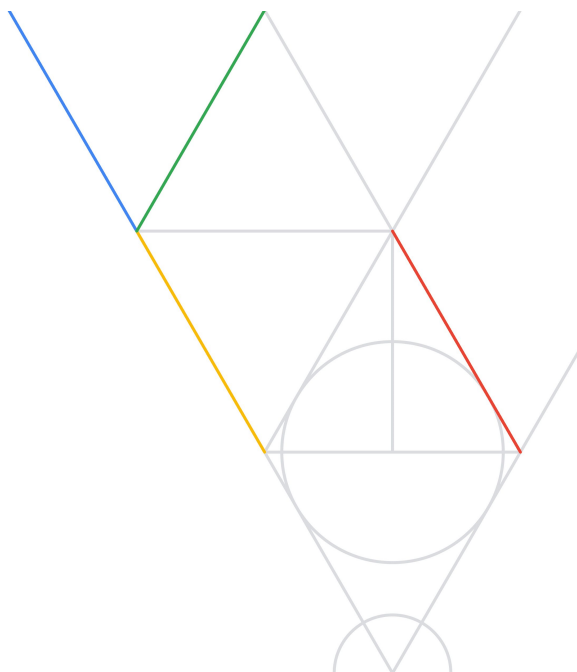


Data Driven Supply Chain Control Tower

March 2023



Kundan Sarkar - Supply Chain Technical Lead - Retail/CPG

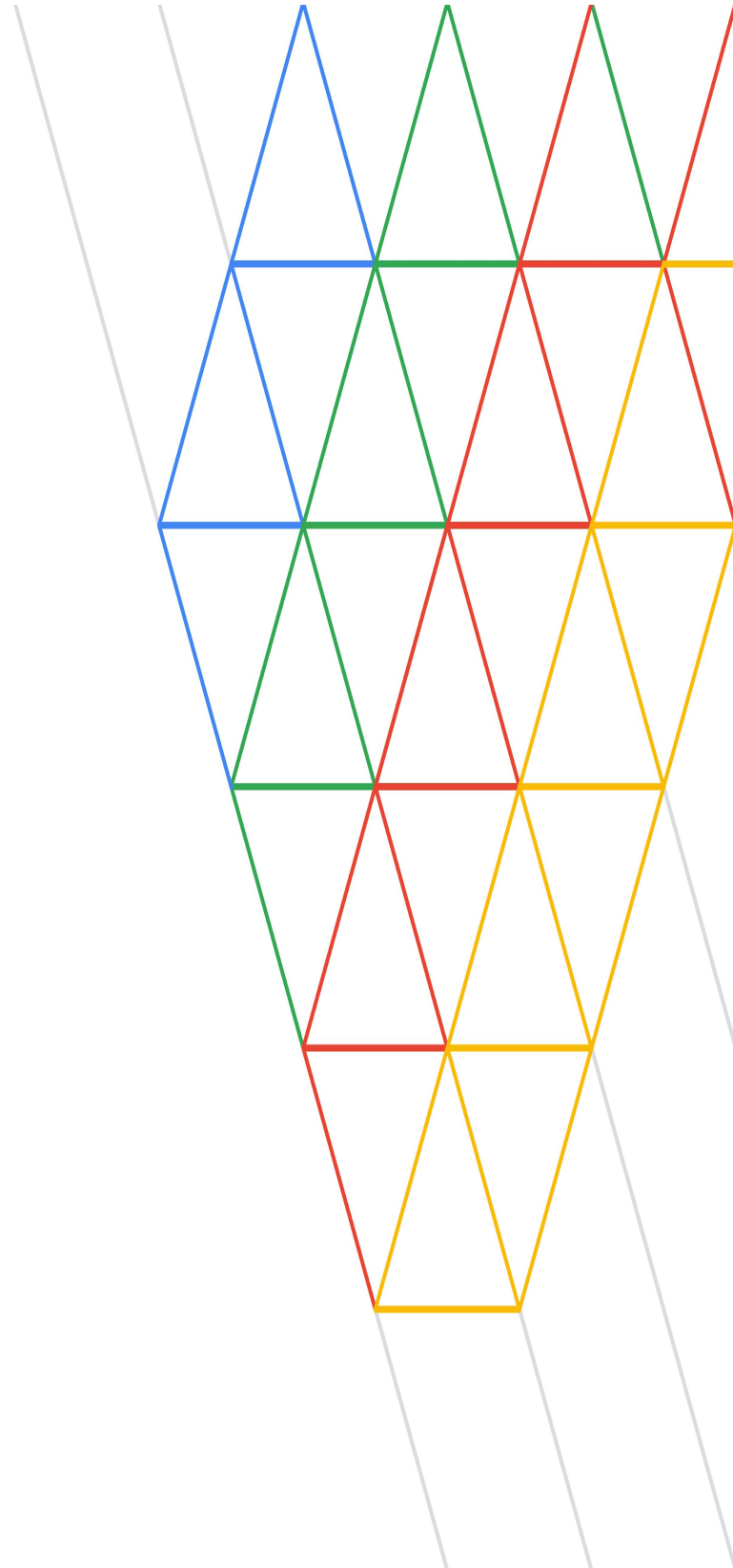
Special thanks to KC Rakam, Steve Townsend and Vish Ganapathy for providing their domain expertise and continuous support to this important supply chain topic.

