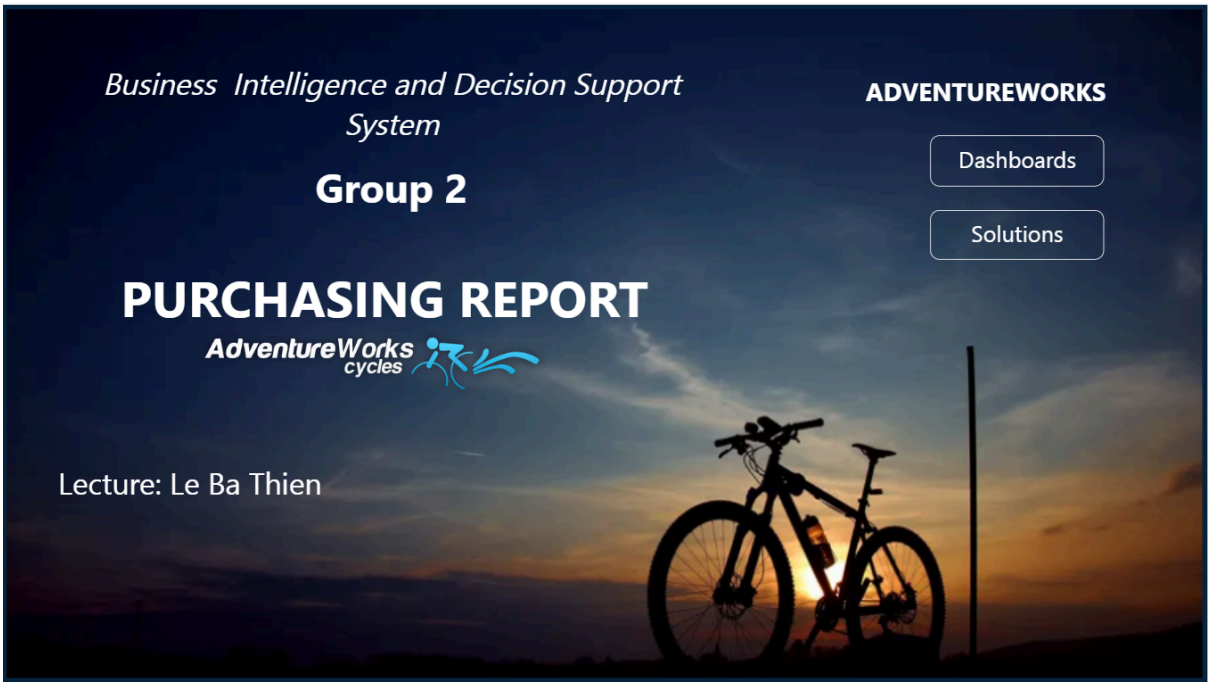


Figure 4.4.3.1: Cover page

b. Summary page

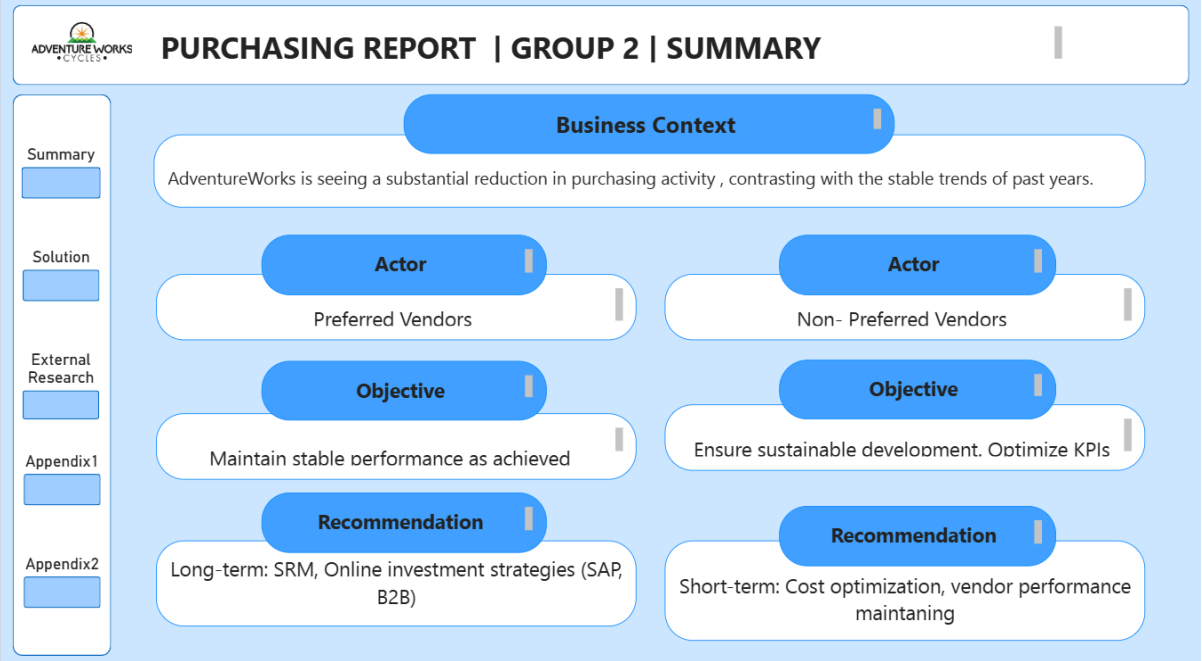


Figure 4.4.3.2: Summary page

The Summary Page provides a high-level overview of the current procurement situation at AdventureWorks. It highlights a recent decline in purchasing activity and outlines a dual-strategy approach for managing vendor relationships. Preferred

vendors are encouraged to maintain their strong performance through long-term technology investment (e.g., SRM, SAP, B2B platforms), while non-preferred vendors are targeted for short-term improvements in cost control and KPI optimization. The summary defines key actors, objectives, and actionable recommendations to ensure sustainable procurement development.

c. Purchasing overview dashboard

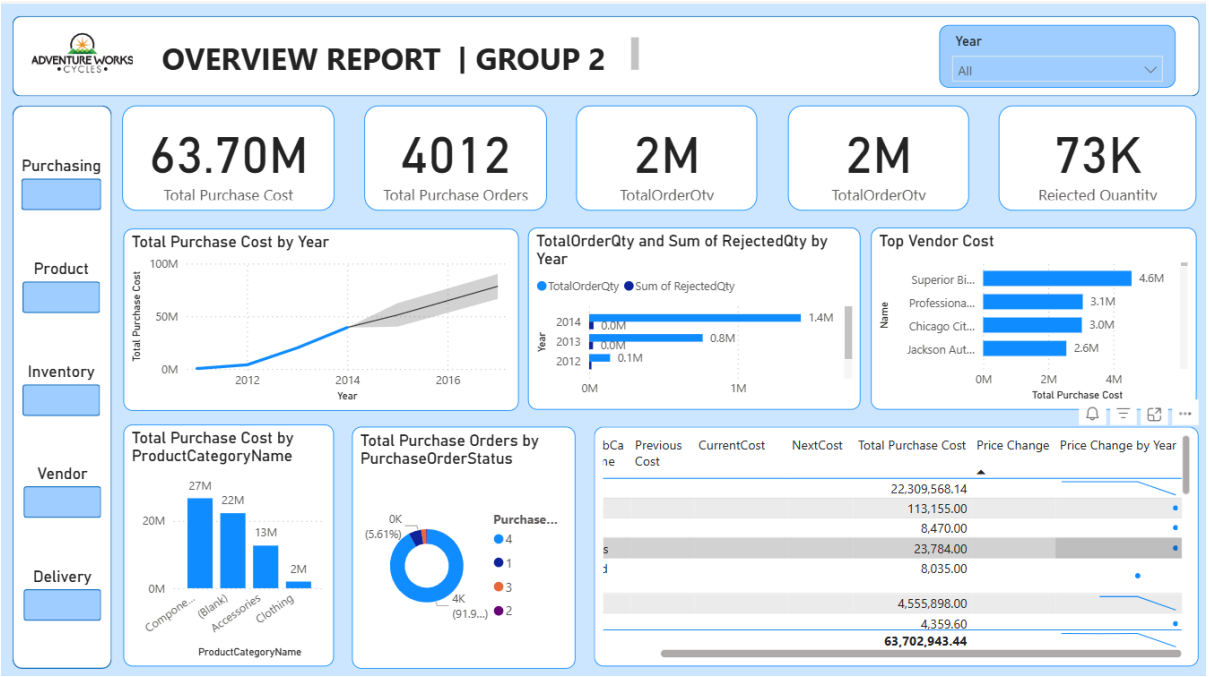


Figure 4.4.3.3: Dashboard Purchasing overview dashboard

The *Purchasing Overview* dashboard is designed to support the monitoring and operational control of purchasing activities at **Adventure Works Cycles** during the period from **2010 to 2015**. As an **operational dashboard**, it focuses on real-time visibility into purchasing performance, including key metrics such as purchase orders, total costs, order status, rejected quantities, and product price changes. The dashboard incorporates various visual elements, including line charts, bar charts, donut charts, and detailed data tables to facilitate trend analysis and data-driven decision-making.

Primary users

Purchasing Staff (Operational users)

The dashboard provides detailed information that supports the day-to-day operations of purchasing personnel. Key uses include:

- Monitoring the status of purchase orders
- Tracking received vs. rejected quantities
- Observing price fluctuations to make cost-efficient recommendations
- Identifying discrepancies or quality issues with suppliers or products

With its granular data and visual insights, the dashboard helps staff execute tasks accurately and respond quickly to operational issues.

Middle Managers (Purchasing Managers / Procurement Supervisors)

In addition to supporting operational users, the dashboard also provides high-level insights for mid-level managers to:

- Track overall purchasing costs over time and across product categories
- Forecast future procurement spending trends
- Analyze rejection rates to identify quality or supplier performance issues
- Evaluate procurement efficiency by comparing vendors and product groups

These users rely on the dashboard for short- to medium-term decision-making, cost optimization, and performance management of the purchasing department.

Key metrics and indicators

- Purchase Orders: A total of 4,012 purchase orders were recorded, indicating a high volume of procurement transactions throughout the observed period.
- Total Purchase Cost: The cumulative purchase cost reached approximately $63.70 million, reflecting the company's significant investment in acquiring raw materials and goods.
- Order Quantity: The company placed orders for around 2 million units, representing the total demand over the six-year period.
- Received Quantity: All 2 million units were successfully received, suggesting efficient order fulfillment and supplier reliability.
- Rejected Quantity: About 73,000 units were rejected, potentially due to quality issues, delivery discrepancies, or non-compliance with order specifications. This accounts for roughly 3.65% of the total ordered quantity.

