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TRUE DEMAND FRAMEWORK FOR DEMAND AND INVENTORY TRANSPARENCY WITHIN SEMICONDUCTOR SUPPLY CHAINS

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ABSTRACT

Accurate demand forecasting is essential for the semiconductor industry to optimize production and meet customer needs. However, challenges like the COVID-19 pandemic, tariffs, and the Bullwhip Effect — the amplification of demand fluctuations along supply chains — create uncertainty and variability. While greater transparency and collaboration could help address these issues, reluctance to share sensitive data across supply chain tiers remains a significant barrier. We present the True Demand Framework for semiconductor supply chains to address these challenges. This framework includes a monthly end-to-end supply chain survey that ensures privacy for all tiers through Multi-Party Computation. The surveys capture key data to reduce variability and connect with annual surveys, linking semiconductor technology nodes to end-market demand. Results are mapped to the semantic Digital Reference model, ensuring interoperability with other surveys and external market data. This enables advanced forecasting and simulation models, improving demand and inventory planning across semiconductor supply chains.

1 INTRODUCTION

The semiconductor industry manages the challenge of up to six months of production cycle times, and the number of fabs available currently binds production capacity. The increase in capacity is capital-intensive; fabs cost billions of euros, and it takes years to build a new fab. The industry already operates 24/7 and has maximised production parallelisation. Consequently, more semiconductors can only be produced if new fabs are built. Therefore, accurate demand forecasts are integral to ensure the optimal production setup to achieve demand fulfillment and customer satisfaction (Frieske and S.Stieler 2022).

Additionally, external factors threaten semiconductor supply chains, e.g, trade wars or tariffs. This leads to a quickly changing market environment due to political decisions requiring an agile supply chain response. Demand disruptions like the pandemic introduce high variability to the market, which necessitates accurately forecasting demand to produce to the customers' requirements. As shortages develop with such disruptions, another phenomenon is amplifying it – the Bullwhip Effect. As shortages grow, buyers seek to guarantee their supply by ordering more than they need (tactical demand). This amplification of demand intensifies across the entire supply chain and affects especially semiconductor companies as they are further upstream in the supply chain (Udenio, Fransoo, and Peels 2015), preventing optimal production planning. As seen during the COVID-19 chip shortage, this disrupted supply chains globally. More transparency in demand and inventory is needed to flexibly handle the challenging environment and overcome shortages, such as the COVID-19 semiconductor shortage (Ghadir, Vandchali, Fallah, and Tirkolaee 2022).

2 RELATED WORK

A central part of the developed True Demand Framework is an industry-wide survey on leading and lagging indicators such as current demand, expected future demand, inventory, or order cancellations. The following section will introduce existing industry surveys such as the WSTS Survey, an industry survey by SEMI, and the Purchasing Manager's Index (PMI) by S&P Global. The three surveys analyzed below all involve an underwriter or third-party entity responsible for managing the data, which means that raw participant input is not entirely anonymous. This arrangement, however, facilitates the detection of outliers and potential manipulation more readily, enhancing the overall data integrity and reliability. By not relying solely on anonymity, these surveys balance maintaining participant confidentiality and ensuring data accuracy and authenticity.

2.1 WSTS

WSTS Inc. is a non-profit organization serving the semiconductor industry by collecting and publishing trade net shipments and industry forecasts. Funded by membership fees from semiconductor companies, WSTS gathers monthly revenue data through its committee of industry representatives. As a widely recognized and standard survey in the semiconductor sector, it enjoys high participation, providing comprehensive market insights. Reports are published monthly, with a one-month lag for data evaluation. Known for its frequency, accuracy, and detailed market coverage, WSTS forecasts are informed by collective industry expertise. Participants receive detailed revenue reports segmented by region and product classification, adhering to WSTS's standard classification system. The organization also conducts biannual market outlook surveys. While its detailed approach is advantageous, it poses challenges for specific projects. Data anonymity is strictly maintained, though not entirely independent of third-party involvement (WSTS 2025).

2.2 SEMI

SEMI, a leading microelectronics industry association, conducts an annual Semiconductor Industry Pulse Check survey with McKinsey, targeting its members and suppliers across the semiconductor supply chain. The survey addresses supply, production management, demand, and general implications using qualitative and quantitative questions. SEMI plans to make the survey biannual to better capture market dynamics (SEMI.org 2025).