Introduction

For the past two years, the Retail & CPG industry has been going through roller coaster rides with the ebb and flow of consumer demands. During the pandemic, in Feb 2020, retailers were recording a high inventory to sales ratio of 43 days¹. As things got back to normalcy, retailers experienced a surge in demand last year with the inventory to sales ratio sliding to 33 days in March 2021. This year, the trend reversed again. With consumer demand returning to more predictable post-pandemic patterns and with logistics constraints easing, retailers are now facing an excess inventory situation. A leading consumer apparel company discounted their products to clear excess inventory from the supply chain. The situation is further worsened by the fear of a global recession looming large. Retailers are facing consumer demand retreats and adjusting their store inventories for lower than normal holiday season sales. All these uncertainties and disruptions are pushing companies to have an end-to-end visibility of their supply chain to improve the decision making, response agility and risk mitigation of the supply chain functions. A recent survey of supply chain professionals by AQPC² showed data, analytics and digitalization of the supply chain as the most dominant trends being anticipated to impact the retail and CPG supply chain in the next three years.

While most of the leading CPGs and retailers have some kind of supply chain visibility in place, they are mostly siloed, spreadsheet driven and reactive in nature. The next generation of the supply chain control tower needs to be digital, data driven, AI optimized and integrated to enable proactive decision making for executives and front-line employees.