Visual analysis and insight narratives

The following visual components from the Purchasing Overview Dashboard provide critical insights into procurement performance at *Adventure Works Cycles* between 2010 and 2015. Through a combination of cost trends, supplier evaluation, category spending, and order quality, this section presents both descriptive and diagnostic analytics.

Total purchase cost over time – Line Chart

- Purpose: Tracks the total purchase cost over the years from 2010 to 2015, and using forecast feature to forecast the value trend for next years (nearest 3 years)
- Insight:

Between **2011 and 2014**, there is a **clear and steady upward trend** in total purchasing cost, reaching nearly **$40 million in 2014** alone. The steepest increase occurred between **2012 and 2013**, signaling a sharp growth in procurement volume or a spike in unit costs.

Purchase Orders by status - Donut chart

- Purpose: Shows the distribution of purchase orders by their status.
- Insight:

  ~89.4% of orders are in status 4 – Complete, meaning they've been fully received and closed.

  ~9.2% remain in status 1 – Pending, which indicates awaiting approval.

  A very small fraction is in status 2 – Approved but not yet completed, and status 3 – Rejected – is almost negligible.

The majority of purchase orders are successfully fulfilled (~92%), with a small percentage pending or facing issues. Roughly **92%** of purchase orders were successfully completed during the five-year span, which reflects **a well-structured procurement process**. However, the remaining **8%**, comprising pending, canceled, or delayed orders, suggest room for operational improvement.Delayed or incomplete orders can directly impact production timelines, making it crucial to **identify patterns in order failure** and address them through supplier performance reviews or process adjustments.

Total Purchase Cost by product category – Bar chart

- Purpose: Breaks down the total purchase amount by product category.
- Insight:

The Components category accounts for the highest expenditure at approximately $27 million, followed by an unnamed group (possibly uncategorized products) at $22 million, Accessories at $13 million, and Clothing at just $2 million.

The heavy concentration in components suggests these are core items in the manufacturing process. Procurement teams should focus cost analysis and supplier evaluation efforts in these high-impact areas to maximize cost efficiency.

Total Order Quantity along with rejected quantity – Bar Chart

- Purpose: To compare the total quantity of goods ordered versus the amount rejected annually, helping to monitor quality performance.
- Insight:

Throughout the analyzed period, the **rejected quantity remained low relative to the total order volume**, indicates that the high consistency in supplier quality, and effective internal inspection and receiving processes.

Bar Chart – Top Vendor Cost

- Purpose: To identify which vendors account for the highest total purchase cost.
- Insight:

Top vendors include:

Superior Bycyles ($4.6M),
Professional Sales & Service ($3.1M),
Chicago City Cycle ($3.0M),
Jackson Auto Parts ($2.6M).

These vendors should undergo regular performance and cost reviews. Leverage high volumes to negotiate better terms or evaluate diversification to avoid supplier dependency.

Detail Table - Product purchase cost and price trends over time

- **Purpose**: To track purchasing details of individual products across time, including:
    - Previous, current, and next cost estimates
    - Total purchase cost per product
    - Price change rates (%)

This enables the procurement team to monitor cost fluctuations, identify cost-intensive items, and anticipate future budgeting.

- **Insight**: Provides a comparative view of price and cost, what products that using most cost.

Insight highlights by year (2011–2014)

2011:

- Total purchase cost was modest (~403K USD).
- Top spending categories: **Brakes**, **Chains**, **Pedals**.
- Minor unit price increases (green arrows) were observed but had limited impact on total cost.

2012–2014:

- Purchase costs skyrocketed from ~3.9M (2012) to ~20M (2013), then to ~39M (2014).
- Despite this surge, most unit prices remained stable or decreased slightly, as shown by mostly negative or near-zero price changes in the table.
- This data show that the main driver of total cost increase is rising due to order volume, or ship cost ,...not price inflation.

While the total purchase cost increased significantly from 2011 to 2014, the majority of unit prices remained stable or declined slightly. The product-level detail table supports this finding, showing mostly negative or negligible changes in unit cost over time. This confirms that the rise in procurement expenditure was primarily due to increased order volume rather than inflation or price hikes.
-> The procurement team should improve demand forecasting and develop long-term sourcing strategies that leverage purchase volume to negotiate more favorable supplier terms.

d. Delivery Monitoring dashboard

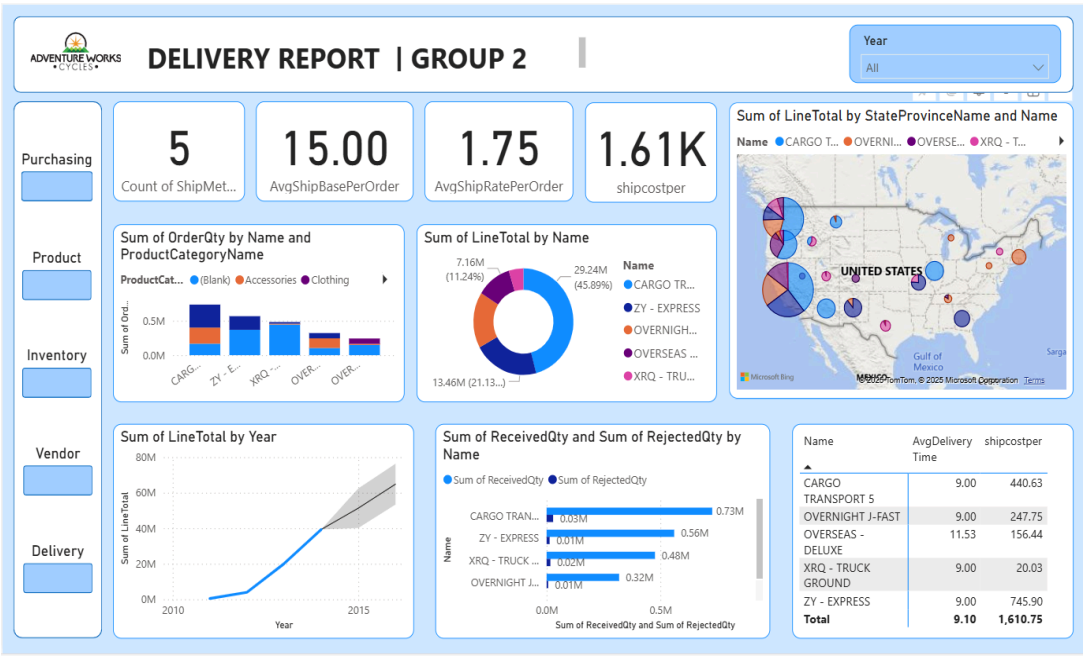


Figure 4.4.3.4: Delivery dashboard

Primary user: Middle Management & Shipping / Logistics Managers:

This dashboard is primarily designed for middle management within the shipping and logistics department. They need to monitor high-level performance indicators such as the total number of shipments, total shipping costs, return rates, the performance of each shipping method, and cost trends over the years. Through this dashboard, middle managers can quickly gain a comprehensive view of delivery performance, identify unusual patterns, and make timely decisions to optimize shipping costs, improve delivery efficiency, and support long-term logistics planning.

Visual charts and insights

Total delivery trips and total shipping costs: The company currently uses five different shipping methods, with a total shipping cost of 1,610.75 for all delivery trips. This reflects a significant scale of logistics operations, indicating an active delivery network and potential opportunities for further optimization in transportation management.

Shipping methods analysis: Donut Chart (Sum of Line Total by Shipping Method Name):

Among the available shipping methods, some handle a significantly larger delivery volume. The method *CARGO TRANSPORT 5* accounts for 45.89% of all deliveries, showing its popularity, customer preference, and suitability for certain purchased goods.

Shipping efficiency:

- The average base shipping cost per order is currently 15.00, while the average actual shipping fee per order is 1.75.
- Shipping Trends: A line chart displays total purchasing costs over the years. From $403.13K in 2011, it surged to over $39 million in 2014 and is projected to continue rising. This indicates either increasing shipping volumes or growing transportation costs, emphasizing the need for proactive logistics planning and tighter cost control moving forward.

Quality control and delivery accuracy: A dual-column chart (Received and Rejected Quantities) provides a comparative view of received versus rejected orders by shipping method. While most methods have a low rejection rate, those with higher order volumes tend to see more rejections, suggesting that more popular methods also face more frequent delivery quality issues.

Shipping methods analysis (Detailed):

- Shipping Method Cost Evaluation: The detailed table shows that the *OVERSEAS - DELUXE* method has the highest average delivery time of 11.53 days due to cross-border shipping. Other methods generally have an average delivery time of about 9 days, with costs ranging from high to low depending on quality and shipping purposes. The most used method, *CARGO TRANSPORT*, offers a moderate cost of around 440.63 USD, with stable quality, making it suitable for most purchasing needs.
- Order Quantity by Shipping Method and Product Category: Certain shipping methods dominate in terms of total order quantity, particularly for specific product categories. While some methods serve various products, their order volumes still tend to concentrate on specific categories. For instance, *CARGO TRANSPORT* can handle three product types, with a total shipping value of 734.6K USD, nearly half of which—333.8K USD—is for components. This highlights the specialization of shipping methods, allowing managers to select the most appropriate method based on product types.
- Regional Shipping Costs: A map chart highlights significant differences in shipping costs across regions. Each region tends to favor certain shipping methods. The map clearly shows that the Eastern region has lower and more specialized shipping activities with one dominant method per area. In contrast, the Western region, particularly Washington and California, utilizes all shipping methods. Notably, *CARGO TRANSPORT* accounts for around 9 million USD in Washington and 11.18 million USD in California. This

suggests varying preferences across regions based on geography, local habits, and logistics models.

Recommendations:

Optimize shipping costs and efficiency: *CARGO TRANSPORT* currently holds the largest share of both shipping costs and order volumes (45.89%). The company should consider renegotiating shipping rates with this provider and evaluate alternatives for non-urgent shipments to reduce overall costs.

Proactive logistics planning and long-term cost control: Given the sharp increase in shipping costs over the years, the company should proactively develop annual shipping budgets, adopt logistics management technologie and allocate costs effectively across regions and shipping methods.