The survey's advantages include comprehensive coverage of demand and inventory, high participation rates, and a focus on shortage causes, offering an end-to-end supply chain view with role-specific questions. However, its complexity and length may cause survey fatigue and withheld information. McKinsey's raises privacy concerns, as participants lack control over the use of their data. Participants receive a detailed analysis and a webinar invitation discussing results. Despite these benefits, privacy concerns and survey complexity may reduce data quality and completeness.

2.3 Purchasing Manager's Index by S&P Global

S&P Global's Purchasing Manager's Index (PMI) is a monthly survey of manufacturing, service, construction, and retail companies across over 40 countries. It monitors economic indicators like production output, orders, inventory, and pricing trends. Participants, including semiconductor manufacturers, receive unrestricted access to the data. The survey, completed online in a few minutes, focuses on qualitative questions about whether business conditions have improved, worsened, or remained the same compared to the previous month, with respondents explaining these changes. Diffusion indexes (0-100) are calculated, with 50 indicating no change, above 50 showing improvement, and below 50 showing deterioration (S&P Global 2024).

The PMI covers variables such as output, new orders, prices, and employment. Unlike the True Demand Framework survey, it spans multiple sectors and focuses on end-market relations rather than the supply chain, limiting its ability to capture the Bullwhip Effect. While it emphasizes sentiment and qualitative data, deeper analysis is needed for meaningful insights. Its broad participation enhances data reliability, but it lacks the quantitative and qualitative balance of the True Demand Survey.

3 UNDERSTANDING THE BULLWHIP EFFECT: BEHAVIOR & IMPACT

Small shifts in customer demand can cause large fluctuations in upstream orders, known as the Bullwhip Effect—first studied by Jay Forrester in the 1950s and widely recognized by the 1980s and 1990s (Lee, Padmanabhan, and Whang 1997). It arises when retailers, wholesalers, and manufacturers react to perceived demand changes with aggressive ordering, amplifying distortions that lead to overproduction, excess inventory, and inefficiencies.

While structural factors like long lead times, batch ordering, and lack of real-time data contribute, behavioral dynamics play a major role. Faced with uncertainty, retailers may inflate orders to secure stock (phantom ordering) (Sterman 2002), triggering artificial demand surges (Lee, Padmanabhan, and Whang 1997) (Cachon and Lariviere 1999) (Armony and Plambeck 2005). Emotional responses such as panic buying and fear of missing out exacerbate volatility (Forrester 2015) (Sterman and Dogan 2015), fueling cycles of overordering and shortages that harm supplier relations and production planning.

Addressing the Bullwhip Effect requires more than technical solutions like reducing lead times and improving forecasts. Cognitive bias-driven instability must also be tackled by enhancing transparency, adjusting incentives, and focusing on real demand signals (Forrester 2015).

4 SEMICONDUCTOR SUPPLY CHAIN

The semiconductor supply chain is highly susceptible to volatility, frequently magnified by the Bullwhip Effect and episodes of panic buying during macroeconomic or geopolitical uncertainty. These dynamics are further complicated by inconsistent measurement units (e.g., chips per device vs. units sold) and strategic information asymmetry across supply chain tiers. As a result, traditional forecasting methods—often based on historical averages or macroeconomic trends—fail to capture subtle, real-time demand signals, leading to recurring cycles of oversupply and shortages.

While GDP growth has traditionally served as a proxy for estimating semiconductor demand, this link is weakened by factors like shifts in consumer behavior, fiscal policies, and rapid technology adoption. Events such as the COVID-19 pandemic and U.S.–China trade tensions have disrupted conventional macroeconomic linkages, revealing the limitations of relying solely on aggregated indicators like GDP.

Semiconductor demand is more accurately shaped by a combination of inventory dynamics, capacity constraints, technological innovation cycles, and budgetary rhythms of key industries. For example, during periods of economic optimism, increased foundry investment can lead to temporary overcapacity, depressing prices and stimulating demand. However, fab construction lead times, often exceeding two years, create a mismatch between investments and market needs.

Traditional regression-based models, assuming stable relationships between macroeconomic variables and demand, are ill-suited for such a complex, dynamic environment. As (Liu 2005) emphasized, industry-specific variables better explain semiconductor cycles than general economic indicators. Their work introduced a 12-variable unrestricted Vector Autoregressive (VAR) model based on data from 1994 to 2001, demonstrating that inventory accumulation and fab capacity expansions strongly predict downturns.