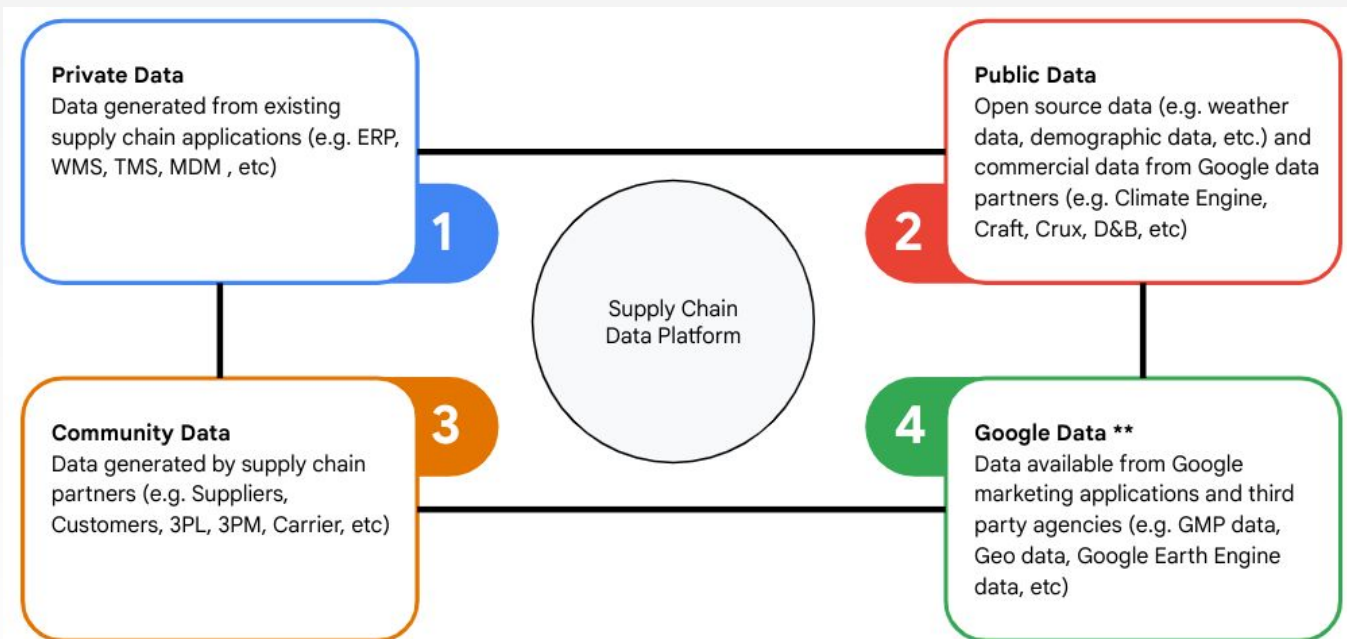
At Google, we collaborated with our customers and developed a point of view on the framework of a modern data-driven Supply Chain Control Tower. In this white paper, we are going to discuss this framework, its underlying principles and the reference architecture to enable this framework.



What is Data Driven Supply Chain Control Tower

The data driven Supply Chain Control Tower is an abstraction layer on top of the organization's existing supply chain systems, enriching the organization's private and community data with the public data and Google data in a common Supply Chain Data Platform (SCDP) and driving the supply chain analytics and intelligence from it. Let's dive deeper into the data ecosystem of the control tower -

- **Private data** - generated by supply chain applications within the organization, e.g. data generated by Enterprise Resource Planning (ERP), Demand Planning/ Supply Planning Warehouse Management Systems (WMS), Transportation Management Systems (TMS) etc. These data sets are primarily transactional in nature, something that organizations are most familiar with and use it in their day to day operations
- **Community data** - generated by organization's business partners e.g. suppliers, third-party manufacturers, transport carriers and in some cases, their customers. Since these data are originated from partners, organizations have less control over the data but nonetheless these data are also mostly operational in nature and available through the existing EDI connections with the partners
- **Public data** - this is publicly available data from open sources (e.g. census.gov, cdc.gov, data.gov, weather data,) that can be added to the SCDP to drive supply chain intelligence with trends and other macroeconomic factors. In addition, customers can subscribe to commercial business data available from the likes of Climate Engine, Craft, Crux and Dun & Bradstreet and can further enhance the public data to drive the supply chain use cases
- **Google data** - Based on customer's contract, authorization and data privacy agreements with Google, they may have access to Google Marketing data (e.g. Google Analytics, Campaign Manager, Merchant's center, Google Ads data), Google Geo data (e.g. Google Earth Engine, Google Maps etc) and Google Trends data to further enhance the intelligence of the supply chain use cases
- **Supply Chain Data Platform (SCDP)** - is the heart of the data driven supply chain control tower. It collects data from multiple sources including the private, community, public and Google data as described above and enables supply chain analytics and supply chain intelligence for business users with a semantic layer and a machine learning layer on top of it.



** Subject to customer's contract with Google / 3rd party agencies on authorized access and usage of such data

Transformation Approach

To build a data driven Supply Chain Control Tower with end-to-end visibility across multiple different functional teams and external partners in the supply chain, organizations should undertake a digital transformation of their existing supply chain processes. In fact, what we are typically seeing in the Retail & CPG sector is that, under the umbrella of digital transformation, customers have initiated multiple transformation journeys at the same time e.g.