Improve delivery quality: To mitigate the growing number of returns associated with higher shipping volumes, the company should implement strict quality control standards, regularly assess carrier performance, and collaborate with shipping providers to improve delivery processes, especially for methods with higher return rates.

Select appropriate shipping methods for each product category: Based on the specialization of each shipping method, the company should develop policies to select shipping methods according to specific product categories. This will optimize costs, reduce delivery time, and ensure service quality.

Optimize shipping by geographic region: The company should maximize the use of shipping methods that best fit each region (e.g., *CARGO TRANSPORT* in Washington and California) and consider expanding warehouses or distribution centers in high-cost areas. Delivery strategies must remain flexible to align with geographic characteristics and local demands.

e. Inventory dashboard

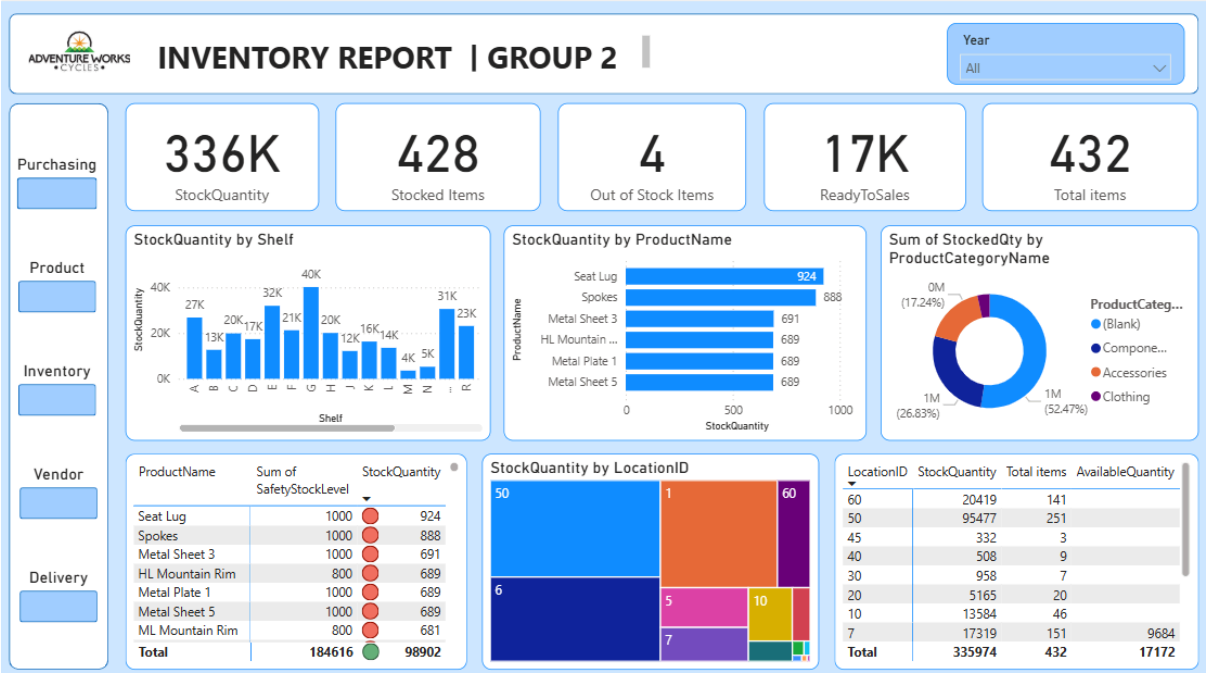


Figure 4.4.3.5: Inventory dashboard

The Inventory dashboard is designed to provide a comprehensive and visual overview of inventory status for Adventure Works Cycles. With a strong focus on key metrics such as total stock quantity, stocked items, out-of-stock items, and stock availability by location and shelf, this dashboard serves as a practical decision-support tool. It is primarily intended for users such as inventory managers, purchasing departments, production planners, and senior management—those who need a real-time, high-level view of inventory performance and status.

Visual chart and insights

StockQuantity by Shelf (Column Chart)

- Purpose: This chart is used to monitor and control how inventory is distributed across different shelves within warehouse locations.
- Insight:

  The chart reveals uneven stock distribution among shelves. For example, shelf 'K' holds the highest volume with 40K units. In contrast, shelves like 'M' and 'X' have as little as 4K and 5K units, respectively. This indicates a possible imbalance in how storage space is utilized. Overstocking certain shelves may lead to reduced efficiency and limited access. Therefore, reallocation or reorganization may be needed to improve space usage and inventory flow within the warehouse.

StockQuantity by ProductName Bar Chart)

- Purpose: This chart lists the products with the highest stock quantities.
- Insight:

  "Seat Lug" and "Spokes" are the two products with the largest inventory (over 800 units), which could be the result of low market demand or overstocking. It is recommended to further investigate their product lifecycle and current market needs to determine appropriate stock levels.

Sum of StockedQty by ProductCategoryName (Donut Chart)

- Purpose:This chart displays how current inventory is distributed across different product categories.
- Insight:
  Over 50% of the inventory belongs to the (Blank) segment, meaning it is not linked to a specific product category. Among the categorized items, “Components” make up the largest share at 26.83%, followed by “Accessories” at 17.24%, and “Clothing” with a much smaller portion. The prominence of the Components category suggests that internal parts or subassemblies dominate the categorized inventory, which could reflect the company’s operational focus on manufacturing or repair. This insight helps prioritize stock review or reallocation based on product type importance and storage demand.

Safety Stock Level Table (Matrix)

- Purpose:This table compares the current stock quantity of each product to its predefined safety stock level.
- Insight:
  The table uses conditional formatting to quickly categorize inventory status.
  Green indicates products with stock levels above the safety threshold, showing strong reserve and low short-term risk. On the other hand, some products have just met or fallen below the safety level — for example, “Metal Sheet 3” and “HL Mountain Rim” are marked in red, indicating a potential stockout risk if sudden demand arises. These products should be prioritized in the upcoming purchasing plan to ensure timely replenishment and maintain supply continuity.

StockQuantity by LocationID (TreeMap & Matrix)

- Purpose: This chart displays inventory quantities by storage location.
- Insight:
  Locations 50 and 1 hold the largest amount of inventory, which may warrant a review of whether storage is being efficiently distributed. Meanwhile, Location 7 stands out with a high Available Quantity of 9,684 units, suggesting that this area may serve as a strategic point for faster stock rotation or distribution.

Recommendation

- **Storage space allocation should be optimized**. The uneven distribution of inventory across shelves within different locations suggests a need to reassess how items are organized. Overloaded shelves may hinder product movement and increase handling time, while underutilized ones represent wasted space. A more balanced layout will improve inventory flow, minimize retrieval risks, and make better use of the available warehouse capacity.
- **Closely monitor low-stock and out-of-stock items**. Currently, there are four products completely out of stock, and others such as “Metal Sheet 3” and “HL Mountain Rim” are below their safety stock thresholds, highlighted in red in the Safety Stock Level Table. To mitigate the risk of stockouts and supply disruptions, the company should implement early warning alerts when stock approaches minimum safety levels and establish regular replenishment plans for critical items.
- **Review high-stock product lines**. Items like “Seat Lug” (over 800 units) and “Spokes” hold large stock quantities but are relatively small components with potentially low turnover. Maintaining excessive inventory for slow-moving items can tie up warehouse space and capital. A detailed assessment of their product lifecycle and sales velocity should be conducted to inform discount strategies or procurement adjustments to avoid unnecessary overstock.
- **Rebalance inventory across warehouse locations.** Location 50 and Location 1 hold a significant share of the overall stock, while Location 7, with an Available Quantity of 9,684 units, appears underutilized. This calls for a more strategic internal stock transfer system to avoid bottlenecks and maximize space usage. A well-coordinated inventory redistribution process would improve flexibility and responsiveness to demand across different regions.

f. Vendor performance dashboard

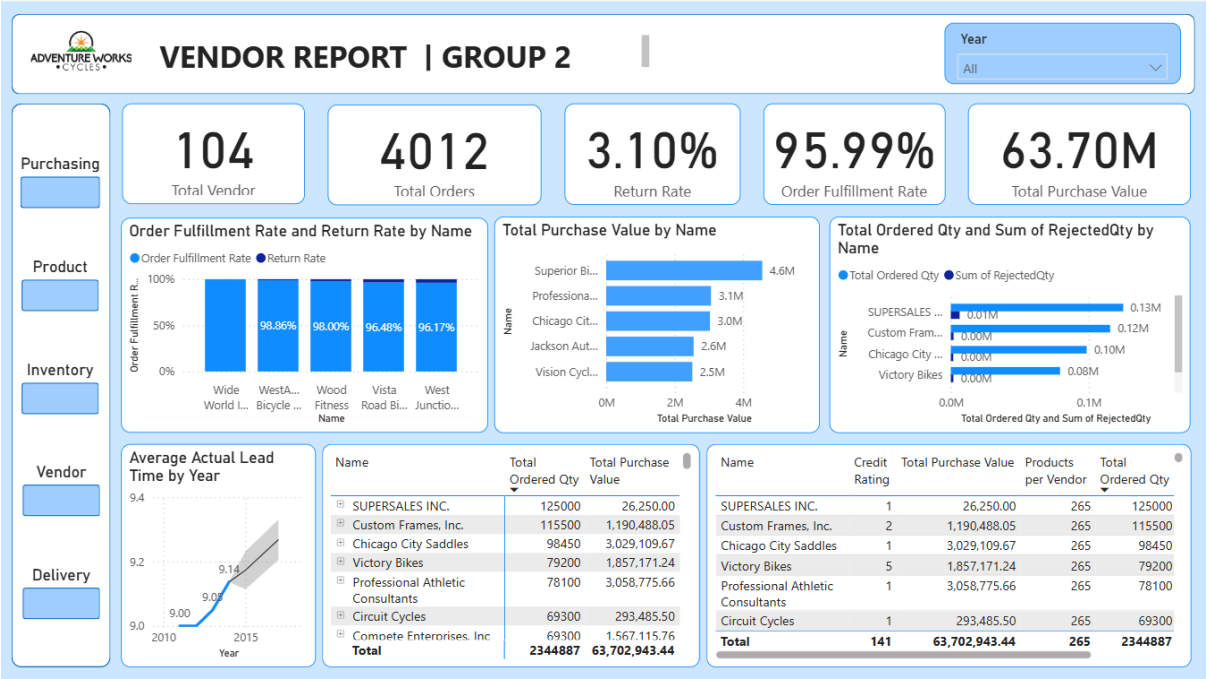


Figure 4.4.3.6: *Vendor performance dashboard*

The **Vendor performance dashboard** is designed to monitor and evaluate the performance of suppliers (vendors) involved in the purchasing activities of Adventure Works Cycles during the period from 2010 to 2015. As an **operational and analytical dashboard**, it enables procurement and supply chain teams to assess key aspects of vendor performance including order fulfillment, return rate, lead time, and total purchase value.