To detect emerging demand disruptions, this study uses Isolation Forests for anomaly detection on a dataset combining WSTS data with key industry and macroeconomic indicators. These include inventory levels (e.g., Manufacturers' Total Inventories), capacity utilization in durable goods, market sentiment (NASDAQ, DJIA, Consumer Sentiment Index), and purchasing trends (JPM PMI). The goal is to uncover early warning patterns preceding market disruptions and assess the role of inventory behavior in semiconductor demand cycles.

Historical crises reveal that inventory levels reliably indicate significant changes in semiconductor market dynamics. During the dot-com bust and the global financial crisis, inventories dropped sharply, while the COVID-19 pandemic was marked by a significant inventory build-up. Inventory data provides a more timely signal than macroeconomic indicators due to its closer link to actual semiconductor demand.

Table 1: Detected anomalies and associated indicators over time

Date	Indicators with Anomalies
2000-12-01	Total Manufacturing Inventories (Computer Storage), JPM PMI, Consumer Sentiment, NASDAQ, SOX
2001-04-01	Manufacturers' Materials and Supplies Inventories, Total Inventories for Electronic Components, Capacity Utilization
2007-06	Capacity Utilization, Total Manufacturing Inventories (Computer Storage)
2008-09	Manufacturing Total Inventory, JPM PMI, VIX
2008-10	VIX, Consumer Sentiment, Capacity Utilization
2008-11	Capacity Utilization, PMI, Total Manufacturing Inventories
2008-12	Total Manufacturing Inventories, Capacity Utilization, JPM PMI, VIX
2019-01	Dow Jones, NASDAQ, Consumer Sentiment (mild anomaly)
2020-03 to 2020-06	VIX, Dow Jones, Consumer Sentiment, JPM PMI, NASDAQ (strong anomalies)
2021-07, 2021-11	Manufacturers' Total Farm Machinery Inventories, Total Manufacturing Inventories
2022-01, 2022-02, 2022-05	SOX, NASDAQ, Dow Jones Industrial Average
2023-12, 2024-01	SOX, Dow Jones Industrial Average, NASDAQ, Consumer Sentiment

While PMI or consumer sentiment reflect overall economic conditions, their relationship to semiconductor-specific cycles is less consistent. These variables may overlap with inventory and utilization trends, or exhibit lagged or contradictory responses. For instance, macroeconomic indicators declined sharply during COVID, yet semiconductor demand surged due to increased sales of electronics for remote work—a misalignment that would have been missed if relying solely on macro data.

This underscores the importance of monitoring both indicators, as they capture different aspects of market behavior. Downstream inventory behavior is the most trustworthy signal for upstream firms, directly influencing order patterns and capacity planning, making it a critical input for demand sensing.

In conclusion, while macroeconomic indicators provide helpful context, they cannot substitute for detailed inventory insights. Inventory dynamics—especially when benchmarked against company-set targets—offer a more actionable view of market shifts in the semiconductor supply chain.

The strong correlation between WSTS (T99) data and U.S. manufacturers' total inventories underscores the interconnectedness of semiconductor demand signals and inventory cycles. Both represent the input and output flows within the semiconductor supply chain, aligning with industry observations that "the business cycle, to a surprisingly large degree, is an inventory cycle." (Blinder 1986).

In conclusion, enhanced visibility into inventory levels across all echelons of the semiconductor supply chain could provide valuable insights into Bullwhip Effects as shown in Figure 1. It enables companies to identify behavioral shifts, such as global de-stocking (decreased inventories and demand) or herding behavior (increased inventories and demand).