- Application Transformation - transforming existing supply chain applications
- Cloud Transformation - transforming from on-premise to cloud
- Data Transformation - transforming to an AI/ML enabled common supply chain data platform

For the purpose of this white paper, we will be focusing on the data transformation and assuming cloud transformation as its enabler. We will be abstracting any impact of the application transformation within the integration layer of the framework.

Working with our customers in this space, we have developed a point of view based on following best practice principles:

- Minimize disruption to existing planning and execution systems with an overlay of Google Supply Chain Data Platform and enable supply chain visibility, analytics and intelligence from it
- In addition to technology, consider people and process as primary enablers of this transformation
- Adopt a phased approach of transformation from tactical to strategic to transformational
- Define capabilities and mature those capabilities across phases
- Define use cases and enhance its value across phases
- Focus on quality and the velocity of the solution
- Embed change management and data governance as a part of the process itself

For the Supply Chain Control Tower, we have defined and categorized capabilities into four distinct areas of the technology pillar. These categorizations are only a guard rail and can be further enhanced or modified based on specific customer situations. For example, there may be a need to add additional pillars like process and people and add related capabilities across the maturity phases. For the purpose of this white paper, capabilities are categorized as :

- **Analytics - Progressively mature the analytics capability from descriptive to predictive to prescriptive across phases.** In the tactical phase, focus on the descriptive nature of the analytics and generate reports to improve the visibility of the supply chain. In the strategic phase, incorporate AI/ML into the analysis, predict what might happen in the future, evaluate alternatives and take actions to mitigate potential future risks and disruptions. In the transformational phase, analytics will be more prescriptive in nature and recommend actions based on optimization algorithm
- **Data - Start with private and community data, the data that the customer is most familiar with and use it for their day to day operations and reporting needs. Progressively add external data in predictive and prescriptive phases.** Evaluate existing datawarehouse, datamarts and datalakes as potential sources because most often, private and community data to operate the supply chain are collected in these repositories . In the strategic phase, start adding public and Google data as applicable and as available from commercial data partners. Mature it further in the transformation phase and harmonize different data types to generate prescriptive insights
- **Tools - Leverage tools that the organization is familiar with today and use more advanced tools in the later phases of their journey.** In the tactical phase, SCDP will be solved for visualization use cases. Tools like Looker , PowerBI, etc can be leveraged in this phase to build end to end visibility dashboards. In strategic and transformational phases, with more predictive and prescriptive use cases, AI/ML tools and models like AutoML, Vertex AI and Generative AI can be leveraged. We recommend using a modern BI application that, besides its rich visual user interface, also enables a semantic modeling layer with enterprise wide governance.

- Insights - Start with insights based on historical data and real time / near real time data and progressively move towards prediction and prescription phases with insights based on probable future events.** In the tactical phase, with the descriptive nature of the analytics and more structured data, insights are more deterministic in nature and based on historical facts and/or real time / near real time data. In the strategic phase, with additional public and Google data in SCDP and with the predictive nature of the analytics, insights will be more stochastic and based on statistical analysis and machine learning algorithms of past events and probable future events. In the transformational phase, with prescriptive nature of the analytics, insights will be synergistic in nature and drive optimization across multiple dependent functions across the supply chain.

Maturity Phases		Descriptive	Predictive	Prescriptive
Capabilities	Tools	Use Datawarehouse and Datamarts	Use statistical analysis and machine learning algorithm	Use machine learning and AI driven operations optimization
	Insights	Deterministic (based on past events)	Stochastic (based on past events and probable future events)	Synergistic (based on optimization of decision algorithms)
	Data	Build Supply Chain Data Platform (SCDP) with private and community data	Enhance SCDP with public and Google data	Enhance SCDP with public and Google data
	Analytics	Descriptive (What happened)	Predictive (What might happen in the future)	Prescriptive (What should we do next)

Table 1 - Capability Maturity of the data driven Supply Chain Control Tower

Let's discuss examples of some common use cases from our Retail & CPG customers:

- Most often, these use cases were selected for their high value to complexity ratio.
- Like capabilities, these use cases will mature across phases
- In the tactical phase, the control tower will enable descriptive reporting and visibility for these use cases
- In the strategic phase, the control tower will generate alerts and route the workflow to the assigned stakeholders to take actions
- In the transformational phase, the control tower will recommend actions optimized for risk, value and the cost of alternatives

Maturity Phases		Descriptive	Predictive	Prescriptive
Example Use Cases	Inventory Management Use Cases	Inventory turnover , Safety stock levels, Days Inventory Outstanding etc	Alerts for stock out situations, impact of demand shaping on inventory levels, etc	Recommend inventory rebalancing
	Procurement Management Use Cases	Spend analysis, OTIF , Lead time analysis etc	Alerts for OTIF exceptions , lead time performance, etc	Recommend alternate sourcing
	Shop Floor Management Use Cases	Automatic measurements of manufacturing performance management	Alerts for non-compliance , line outage, low yields, etc	Recommend preventive maintenance

Table 2- Example Use Cases of the data driven Supply Chain Control Tower

For any digital transformation, along with technology, people and processes play a critical role. With changes in processes and technologies triggered by the transformation, there should be a change management program to support employees through the transition and enable them to adopt and use new technologies and processes.

Any analytics and insights are as good as the quality of data being collected in the supply chain data platform. Tools and processes should be in place to accelerate the data quality. Policies and stewardships should be defined and implemented to govern the data in the ecosystem.

Both Change Management and Data Quality / Data Governance initiatives are foundational in nature and pre-requisites for the success of the transformation to the data driven supply chain control tower. Like capabilities and use cases, these disciplines mature across phases but most often, being enablers, they establish the guard rails for use cases and capabilities to progress.

Considering all the above, recommended framework to approach the digital transformation of a data driven Supply Chain Control Tower is shown below :

		Change Management		
Capabilities	Tools	Use Datawarehouse and Datamarts	Use statistical analysis and machine learning algorithm	Use machine learning and AI driven operations optimization
	Insights	Deterministic (based on past events)	Stochastic (based on past events and probable future events)	Synergistic (based on optimization of decision algorithms)
	Data	Build Supply Chain Data Platform (SCDP) with private and community data	Enhance SCDP with public and Google data	Enhance SCDP with public and Google data
	Analytics	Descriptive (What happened)	Predictive (What might happen in the future)	Prescriptive (What should we do next)
	Maturity Phases	Descriptive	Predictive	Prescriptive
Example Use Cases	Inventory Management Use Cases	Inventory turnover , Safety stock levels, Days Inventory Outstanding etc	Alerts for stock out situations, impact of demand shaping on inventory levels, etc	Recommend inventory rebalancing
	Procurement Management Use Cases	Spend analysis, OTIF , Lead time analysis etc	Alerts for OTIF exceptions , lead time performance, etc	Recommend alternate sourcing
	Shop Floor Management Use Cases	Automatic measurements of manufacturing performance management	Alerts for non-compliance , line outage, low yields, etc	Recommend preventive maintenance
		Data Quality and Data Governance		

Table 3 - Transformation framework of a data driven Supply Chain Control Tower

Reference Architecture

Functional Reference Architecture

Based on the principles and the frameworks discussed above, our PoV on the functional reference architecture of a data driven Supply Chain Control Tower is outlined below (Fig 1). Please note that

- Every customer has a unique set of systems and processes that need to be taken into account
- This is a generic architecture and may differ from one customer to the next based on their specific environment, desired capabilities, current state maturity and future state aspirations
- Supply Chain use cases are progressively matured to align the learning curve of the data science team with AI/ML based solutions in the predictive and prescriptive phases of the maturity timeline

- Data is shown as a separate swim lane to reinforce the fact that during the tactical phase, when the analytics is descriptive in nature, the private and community data from organization’s existing ecosystem will suffice. As the control tower gets more matured in the strategic and the transformational phase, contextual public and Google data will be added to the mix to derive the intelligence out of it.