This dashboard helps ensure procurement efficiency, supplier reliability, and supports strategic decisions such as vendor selection, renegotiation, or diversification.

Primary users

Procurement officers and purchasing staff are the primary operational users of this dashboard. They rely on it to continuously monitor the performance of vendors in real time. This allows them to quickly identify suppliers with high return or rejection rates and to detect potential issues in order fulfillment. By accessing up-to-date visual indicators, purchasing staff can take immediate corrective actions, communicate with suppliers more effectively, and ensure that purchasing operations run smoothly on a daily basis.

Mid-level managers, such as Purchasing Supervisors or Vendor Managers, use the dashboard for more strategic oversight. It enables them to evaluate how each vendor contributes to overall procurement costs and compare vendors based on lead time, order volume, and rejection rates. With these insights, managers can assess supplier performance, optimize vendor selection, and make informed decisions to improve procurement efficiency. This includes negotiating better terms with high-performing suppliers and reconsidering relationships with underperforming ones.

Key metrics and indicators

The Vendor Overview Dashboard includes several important metrics that help users monitor and evaluate supplier performance. Below is a breakdown of each key indicator with simple explanations:

- **Total Vendors – 104 :** This shows the number of suppliers that the company worked with during the selected time period. A large number of vendors may suggest a diverse supply base, which can reduce risk but also requires more management.
- **Total Orders – 4,012:** This represents the total number of purchase orders sent to vendors. A higher number of orders reflects an active and busy procurement process.
- **Return Rate – 3.10%:** This is the percentage of items that were returned after delivery, possibly due to damage, wrong specifications, or poor quality. A lower return rate indicates better supplier reliability.
- **Order Fulfillment Rate – 95.99%:** This shows the percentage of orders that were delivered completely and on time. A high fulfillment rate means that vendors are meeting the agreed delivery terms.
- **Total Purchase Cost – $63.70 million:** This is the total amount of money the company spent on purchasing goods from all vendors. It reflects the scale of procurement activity and helps identify top-spending vendors.

These metrics give both operational staff and managers a quick overview of the overall performance of the supplier network. They support decisions about which vendors are reliable, where quality issues may exist, and how to improve procurement efficiency.

Visual analysis and insight narratives

Bar Chart – Order Fulfillment rate and Return rate by vendor

- Purpose:
  To display and compare the order fulfillment rate and return rate of each vendor.
- Insight: Vendors such as *Wide World Importers* and *West A Bicycle* have fulfillment rates above 98%, indicating strong delivery reliability. Meanwhile, vendors like *West Junction* show slightly lower fulfillment rates. Return rates for most vendors are relatively low, suggesting acceptable product quality overall.

Horizontal Bar Chart – Total Purchase Value by Vendor

- Purpose: To rank vendors based on total purchase value over the selected time period.
- Insight: *Superior Bicycles* leads with a total purchase value of $4.6 million, followed by *Professional Consultants* ($3.1 million) and *Chicago City Saddles* ($3.0 million). These vendors represent the highest procurement costs among all suppliers.

Bar Chart – Ordered Quantity versus Rejected Quantity by vendor

- **Purpose:** To compare the total quantity of goods ordered from each vendor with the quantity that was rejected.
- **Insight:** *SUPERSALES INC.* recorded the highest ordered quantity (125,000 units) but also showed a notable number of rejections. In contrast, vendors like *Victory Bikes* had high order volumes with minimal or no rejected units, reflecting consistent delivery quality.

Line Chart – Average Actual Lead Time by year

- Purpose: To track the trend in average actual lead time for deliveries across the years.
- Insight: From 2010 to 2015, the average lead time gradually increased from around 9.0 days to approximately 9.14 days. Although the change is slight, it shows a consistent upward trend over the years.

Vendor detail tables

The two vendor detail tables provide a deeper view of supplier performance by combining purchase volume, purchase cost, credit rating, and product coverage.

Purchase quantity and purchase cost

There is a noticeable mismatch between ordered quantity and purchase value among several vendors. For example, some vendors processed very high quantities but generated very low total cost, while others supplied fewer units with significantly higher costs.

This clearly indicates that vendors are supplying products at **different unit price levels**. For instance, one vendor with over 125,000 units ordered contributed less than $30,000 in total cost, reflecting extremely low per-unit prices. Meanwhile, other vendors with 60,000 to 80,000 units reached purchase totals of over $3 million, pointing to higher-priced goods.

This shows that **purchase value is driven more by unit price than by volume**, and that vendors play different roles based on the type or value of items they provide.

Credit rating and product uniformity

All listed vendors supply the same number of products, suggesting that the product portfolio is evenly distributed. However, their credit ratings vary significantly, from the lowest level (1) to the highest (5).

Interestingly, some vendors with low credit ratings are still responsible for a large share of the company's total procurement value. This raises a potential concern for procurement risk, as financial or reliability issues may be present despite the high transaction volume.

On the other hand, vendors with higher credit ratings, such as Victory Bikes, also show strong performance in both quantity and value, indicating good reliability and strategic importance.

Overall observations and recommendations

Purchase cost does not align with quantity ordered – some vendors supply fewer units at high total cost due to higher unit prices. Review unit price structures to identify cost-saving opportunities and negotiate better pricing for high-cost items.

Vendors with low credit ratings contribute significantly to purchase value, posing potential financial or delivery risks. Strengthen monitoring of low-credit vendors and consider diversifying supply sources to reduce dependency.

All vendors supply the same number of products, but performance varies in terms of cost, fulfillment, and returns. Implement a vendor performance scorecard to evaluate suppliers beyond product range—focus on delivery quality, reliability, and value.

Vendors like Victory Bikes combine strong credit rating with high performance, making them strategic partners. Establish long-term collaboration with high-performing vendors and consider prioritizing them in future procurement plans.

g. Product performance dashboard

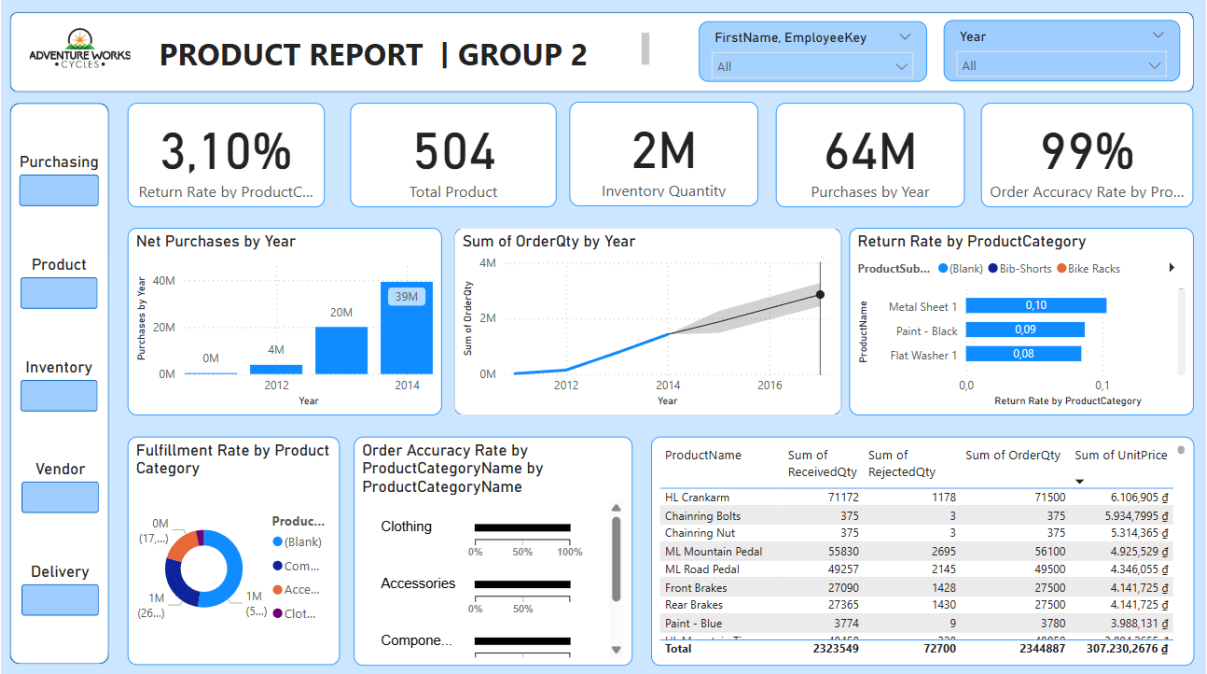


Figure 4.4.3.7: Product Dashboard

The Product Dashboard provides a strategic overview of key purchasing metrics for the AdventureWorks Purchasing Department. It supports data-driven decisions by allowing managers and staff to assess product performance, procurement trends, and supplier reliability.With interactive visualizations and real-time filters by product, vendor, employee, and shipping method, users can:

- Analyze purchasing behavior at multiple levels
- Identify issues in fulfillment or returns
- Track volume trends over time
- Improve planning for inventory, vendor negotiation, and restocking.

Key metrics and indicators

- **Total Product: 504**

Reflects the total number of unique products managed within the purchasing system. This figure indicates a wide product portfolio that requires systematic procurement oversight and inventory planning.

- **Inventory Quantity: 2 million units**

Indicates the total number of product units that have been successfully ordered and received into inventory. It reflects the actual volume of goods procured and helps track stock accumulation over time.

- **Net Purchases: $64 million**

Represents the cumulative monetary value of all purchase transactions. This figure highlights the scale of financial investment made in procurement and underscores the need for cost control and vendor management.

- **Order Accuracy Rate: 99%**

Measures the percentage of purchase orders fulfilled exactly as requested, without discrepancies. A high accuracy rate signifies strong coordination with suppliers and effective internal controls.