5 TRUE DEMAND FRAMEWORK

The True Demand Framework aims to increase information exchange and transparency regarding demand and inventory, addressing issues within semiconductor supply chains. True demand refers to end market demand that flows through supply chain echelons,excluding echelon inventories and safety stocks. Thus, true demand does not reflect the tactical behaviour of companies. Based on the expertise of semiconductor

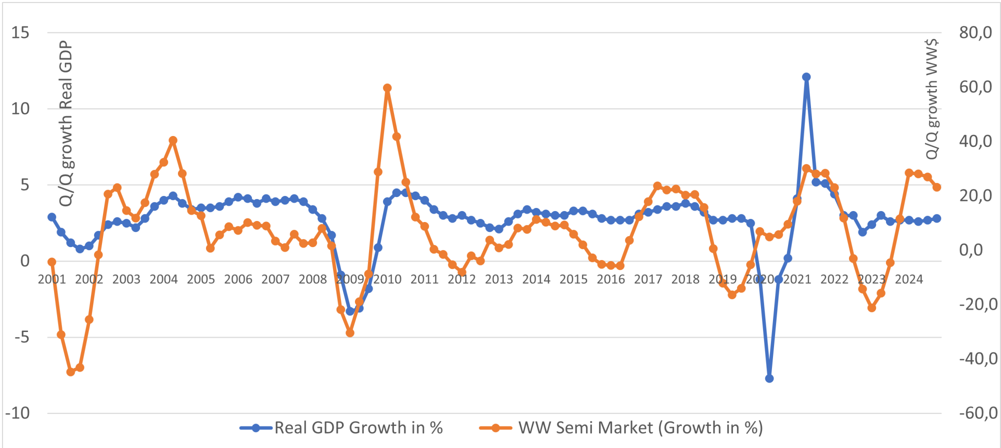

Figure 1: Bullwhip Metric – Real GDP compared to worldwide semiconductor market

manufacturers and a major semiconductor equipment manufacturer, a framework was specified and is outlined in the following section.

5.1 Framework Overview

Figure 2 depicts the core components of the framework: the MPC Survey, True Demand Knowledge Graph, Analytics, and Visualization Services.

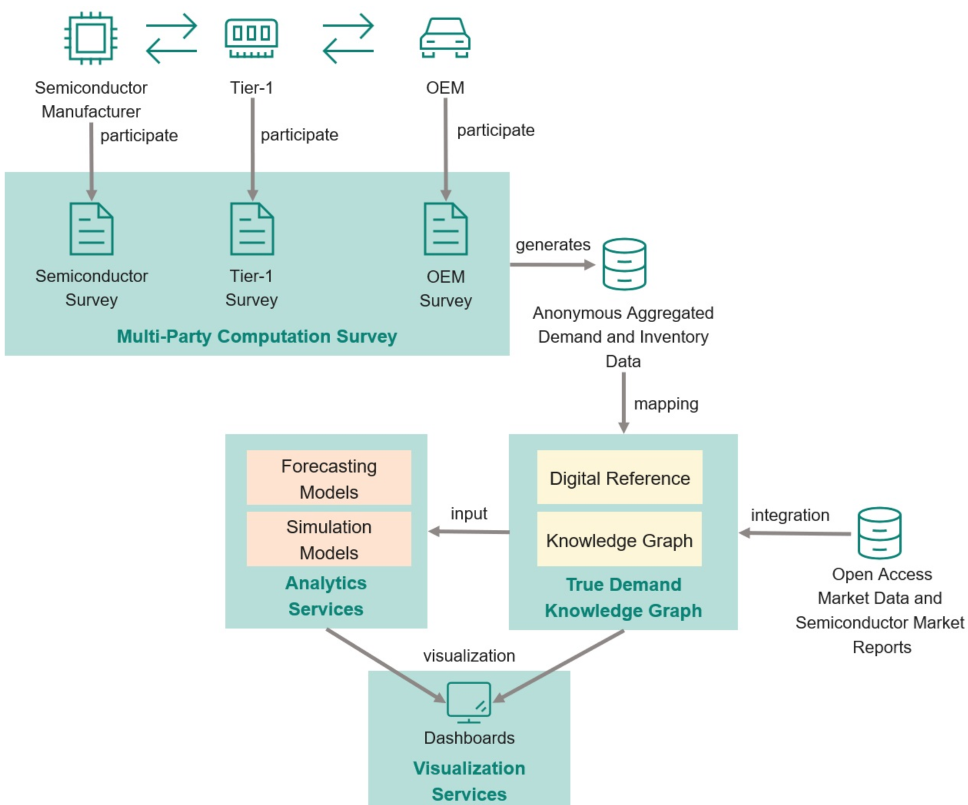

Figure 2: True Demand Framework.