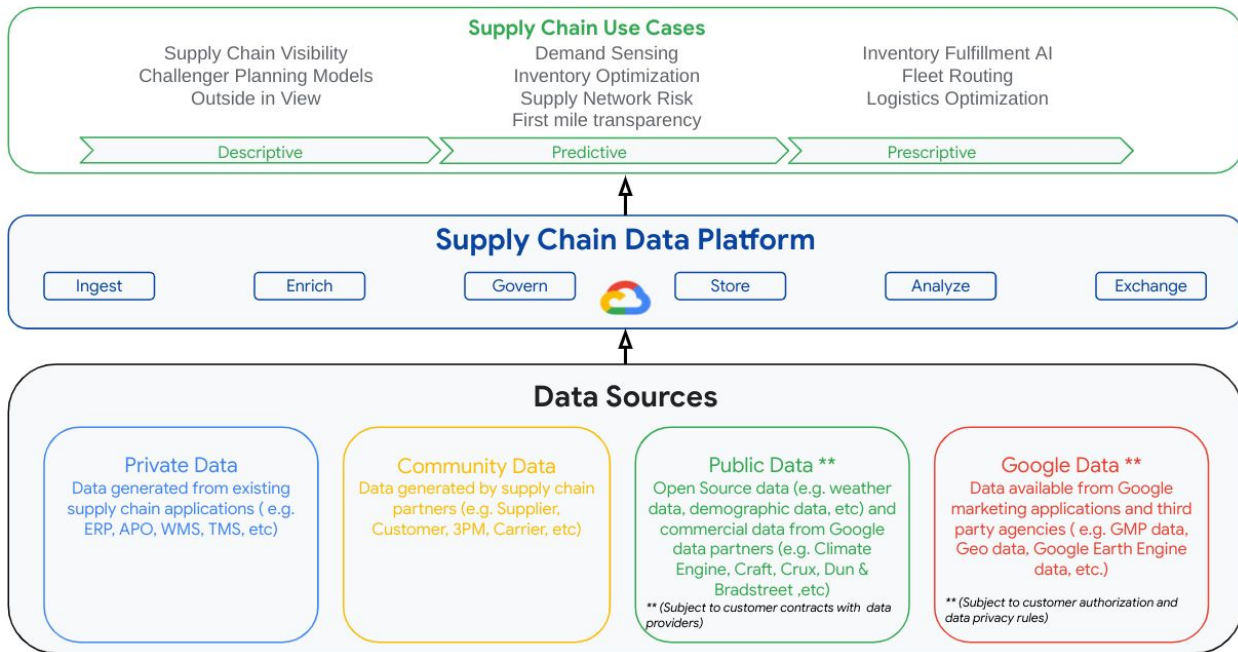


Fig 1 - Functional Reference Architecture of a data driven Supply Chain Control Tower

Technical Reference Architecture

Technical reference architecture maps GCP services to the functional architecture and provides a guideline on the Google Cloud tools and technologies that can be leveraged across different layers of the architecture. Basic building blocks of the architecture are as follows -

- Integration layer** - This includes all data management and data integration related GCP services required to ingest, process and store all private, community, public and Google data. Some potential GCP services include:
 - Dataflow - Streaming analytics for stream and batch processing
 - Pub/Sub - Messaging service for event ingestion and delivery
 - Datastream - Serverless change data capture and replication service
 - Cloud Composer - Workflow orchestration service
 - Apigee - API development, management and security platform
 - Data Fusion - Data integration for managing and building data pipelines
 - Data Catalog - Metadata solution for exploring and managing data
 - Dataprep - Service to prepare data for analysis and machine learning
- Data Platform layer** - This is the common data platform of the supply chain control tower acting as the single source of truth for all use cases and for all types of analytics. GCP services for this layer includes
 - BigQuery - Serverless data warehouse for business agility and insights
 - Analytics Hub - Service for securely and efficiently exchanging data
 - Looker - Platform for BI, data applications and embedded analytics
- Intelligence layer** - This is the AI/ML layer on top of SCDP to be leveraged for building advanced use cases in the predictive and prescriptive phases. GCP services for this layer includes
 - Vertex AI - Unified platform for training, hosting and managing ML models