- **Return Rate: 3.10%**

Reflects the percentage of orders returned due to issues such as incorrect delivery, product defects, or quality mismatch. Although relatively low, this rate still signals potential areas for quality assurance improvements.

Insight Summary:

Adventure Works Cycles handles a product portfolio of 504 unique items, with a large quantity of goods in stock and a substantial procurement expenditure. Operational performance is strong, with a 99% order accuracy rate. However, a 3.10% return rate suggests potential issues in quality control or vendor coordination. Addressing these issues would further enhance procurement efficiency.

- **Fulfillment Rate by Product Category (Donut Chart)**

Illustrates the share of successfully fulfilled orders across all product categories. Clothing stands out with the highest fulfillment rate. In contrast, Components, Accessories, and other categories demonstrate lower fulfillment, signaling potential bottlenecks or supply chain inefficiencies.

Recommendation:

Prioritize investigating fulfillment issues in the underperforming categories (e.g., Components). Re-evaluate inventory policies, vendor agreements, and order lead times to increase fulfillment reliability across the board.

- **Return Rate by Product Category (Bar Chart)**

Displays the return rate percentage across individual product lines within each category. Products such as Metal Sheet 1, Paint – Black, and Flat Washer 1 exhibit the highest return rates. These returns could be due to incorrect specifications, delivery issues, or product defects.

Recommendation:

Conduct root cause analysis for the top-returned items. Engage suppliers in quality discussions and consider introducing stricter acceptance criteria or pre-shipment inspections to lower return rates.

- **Order Accuracy Rate by Product Category (Bullet Chart)**

Compares actual order accuracy against predefined performance targets.

Clothing outperforms the target KPI, showing exceptional accuracy.Components and Accessories are nearing target levels but have room for improvement.

Recommendation:

Maintain quality processes for high-performing categories. Implement corrective measures for lagging ones — such as refining order forms, improving staff training, or enhancing supplier communications.

- **Purchases cost by Year (Column Chart)**

This column chart visualizes the total net purchase value by year, offering insight into how procurement spending has evolved over time. The data reveals a consistent increase in total purchasing expenditure from 2011 to 2014. In particular, the spending jumped significantly in 2014, reaching approximately $39 million,

compared to only $4 million in 2012. This pattern suggests that either product demand, pricing, or volume of purchases has increased substantially in recent years.
Recommendation:

Purchasing managers should analyze the factors contributing to this cost growth—such as vendor pricing changes or order volume—and assess opportunities for cost optimization through vendor negotiation or alternative sourcing.

- **Sum of Order Quantity by Year (Line Chart)**

This line chart presents the total quantity of products ordered each year, providing an overview of purchasing volume trends. The quantity of products ordered has steadily increased from 2011 to 2014. This trend aligns with the rise in net purchase values but provides deeper insight into volume-driven growth, rather than just cost-driven. It indicates increased operational needs, inventory buildup, or rising customer demand.
Recommendation:

Buyers and purchasing planners should correlate this trend with inventory turnover rates and customer demand forecasts. If order quantity is increasing faster than actual consumption, it may indicate risks of overstocking, which can be costly. A more precise procurement plan may be necessary to balance inventory levels and optimize working capital.

- **Product Performance Summary (Matrix Table)**

Displays line-level transactional data, including: Received Quantity, Rejected Quantity, Order Quantity, Unit Price, Products like HL Crankarm and ML Mountain Pedal have high volumes, making them key contributors to total procurement. Items with high rejection rates (e.g., ML Road Pedal) demand vendor review.
Recommendation:

Monitor product-level trends regularly. Flag high-risk items for immediate vendor engagement and adjust reorder strategies accordingly.

Overall Observations and Recommendations

- **Optimize Procurement Spending and Forecasting**

Regularly audit total purchasing expenditures (currently $64 million) to detect overspending patterns and renegotiate supplier contracts for high-cost product categories.

Leverage historical purchasing data and Power BI trend analytics to enhance budget planning, forecasting, and prepare for seasonal fluctuations in demand.

- **Enhance Fulfillment Efficiency and Inventory Planning**

Use visual insights (e.g., fulfillment donut chart) to identify underperforming categories like Components and investigate delays or inefficiencies in the fulfillment process.

Monitor inventory in real time (currently 2.25 million units) and configure automated alerts for items nearing their safety stock thresholds to prevent stockouts and improve service continuity.

- **Strengthen Product Quality Assurance and Vendor Collaboration**

Address the 3.10% return rate by conducting root cause analysis for frequently returned items, such as Metal Sheet 1 or Paint – Black.

Partner with vendors to ensure alignment with product specifications, leveraging inspection results and performance metrics to improve supplier accountability and reduce quality-related returns.

- **Sustain Order Accuracy and Process Reliability**

Maintain the current 99% order accuracy by enhancing pre-order validation, automating data integrity checks, and addressing recurring discrepancies through process improvement and staff training.

- **Leverage Data for Smarter, Proactive Procurement**

Empower decision-making with Power BI filters by product, vendor, employee, and time to uncover inefficiencies, assess vendor performance, and refine sourcing strategies.

Keep product master data (e.g., price, category, vendor info) accurate and updated to reduce administrative errors and streamline procurement workflows.

h. Solution

Figure 4.4.3.8: Solution

i. External research

Figure 4.4.3.9: External research

j. Appendix 1

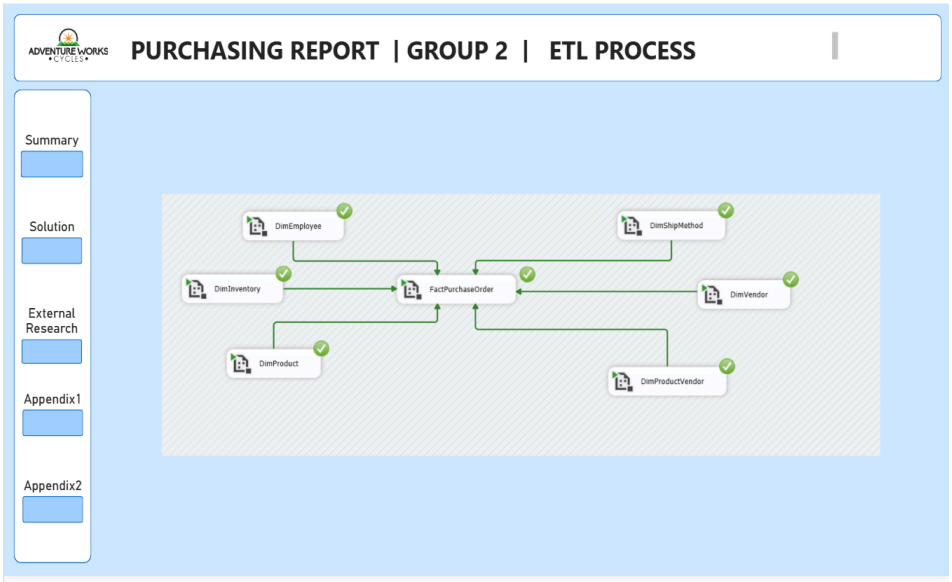


Figure 4.4.3.10: Appendix 1 - ETL Process

k. Appendix **2**

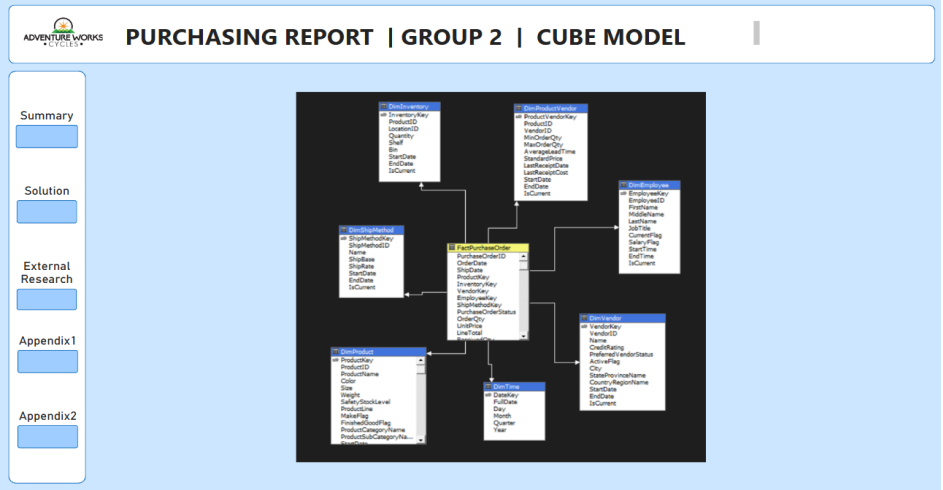


Figure 4.4.3.11: Appendix 2 - CUBE Model

4.5. Discuss and evaluate the results of data analysis and visualization

This project successfully designed and implemented a Business Intelligence (BI) system to assess purchasing performance across key areas such as products, inventory, delivery, and suppliers. The analysis was based on data sourced from the purchasing department of the simulated company, AdventureWorks. To support this, a data warehouse was developed, structured around a central fact table — FactPurchaseOrders — following a star schema design. This structure enabled the creation of a data cube that supports efficient aggregation and analysis aligned with business requirements.

Power BI was chosen as the visualization platform, where various cards and charts were built to address decision-making needs. Interactive elements, such as slicers, were incorporated to allow users to filter data by different dimensions, increasing the depth and flexibility of insights.

The outcomes from the data analysis and visual exploration revealed meaningful patterns and operational insights within the purchasing process. The integration of the data cube with dynamic visuals enabled users to gain a comprehensive understanding of purchasing trends, stock levels, delivery efficiency, and supplier reliability. With the ability to filter and drill down into specific aspects,

stakeholders can quickly identify areas for improvement, mitigate risks such as stock shortages, and make more informed vendor selection decisions.

Overall, the BI system proved to be an effective tool in supporting the purchasing department's strategic and operational goals. It enhances transparency, improves responsiveness, and enables more data-driven decision-making within the procurement function.

4.6. Cloud deployment

In the process of developing the reporting system, the project team established a connection between SQL Server Management Studio (SSMS) and Power BI Desktop to design and construct interactive dashboards. To ensure seamless data communication between the on-premises data infrastructure and the Power BI cloud environment, a Gateway was deployed.