At its core is a semiconductor supply chain survey, which aggregates information from each tier in the supply chain. Key tiers, such as semiconductor manufacturers, Tier-1, and OEM, need to be surveyed to capture the Bullwhip Effect dynamics and market shifts.

Surveys are evaluated with the MPC protocol, which aggregates demand and inventory information per supply chain tier. The surveys provide a connected view of demand and inventory across the supply chain. The DR model, an ontology for semiconductor and related supply chains, maps the data from the different surveys to a semantic description of the supply chain. As a result, a knowledge graph, called the True Demand Knowledge Graph, is generated. This graph and the DR support further analysis and benchmarking by integrating RDF open-access data sources or market reports such as WSTS and SEMI. Unlike isolated surveys, this approach enables integration across domains. The True Demand Knowledge Graph can improve forecasting and simulation models by providing up-to-date semiconductor supply chain data, market insights for system dynamics simulations, and traditional forecasting models. Finally, as part of the Visualization Services, pre-configured dashboards ensure that non-expert end users can explore, analyze, and filter various data extracted from the True Demand Graph.

5.2 Multi-Party Computation Survey

To address the issue of herding behavior, the incentives for submitting tactical demands must be removed. In the order system, companies inflate demand tactically, driving the Bullwhip Effect and its amplification along the supply chain. This inflation leads to allocating more semiconductors to ensure demand fulfillment, especially in a shortage situation such as the COVID-19 semiconductor shortage. The survey, therefore, needs to be decoupled from the order system, with inputs fully anonymized with MPC after entry so that companies can fill in the data without the fear of losing out on the supply of semiconductors. Anonymizing inputs of across supply chain tiers removes the incentive to inflate demand. However, MPC surveys are not immune to manipulation. Some actors may exploit anonymity to manipulate data, requiring algorithmic measures to detect such behavior and outliers.

MPC ensures distributed, anonymous computation of survey results without the need for a third party to see the raw inputs of the supply chain, breaking the trust of the participants. Inputs are encrypted and split into secret shares when they leave the company premises. Trusting the third-party hosting the survey is unnecessary. Participants only need to trust that the technical implementation is secure. Demand and inventory data are securely aggregated across inputs.

Third party-hosted surveys request distributed processing on independent, unbiased computing nodes to securely evaluate the final aggregated result. These nodes can represent semiconductor industry associations, which could also represent competing world regions or different tiers of the semiconductor supply chain, representing their specific interests.

5.3 Survey Specification

A minimalistic and lightweight survey design is mandatory for a monthly semiconductor demand and inventory survey to maximize industry participation and acceptance. Survey fatigue must be avoided, as organizations already respond to numerous quarterly, yearly, or on-demand surveys from suppliers, customers, associations, or government institutions. High participation ensures accurate and connected information from the various supply chain tiers, necessary for identifying Bullwhip events and market trends shifts. Overarching surveys, including the entire supply chain, ensure data transparency.

Survey Process By eliminating the need for third-party evaluation, survey results can be published almost instantly, offering up-to-date data with minimal delays. Traditional surveys with an underwriter require lengthy evaluation processes before finalizing results.

Filling in the survey and gathering data from the previous month still takes time, typically one to two weeks for semiconductor companies. For example, companies will complete the survey on the 15th by providing data for the last month. Survey results will be one to two weeks old, compared to traditional surveys, which take a month or more for evaluation. This is especially needed in a rapidly changing market environment and geopolitical challenges that significantly change semiconductor markets every month. The yearly survey at the beginning of the year gathers information for integration between supply chain tiers, such as relationships between technology nodes and product segments.

Participants For simplicity, three tiers are shown in Figure 2; however, additional surveys such as Outsourced Semiconductor Assembly and Test (OSAT), semiconductor distributors, or wafer equipment manufacturers will be needed for operational surveys within the industry. These contribute by filling in specialized surveys based on their tier and industry, targeting demand and inventory. Capturing different end-markets with specialized surveys is needed to capture the shifts in demand and inventory during Bullwhip events. An example is the demand shift from automotive to consumer electronics during the COVID-19-induced semiconductor shortage. Supply chain participants can only enter data once, but can overwrite their previous input if needed, as long as the survey has not closed.