- Visualization and Semantic layer** - This is the user interaction layer with dashboards, insights, alerts and recommendations to analyze, explore, visualize and act on the control tower outputs GCP services for this layer includes
 - Looker - Platform for BI, data applications and embedded analytics
 - Data Studio

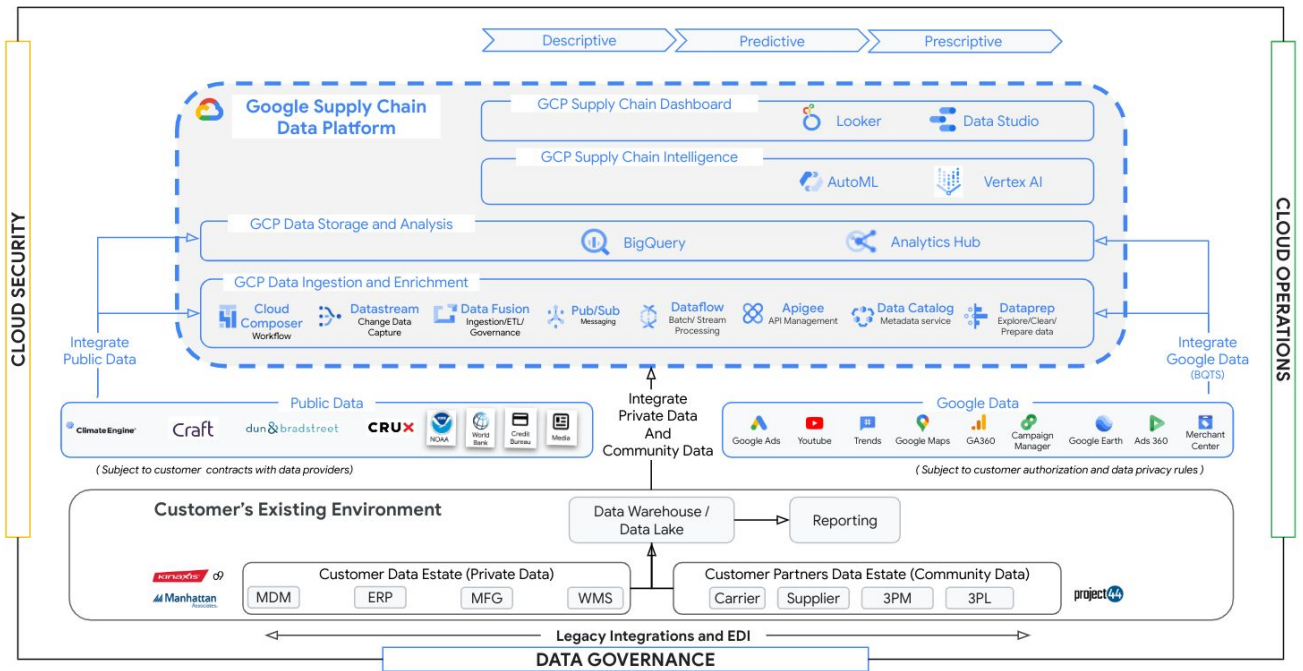


Fig 2 - Technical Reference Architecture of a data driven Supply Chain Control Tower

Conclusion

In this white paper we have discussed some principles, best practices, frameworks and reference architectures of the data driven Supply Chain Control Tower. While principles and best practices can be applied to multiple organizations, frameworks and reference architectures are generic in nature and need to be customized from one organization to the next based on multiple factors e.g. their current state and challenges, their urgency to undertake a digital transformation program and their willingness to modernize supply chain processes with data and machine learning technologies. Maturity of the organization’s supply chain digitization and its ongoing initiatives of cloud migration also mandates the customization of this reference architecture to fit with the organization’s transformation plan.

References

- <https://www.whitehouse.gov/cea/written-materials/2021/06/17/why-the-pandemic-has-disrupted-supply-chains/#:~:text=The%20situation%20has%20been%20especially,are%20likely%20to%20be%20transitory>
- https://www.apqc.org/system/files/resource-file/2022-02/K012318_2022%20SCM%20Priorities%20and%20Challenges%20White%20Paper.pdf