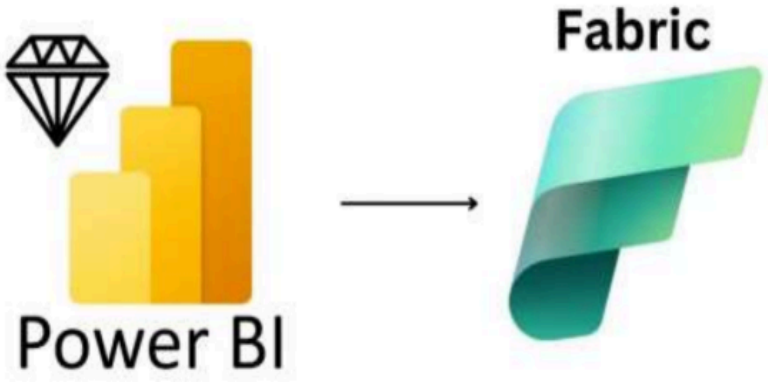


Figure 4.6.1: Cloud Deployment Model (Source: Authors, 2024)

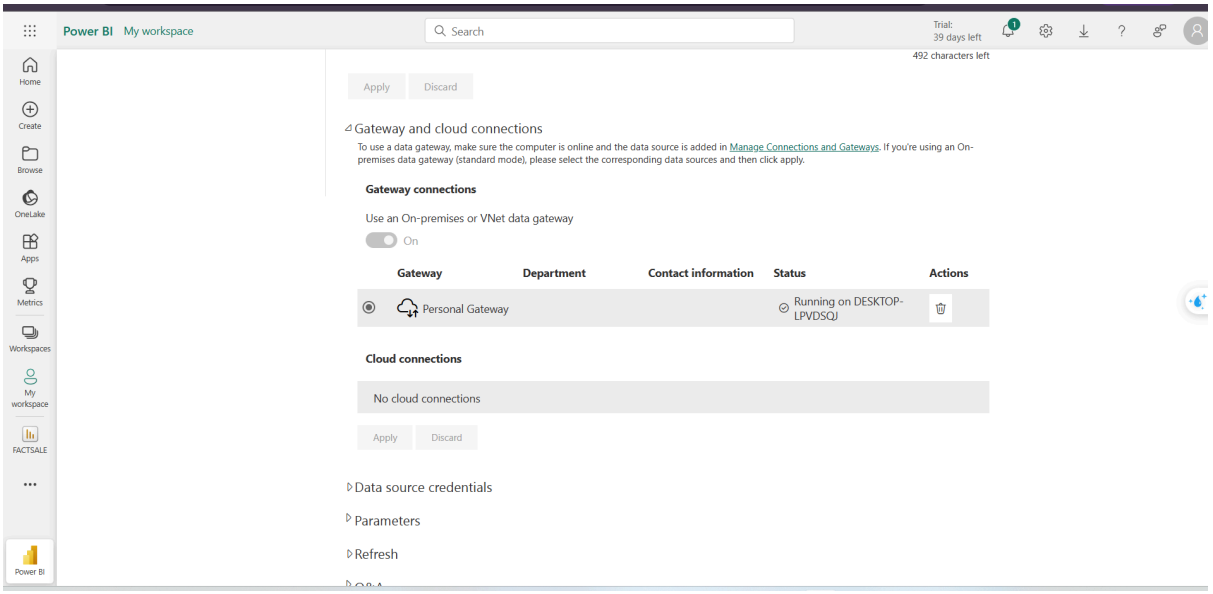


Figure 4.6.2: Deployed Gateway screen

For data access, the team adopted the Direct Query method, which allows reports and dashboards to retrieve data directly from the source in real time. This approach ensures that any changes in the underlying database are instantly reflected in the visualizations, eliminating the need to configure scheduled data refreshes. As a result, the data presented in the reports is always current, which is particularly valuable in scenarios requiring up-to-date decision-making.

Furthermore, the use of Direct Query contributes to simplifying the data maintenance process, reducing administrative workload related to refresh configurations, and improving overall system responsiveness. This setup aligns well with the organization's objective of creating a responsive and real-time business intelligence environment, supporting timely and accurate analysis for operational and strategic decision-making.

4.7. Automating SSIS Master Pipeline Execution via SQL Server Agent

To ensure that the ETL process is executed consistently and without manual intervention, we implemented an automated job execution mechanism for our SSIS Master Pipeline using SQL Server Agent. This process involved four main stages: deploying the package, configuring the SSISDB catalog, creating a SQL Agent Job, and capturing execution logs for monitoring and debugging.

4.7.1. Deploying the Master Pipeline Package to SSISDB

The Master Pipeline, which orchestrates the execution of child packages and manages control flow, was first developed in SQL Server Data Tools (SSDT). After validation, the project was built to generate an .ispac file, which encapsulates all control flow logic and metadata.

We then deployed this .ispac file to SSISDB (Integration Services Catalog) on the target SQL Server instance via the Deployment Wizard. This allowed the package to be managed centrally, and provided built-in logging and environment configuration.

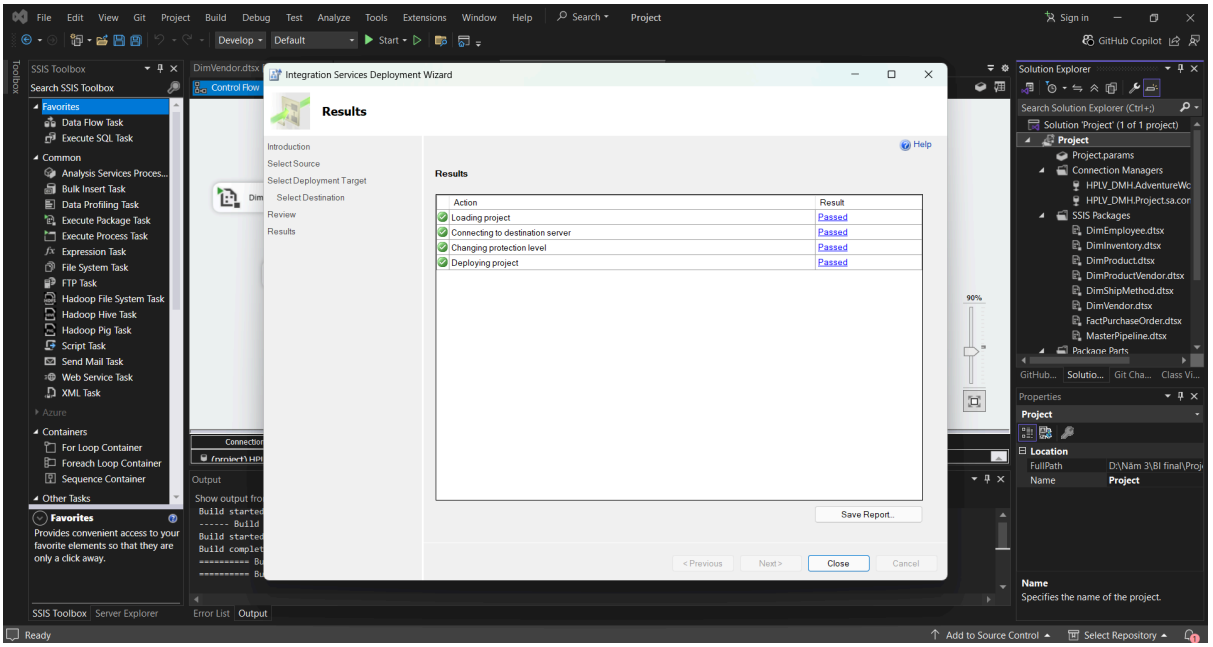


Figure 4.7.1.1: Successfully deployment

4.7.2. Creating the SSIS Catalog (SSISDB)

Before deploying the package, we ensured that the Integration Services Catalog (SSISDB) was created in SQL Server.

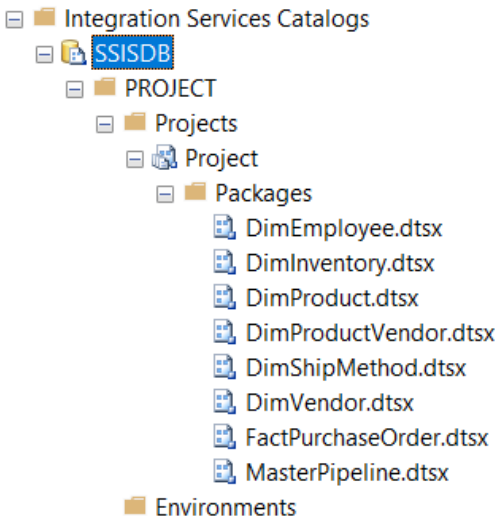


Figure 4.7.2.1: The SSISDB folder structure created

4.7.3. Creating the SQL Server Agent Job to execute the package

To automate the ETL process, we configured a SQL Server Agent Job with a single execution step that triggers the Master Pipeline. The job type is defined as a SQL Server Integration Services (SSIS) Package, with the source pointing to the SSIS Catalog where the deployed package resides. During setup, the appropriate SSIS environment was selected to pass required parameters dynamically. For scheduling, the job is set to run daily or at custom intervals, depending on business requirements. This approach ensures consistent execution and reduces manual effort