Survey Granularity To further secure companies' data privacy and facilitate participation, anonymous surveys should include questions on a broader level, such as broader product groups or semiconductor nodes. This method enables more truthful answers compared to inflated demands. Finer-granularity surveys, such as surveying a specific type of car for automotive, would inflate the survey disproportionally. This is especially true for semiconductor manufacturers who manufacture thousands of different products. Answers are provided as percentage values compared to a baseline instead of using absolute values to facilitate information sharing even further while still allowing for the detection of trends. Broad-level data from the monthly surveys can be transformed into fine-granular data based on data from the yearly survey and semantic connections between the surveys.

Survey Integration Semantic models enable integration of monthly surveys for advanced analytics a Bullwhip mitigation. For this, more information from the semiconductor supply chain is needed. However, this should not be integrated into the monthly surveys as it would significantly increase the workload of filling in the survey. Furthermore, this information is not changing as fast as the demand, inventory, or the current state of order cancellations, which are monthly indicators.

Additional information will therefore be surveyed only once a year in a supply chain integration survey. The information from the yearly survey will be integrated into the semantic models to translate, break down, and analyze fine-granular monthly survey data.

6 SEMICONDUCTOR SURVEY

In the following section, we outline the design of the Semiconductor Survey as part of the MPC Surveys shown in Figure 2. The focus is set on the semiconductor manufacturers' questionnaire. Similar surveys are needed to capture the demand and inventory of other semiconductor supply chain tiers.

6.1 Demand

The survey focuses on two critical aspects of semiconductor demand. Firstly, the current demand of the semiconductor manufacturers is defined as the total demand in units from the market received in the last month compared to a baseline from the previous year. Secondly, the expectation of future demand is surveyed. For both the current and expected demand, the resulting value will be a percentage value indicating stagnation or an upward or downward trend, split by semiconductor technology nodes.

Figure 3 depicts an exemplary result from the current demand question with an upwards trend for all technology node categories except the 180-500nm category. The accompanying question is 'What is the total demand (units) from the market received in the last month compared to the average sales/billings of last year?'.

The current and the expected future demand can be referred to different baselines. For the current demand, it can be chosen between the average sales and billings of the last year, which has the advantage of smoothing seasonality by averaging over twelve months, or the sales and billings of the last month, which

Technology node category	Current Demand
2-7 nm	18,06%
10-16nm	21,86%
28-55nm	22,35%
65-150nm	18,54%
180-500nm	-15,98%

Figure 3: Current demand question.

indicates the most recent development. A stable baseline is recommended for the future expected demand question to ensure better comparability. A good option is to take the average demand in the quarter of the last full year as the baseline. However, using the last quarter as a baseline for the more recent development is equally possible. Inputs of the semiconductor manufacturers will be averaged in the MPC. No weighting will be applied in the calculation. A significant number of participants is needed to ensure anonymity, at an absolute minimum of five participants per technology node category. Otherwise, the nature of the average calculation would allow participants to deduce or estimate the inputs of the other semiconductor manufacturers. This would break the anonymity and hinder trust in the survey. With only two participants, each participant would be able to calculate the exact input of the other from the common average.

Figure 4 shows the expected demand for the currently active quarter and the upcoming seven quarters based on the question text "What is the expected future demand (units) from the market received in the next quarters compared to the average sales/billings of last year?". The temporal granularity is quarterly instead of monthly for the current demand to minimize the values that need filling in without losing too much detail. Expected demand can be compared to the semiconductor manufacturers' unbound sales and marketing forecast. It depicts the expectation of what can be sold, ignoring the capacity restrictions of the semiconductor manufacturer.

Technology node category	Current Quarter	Q2 2025	Q3 2025	Q4 2025	Q1 2026	Q2 2026	Q3 2026	Q4 2026
2-7 nm	6,67%	15,63%	-17,84%	9,21%	4,22%	5,32%	5,93%	8,81%
10-16 nm	-0,83%	1,68%	-8,17%	8,02%	-1,68%	4,24%	4,07%	4,69%
28-55nm	-2,22%	6,06%	1,43%	-9,15%	3,88%	1,49%	1,47%	3,62%
65-150nm	1,89%	1,23%	0,37%	4,74%	-4,76%	-0,24%	0,73%	7,64%
180-500nm	0,20%	0,30%	10,55%	-9,36%	0,10%	0,10%	-0,70%	-0,20%

Figure 4: Expected demand question.