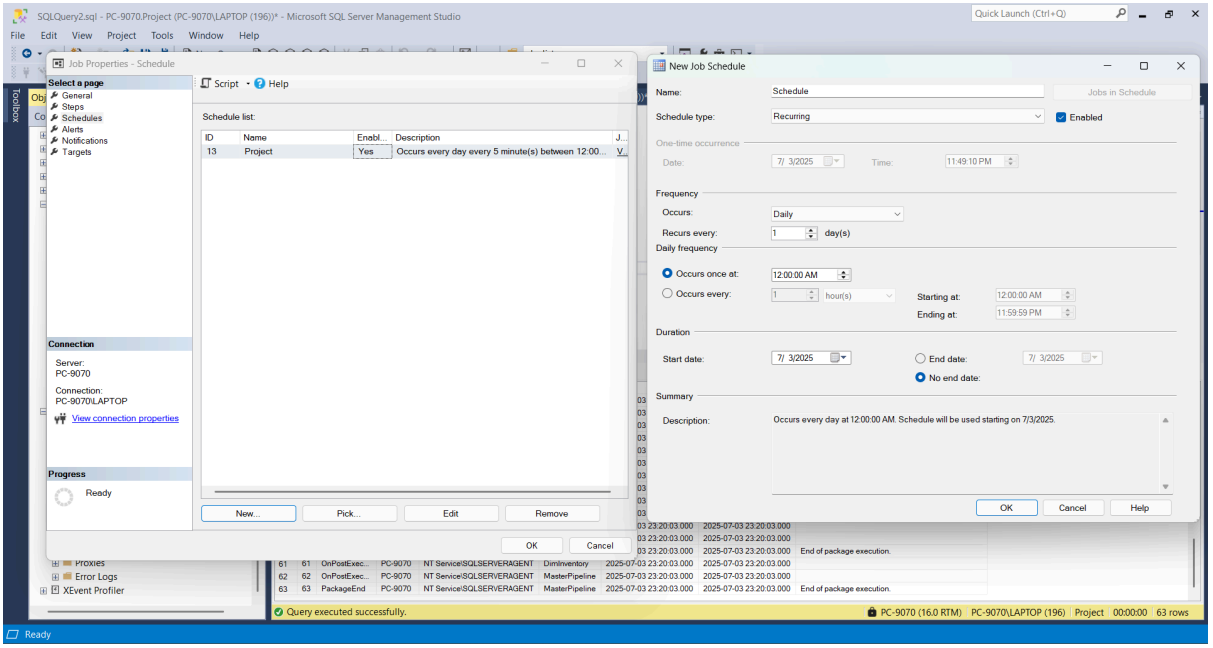


Figure 4.7.3.1: Schedule new sql server agent job

4.7.4. Capturing and Monitoring Execution Logs

To support monitoring and error tracking during automated executions, the team configured SSIS to log directly into the table Project.dbo.sysssislog. This is a system-generated table that is automatically created when the SQL Server logging option is selected during package design.

Through this log table, we are able to:

- Track detailed errors during execution (event = OnError)
- Identify the start and end time of each package execution (starttime – endtime)
- Pinpoint the exact source of the error (source), whether it originates from a specific package or task in the pipeline.

	id	event	computer	operator	source	starttime	endtime	message
111	1...	OnError	PC-9070	NT Service\SQLSERVERAGENT	DimInventory	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	The connection "" is not found. This error is thrown b...
112	1...	OnError	PC-9070	NT Service\SQLSERVERAGENT	MasterPipeline	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	The connection "" is not found. This error is thrown b...
113	1...	OnError	PC-9070	NT Service\SQLSERVERAGENT	DimInventory	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	The connection manager "" is not found. A compon...
114	1...	OnError	PC-9070	NT Service\SQLSERVERAGENT	MasterPipeline	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	The connection manager "" is not found. A compon...
115	1...	User:Packag...	PC-9070	NT Service\SQLSERVERAGENT	DimInventory	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	Beginning of package execution.
116	1...	User:OnPre...	PC-9070	NT Service\SQLSERVERAGENT	DimInventory	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	
117	1...	User:OnPre...	PC-9070	NT Service\SQLSERVERAGENT	Data Flow Task	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	
118	1...	OnPostExec...	PC-9070	NT Service\SQLSERVERAGENT	Data Flow Task	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	
119	1...	OnPostExec...	PC-9070	NT Service\SQLSERVERAGENT	DimProductV...	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	
120	1...	PackageEnd	PC-9070	NT Service\SQLSERVERAGENT	DimProductV...	2025-07-03 23:50:30.000	2025-07-03 23:50:30.000	End of package execution.
121	1...	User:OnPost...	PC-9070	NT Service\SQLSERVERAGENT	Data Flow Task	2025-07-03 23:50:57.000	2025-07-03 23:50:57.000	
122	1...	User:OnPost...	PC-9070	NT Service\SQLSERVERAGENT	DimInventory	2025-07-03 23:50:57.000	2025-07-03 23:50:57.000	
123	1...	User:Packag...	PC-9070	NT Service\SQLSERVERAGENT	DimInventory	2025-07-03 23:50:57.000	2025-07-03 23:50:57.000	End of package execution.
124	1...	OnPostExec...	PC-9070	NT Service\SQLSERVERAGENT	DimInventory	2025-07-03 23:50:57.000	2025-07-03 23:50:57.000	
125	1...	OnPostExec...	PC-9070	NT Service\SQLSERVERAGENT	MasterPipeline	2025-07-03 23:50:57.000	2025-07-03 23:50:57.000	
126	1...	PackageEnd	PC-9070	NT Service\SQLSERVERAGENT	MasterPipeline	2025-07-03 23:50:57.000	2025-07-03 23:50:57.000	End of package execution.

Figure 4.7.4.1: Log table

CHAPTER 5. CONCLUSION

5.1. Summary of findings

In this project, our team focused on developing a Business Intelligence (BI) system specifically for the Purchasing Department of AdventureWorks, utilizing data from the purchasing database to optimize procurement strategies and improve operational efficiency.

Our project team analyzed sample data from the AdventureWorks database, and through the implementation process, we practiced building a Data Warehouse using various data analysis tools and techniques such as SSIS and SSAS. We successfully designed a Star Schema data model with the FactPurchaseOrders table serving as the central fact table, enabling structured and effective data summarization and analysis. The development of the Data Cube allowed for multidimensional analysis, providing the Purchasing Department with a comprehensive view of procurement activities.

Key Performance Indicators (KPIs) were also identified and established, including order accuracy, return rate, supplier performance, shipping method efficiency, and product inventory levels. These quantitative measures play a crucial role in evaluating the effectiveness of purchasing operations and serve as a foundation for making accurate and timely procurement decisions.

In addition, our team utilized Power BI to design interactive dashboards that visualize key metrics related to purchasing, inventory levels, supplier performance, and shipping efficiency, thereby enhancing the decision-making capability of the Purchasing Department.

The study also emphasized the importance of fostering interaction between users and BI tools, while recommending enhanced training and user support to ensure that purchasing staff can effectively and sustainably utilize the BI system.

Through this project our team acquired essential knowledge and skills in data analysis, BI implementation, and KPI evaluation methods. Furthermore, we gained valuable hands-on experience in developing analytical reports to support business decision-making.

5.2. Limitations

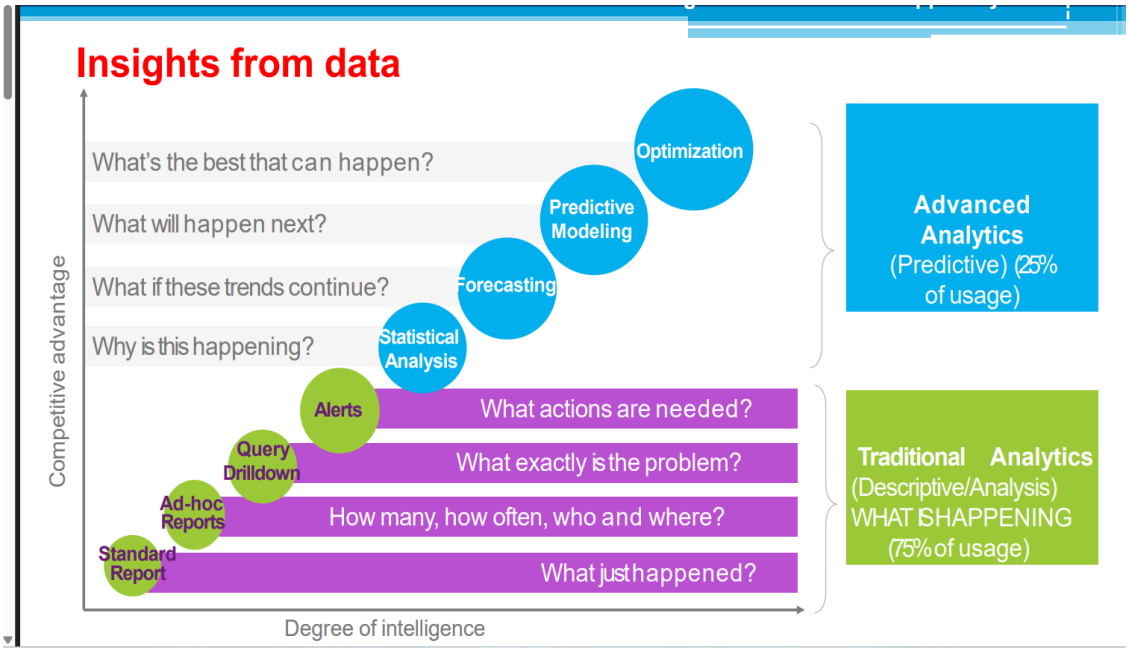


Figure 5.2.1: Degree of intelligence

This project, while providing valuable insights, has several limitations. Firstly, the team worked in a sequential manner rather than collaboratively in real time, which reduced efficiency and made consistency across visuals more difficult to maintain. Additionally, the dashboard lacks advanced features such as automated alerts or dynamic filters that would enhance user interaction and real-time monitoring. Moreover, although the project did implement calculated measures using SQL Server Analysis Services (SSAS), these measures were not successfully integrated into Power BI. As a result, all reporting logic was recreated directly within Power BI, which limits scalability and reusability in enterprise environments.

Furthermore, the project remains within the scope of traditional analytics—mainly descriptive and diagnostic analysis, such as standard reports and drilldowns. It does not yet incorporate advanced analytics techniques like forecasting, predictive modeling, or optimization, which are essential for answering higher-level questions such as *"What will happen next?"* or *"What's the best that can happen?"* As a result, the insights are limited to historical and current-state analysis. Lastly, the dataset is static and based on simulated data from AdventureWorks, meaning it may not fully reflect real-world inventory dynamics, such as seasonality, demand spikes, or supply chain variability.

5.3. Future directions

To enhance the analytical depth, scalability, and practical applicability of the current Business Intelligence (BI) solution, several directions are proposed for future development:

The current dashboard focuses primarily on descriptive and diagnostic analysis. Future iterations need to incorporate advanced analytics methods such as forecasting, clustering, and predictive modeling. These capabilities would allow the system to answer forward-looking questions (e.g., "What is likely to happen?" or "Which suppliers are at risk of underperforming?"), thereby enabling more proactive and data-driven procurement strategies.

Currently, all measures are embedded directly within Power BI, which limits reusability and scalability in enterprise settings. Future development will consider centralizing business logic using SQL Server Analysis Services (SSAS) or transitioning to Microsoft Fabric. These approaches will enhance data governance, performance, and the ability to scale the solution across departments.