6.2 Inventory

We aim to monitor relative inventory changes. These metrics can serve as early signals of demand-supply mismatches, strategic stockpiling, or under-ordering behaviors that often precede or result from Bullwhip dynamics. Inventory is defined as the finished goods stock in units for semiconductor manufacturers. The inventory target is set by the company individually and is thus anomalous. The current inventory is compared to the target inventory level on a product level. The defined questions are as follows: "How did the inventory (in units) of your company develop in comparison to the end of last month?", and, "Was the inventory (units) of your company at the end of last month below target level, at target level, or above target level?". Figure 5 shows an exemplary evaluation for the inventory question.

6.3 Order Cancellations

Certain phases, such as a shortage, order cancellations, and the trend of cancellations, can indicate tactical order behavior within the supply chain. Companies are ordering more than needed to ensure

Technology node category	Inventory Trend (to the end of last month)	Target Indicator
2-7 nm	Increase	At target
10-16 nm	Decrease	Above target
28-55nm	Increase	At target
65-150nm	Stable	Below target
180-500nm	Decrease	Above target

Figure 5: Inventory question.

demand fulfillment and are cancelling unnecessary phantom orders on short notice. Recognizing a spike in phantom orders early on can prevent unnecessary production ramp-ups at the semiconductor tier or misallocated capacity, which can be detrimental to supply chain performance with the long production times in semiconductor manufacturing. Similarly, identifying trends in stockpiling behavior can guide more targeted communication towards customers or company policy adjustments. Figure 6 depicts an exemplary question to depict the trend of order cancellations seen by the semiconductor manufacturers. The accompanying question text is "How did the order cancellations (units) your company received last month changed in comparison to last month?".

Technology node category	Order Cancelations (to the end of last month)
2-7 nm	Increase
10-16 nm	Decrease
28-55nm	Increase
65-150nm	Stable
180-500nm	Decrease

Figure 6: Order cancellations question.

7 TRUE DEMAND KNOWLEDGE GRAPH

The True Demand Framework is designed to enhance transparency and collaboration in semiconductor supply chains by leveraging advanced data integration and semantic technologies. A central component of this framework, as seen in Figure 2, is the True Demand Knowledge Graph, which aggregates data from anonymous surveys enriched with semantic models. This approach allows for efficient, joint analysis of demand and inventory data from various survey levels and includes external data sources to provide actionable insights.

Semantic technologies play a crucial role within this data ecosystem, providing several important benefits. Semantic technologies ensure that data from multiple surveys and supply chain tiers is interconnected and interoperable, facilitating seamless integration and analysis. They organize survey data into a structured, machine-readable format, enhancing transparency and enabling a unified representation of supply chain dynamics(Ramzy 2022)(Ji et al. 2022). This semantic layer supports additional functionalities, including:

- **Data Disaggregation** – Survey data mapped onto semantic models represents aggregated information of coarse granularity. Semantic models, enriched with inherent knowledge structures, enable the disaggregation of data, such as splitting demand and inventory information down to the country level.
- **Cross-Tier Information Exchange** – Semantic layer facilitates the translation of data between different units, such as technology nodes and market segments. This supports seamless communication and alignment between supply chain tiers, allowing for efficient demand analysis, optimization, and planning.

- **End-to-End Supply Chain Transparency** – By connecting data from multiple surveys, semantic technologies ensure an end-to-end depiction of the supply chain at the data level. This connectivity fosters a holistic understanding of supply-demand dynamics across all tiers.
- **Common Definitions and Aligned Data Structures** – Ontologies provide a standardized vocabulary and aligned definitions for survey data. This consistency reduces ambiguities, ensures data quality, and supports more reliable and accurate analysis.
- **Integration with External Data** – By linking survey data with external datasets, such as global trade data or market trends, semantic technologies allow for deeper and more comprehensive analyses. This capability enriches the survey data with additional contextual insights.

The True Demand Knowledge Graph is built upon the Digital Reference (DR 2025) (Ehm et al. 2019), a comprehensive semantic model for semiconductor and supply chains containing semiconductors. As a top-level model, the DR enables the integration of diverse industrial use cases and provides a foundation for extending the True Demand Knowledge Graph to other data-intensive applications. By being part of the DR ecosystem, the True Demand Framework can link seamlessly to additional external data sources, enabling more advanced applications and analyses.