To improve development efficiency and visual consistency, the team needs to adopt collaborative BI development platforms that support real-time editing and version tracking. Utilizing Power BI workspaces or cloud-based environments would allow multiple developers to work concurrently while maintaining standardization.

The use of static, simulated data limits the system's relevance to real-world operational dynamics. Future projects need to connect to real-time data from ERP systems (e.g., SAP), CRM platforms, and inventory management tools. This integration would enrich the data context and enable up-to-date monitoring of procurement performance, including seasonal demand shifts and supply chain disruptions.

To support operational agility, future dashboards need to include interactive features such as dynamic filtering, drill-through capabilities, and automated alerting systems. These enhancements would empower end users to gain insights quickly and respond to issues as they emerge.

A formal feedback mechanism should be implemented to collect input from business users on dashboard usability, data relevance, and visualization clarity. This feedback would inform ongoing improvements and ensure that the BI solution continues to evolve in alignment with user needs.

By incorporating predictive analytics, transitioning to scalable data models, integrating real-time systems, and enhancing user collaboration, the BI solution can

evolve from a foundational reporting tool into a comprehensive, intelligent decision-support system for procurement operations

5.4. Conclusion

The completed development and deployment of a Business Intelligence (BI) system for the Purchasing Department at AdventureWorks has illustrated the transformative impact of data-driven decision-making on operational control and procurement efficiency. By designing a structured data model and developing interactive Power BI dashboards, the project has enabled clearer visibility into key purchasing metrics, supplier performance, product cost trends, and inventory behavior.

The implementation of descriptive and diagnostic analytics has not only improved the department's ability to monitor purchasing activities but also laid the groundwork for future analytical capabilities such as forecasting and optimization. Key performance indicators (KPIs) and visual storytelling elements within the dashboard have empowered stakeholders to quickly identify spending priorities, quality control issues, and supplier concentration risks.

Despite its achievements, the project encountered certain limitations, including the absence of advanced analytics, reliance on static simulated data, and limited integration with broader enterprise systems. Nevertheless, these constraints have served to identify valuable opportunities for future enhancement, including the adoption of predictive modeling, cloud-native architecture (e.g., Microsoft Fabric), and deeper integration with ERP and CRM platforms.

Overall, this BI project has demonstrated the foundational value of leveraging business intelligence tools in procurement management. As AdventureWorks continues to expand and refine its analytics capabilities, the insights derived from this system will play a critical role in supporting strategic sourcing, cost control, and organizational agility in a highly competitive industry landscape.

* To complete the project, here is the table of the team's work space that shows the work collaboration process of the team 2.

Building a Business Intelligence System Purchasing Department of AdventureWorks Company			
No.	**TASK**	**Name**	Deadline
Meet choose topics 10/6/2025			
Chapter I	**I. OVERVIEW OF THESIS**		
	1. Industry business case overview	Lộc	14/06/2025
	2. Goal	Tuyến	15/06/2025
	3. Scope	Hân	16/06/2025
	4. Tools	Hân	17/06/2025
	5. Research implications	Minh	18/06/2025
	6.Structure of the report	Châu	19/06/2025
	Meet		19/06/2025
Chapter II	**II. THEORETICAL BASIS**		
	2.1. Overview of BI	Hân	20/06/2025
	2.2. Overview of ETL	Hân	20/06/2025
	2.3. Data warehouse and data mart	Minh	20/06/2025
	2.4. KPIs	Minh	20/06/2025
	2.5. MDX and OLAP	Tuyến	20/06/2025
	2.6. Visualization	Minh	20/06/2025
	Review + Xây outline tiếp		**19h 20/6**
Chapter III	**ANALYSIS OF USER REQUIREMENTS AND DATA DESCRIPTION**		
	1.Purchasing Department(role based PD need)	Hân	
	2. Purchasing Management (activity)	Hân	
	3.Business Requirements	Hân	
Meet	4.KPIs	Tuyến	**24/06/2025**

	5. Functional Requirements	Hân	24/06/2025
	6.Data preparation	Lộc, Tuyến	24/06/2025
	7. Design data warehouse	Châu Minh	25/06/2025
	8. Data Modeling	Lộc	25/06/2025
	9. Build data warehouse	Lộc, Châu	25/06/2025
	10. ETL Proccess	Tuyến, Châu, Hân, Lộc	25/06/2025
	Meet	19h30	**25/06/2025**
	CHAPTER 4. DATA ANALYSIS AND VISUALIZATION		
	4.1. Data analytics with SSAS technology	Châu	**29/06/2025**
	4.2. Building the KPIs system	Châu	**30/06/2025**
	4.3. Introduction to the structure of the reporting system	Lộc	**01/07/2025**
	4.4. Analyze and visualize data	Cả nhóm	**02/07/2025**
	4.1.1 Purchasing Overview dashboard	Tuyến	**28/06/2025**
	4.1.2 Inventory dashboard	Châu	**28/06/2025**
	4.1.3 Vendor Performance dashboard	Hân	**28/06/2025**
	4.1.4 Delivery dashboard	Lộc	**28/07/2025**
	4.1.5 Product Dashboard	Minh	**28/07/2025**
	4.5. Discuss and evaluate the results of data analysis and visualization	Minh	**2h pm, 03/07/2025**
	Meet		**03/07/2025**
	CHAPTER 5. CONCLUSION		
	5.1 Summary of findings	Lộc	**5h**
	5.2 Limitations	Châu	**5h**
	5.3 Future directions	Tuyến	**5h**

	5.4 Conclusion	Tuyến	**5h**
	DASHBOARD, lastupdate time	Hân	1h
	Slide	Canva	4/07/2025
	Word	Cả nhóm	11h pm 03/07/2025
	Create agent job	Lộc, Châu	
	Meet		11h pm 03/07/2025
	FINISH at 8h, 4/7/2025		
	Bìa của báo cáo		
	List of Tables		
	List of Figures		
	List of Abbreviations		
	Appendix		
	3. Data bakup , docs		
	4. Power BI file and related filed, https://app.powerbi.com/groups/me/reports/2fe4d396-54d8-42cb-a160-64bf41a099a7/93baf420dd0262b6aeee?experience=power-bi		

Table 5.4.1: Team 2 ’s work space

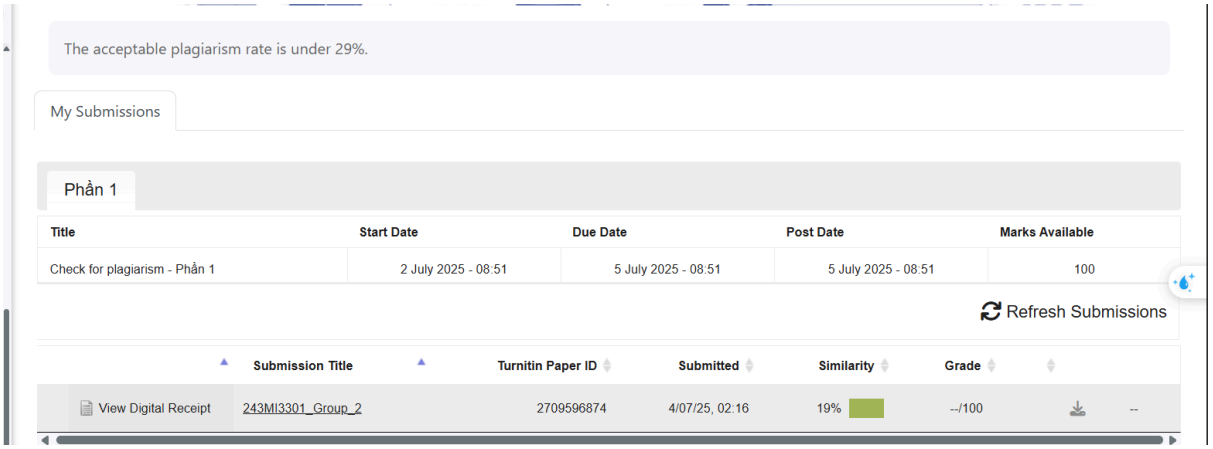


Figure 5.4.1: Check for plagiarism

REFERENCE

[1] Mckinsey. "Tech-and-regionalization-bolster-supply-chains-but-complacency-looms." mckinsey, https://www.mckinsey.com/capabilities/operations/our-insights/tech-and-regionalization-bolster-supply-chains-but-complacency-looms.

[2] Acharya, Harshida. "Logistics as Strategy: How Fulfillment Drives Revenue & Growth." Fulfillment IQ, 6 March 2025, https://fulfillmentiq.com/logistics-strategy-drives-revenue/. Accessed 4 July 2025.

[3] "Bicycle Market Report | Industry Analysis, Size & Forecast." Mordor Intelligence, https://www.mordorintelligence.com/industry-reports/bicycle-market. Accessed 4 July 2025.

[4] "Bicycle market." grandviewresearch, https://www.grandviewresearch.com/industry-analysis/bicycle-market.

[5] Jain, Sandeep. "Difference between Data Warehouse and Data Mart." GeeksforGeeks, 14 May 2025, https://www.geeksforgeeks.org/dbms/difference-between-data-warehouse-and-data-mart/. Accessed 4 July 2025.

[6] "Data Mart vs. Data Warehouse: The Difference with Examples [2024 Updated]." Panoply, http://panoply.io/data-warehouse-guide/data-mart-vs-data-warehouse/. Accessed 4 July 2025.

[7] "Business intelligence: A complete overview." Tableau, https://www.tableau.com/business-intelligence/what-is-business-intelligence. Accessed 4 July 2025.

[8] Ishabhsoft.com. "10 Steps for Successful Business Intelligence Implementation."

[9] "Bicycle Market Report | Industry Analysis, Size & Forecast." Mordor Intelligence,https://www.mordorintelligence.com/industry-reports/bicycle-market. Accessed 4 July 2025.

[10] "Master Data vs. Transactional Data: Unveiling the Data Symphony." Atlan, 9 November 2023, https://atlan.com/what-is/master-data-vs-transactional-data/. Accessed 4 July 2025.

[11] "Kaplan, R. S., & Norton, D. P. (1996). The Balanced Scorecard: Translating Strategy into Action. Harvard Business School Press."

[12] Dataedo.com. n.d. "AdventureWorks." Samples. https://dataedo.com/samples/html/AdventureWorks/doc/AdventureWorks_2/home.html.