8 APPLICATION OF THE FRAMEWORK

We outline the application of the framework depicted in Figure 2 on the example of the current demand question from the semiconductor survey. Values for the current demand are filled in for the technology node categories. Table 2 shows an exemplary input from three semiconductor companies (IDM) for the technology node category 10-16nm. After the survey closes, the inputs of the participants are averaged to a current demand change of 20.2% . Only the average, the result of the MPC, is used further, ensuring anonymity is ensured for the supply chain participants.

Table 2: Companies Survey Input for the current Demand

Company	Input Value (%)	Technology Node Category
IDM_1	5.0	10-16nm
IDM_2	35.0	10-16nm
IDM_3	20.6	10-16nm

The averaged demand is now assigned to classes from the ontology model, a process known as mapping. Figure 7 depicts a small example of the knowledge graph based on the ontology model. In this example, the true demand knowledge graph allows the transformation of technology node to market segments and vice versa. Table 3 outlines the split of the current demand across market segments for the node category 10-16nm retrieved from the yearly survey. This enables the survey data to be connected to other open access market data such as trade data from UN Comtrade, by mapping market segments to respective harmonized system (HS) trade codes. Figure 7 depicts the connection of survey data to trade data via market segments.

9 DISCUSSION

The True Demand Framework, while offering significant potential, faces several challenges that require attention to maximize its effectiveness. Translating survey data into nodes and market segments remains complex and demands standardization. Striking the right detail level in surveys is essential to balance participation ease with sufficient granularity for detecting trends and mitigating Bullwhip Effects. Additionally, limited participation and risks of data manipulation in an anonymous setting necessitate mechanisms for encouraging engagement and robust outlier detection methods.

Another limitation is the lack of fine-grained data for detailed analysis of bullwhip effects and inventory behavior, though semantic ontologies and knowledge graphs partially address this gap. Furthermore, while

Table 3: Market Segement Translation Table from Technology Node Category 10-16nm

Market Segment	Percentage Contribution (%)
Automotive	18.5
Consumer	15.5
Mobile Phone	25.0
Server/HPC	20.0
PC/Tablets	10.0
Communication Infrastructure	7.5
Industrial	3.5

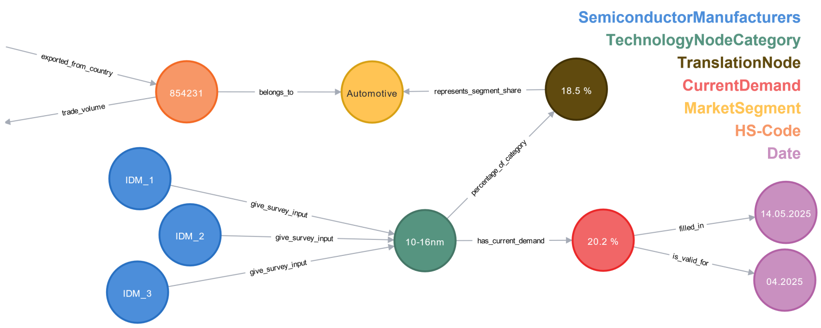

Figure 7: Knowledge Graph Use Case

semiconductor-related surveys are easier to design due to the generic nature of components, surveys for Tier-1 suppliers or OEMs are more challenging, as their unique market segments require tailored approaches. Overcoming these issues will be critical for the framework's broader adoption and impact.

10 CONCLUSION

Because of the significant challenges due to the Bullwhip Effect and panic buying in the semiconductor supply chain, traditional demand forecasting methods often fail to capture the nuanced and real-time demand signals to mitigate these effects and the periods of oversupply and shortages. Better insights into demand and inventory development are necessary. Referring to the Analysis above, more information can provide valuable insights into the Bullwhip Effect. Therefore, the goal of the True Demand Framework is to develop a comprehensive demand and inventory survey to increase the demand and inventory picture within the semiconductor supply chain. Taking it even a step further by proposing the True Demand Framework - as described above - with the survey as its core, the data then mapped by the DR into a semantic description of the supply chain, followed by the True Demand Knowledge Graph as a result. The knowledge graph can then be used for further analysis and benchmarking of the survey information, which can improve forecasting and simulation models by providing the most recent data from the semiconductor supply chain, improving future response of the semiconductor supply chains to disruptions.

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