Proceedings of the 2023 Winter Simulation Conference
C. G. Corlu, S. R. Hunter, H. Lam, B. S. Onggo, J. Shortle, and B. Biller, eds.

ASSESSING DELIVERY COMMITMENTS IN SUPPLY CHAINS: A MATRIX-BASED FRAMEWORK

Madhurima Vangeepuram
Stefan Faußer

Hochschule Neu-Ulm
Wileystr. 1
89231, Neu-Ulm, Bavaria, GERMANY

Hans Ehm
Marco Ratusny
Stefan Heilmayer
Tobias Leander Welling

Infineon Technologies AG
Am Campeon 1-15
85579, Neubiberg, Bavaria, GERMANY

ABSTRACT

Ensuring reliable and timely customer deliveries is crucial to supply chain management. The ability to meet delivery commitments is essential for maintaining customer satisfaction. Despite the importance of delivery commitments, there is a lack of standard measurement techniques for evaluating their quality. Therefore, this paper introduces the term Commitment Measurement (CQ) and develops a CQ matrix that can be used to measure the quality of delivery commitments. The CQ matrix provides a comprehensive set of quantitative measures to evaluate different aspects of delivery commitments. Finally, a numerical example based on an order data sample from a semiconductor manufacturer is presented and discussed. The proposed framework aims to standardize the CQ, enhancing transparency in delivery commitments.

1 INTRODUCTION

Globalization of Supply Chains (SCs) and intensive competition of firms have enabled companies to become more agile and specialize in improving their core competencies (Ehm et al. 2011; Seitz et al. 2016). Due to this global competition, companies have broadened their SC network to cater to the increased product and service complexity, outsourcing needs, and customer responsiveness (Harland et al. 2003; Blackhurst et al. 2008; Khan and Burnes 2007). However, this made the SC more complex and unstable with the demand uncertainties and delays (Kamalahmadi and Mellat-Parast 2015). For example, aircraft manufacturer Boeing had an estimated loss of 2.6 billion dollars due to two suppliers' failure to deliver critical parts on time (Radjou 2002). Hence, in today's market conditions, suppliers focusing on providing products reliably with commitments have gained importance among their customers to reduce SC impacts and keep the end-to-end supply chain in balance (Ehm and Ponsignon 2012).

Successful SC management includes effectively monitoring its processes through performance metrics where the everyday understanding, the processes, the algorithms in the IT systems, and the measured Key Performance Indicators (KPIs) on delivery commitments are synchronized. This is especially true in the semiconductor industry's global 365/24 manufacturing setup with its intrinsic long cycle time of up to six months, where the Available to Promise is vital for a high-level order management system. Performance metrics offer visibility and help assess the accuracy of execution performance (Chae 2009). Furthermore, to develop an efficient and flexible SC system, performance measurement is essential for the management in formulating future strategies (Gunasekaran et al. 2004; Cirtita and Glaser-Segura 2012). Although many companies have realized the importance of financial and non-financial performance measures, a balanced approach to metrics must still be included (Gunasekaran et al. 2004). In SCs, performance measurement metrics like on-time delivery, delivery at request date, delivery to commit date, and order fill lead time

979-8-3503-6966-3/23/$31.00 ©2023 IEEE

serve as KPIs for the customer service levels (Stewart 1995; Gunasekaran et al. 2004). Considering the dynamic nature of SCs, suppliers often face challenges like changes in customer orders, either requesting earlier due dates or changes in order quantities. The Supply Chain Operation Reference (SCOR) model provides KPIs for reliability measures such as Perfect order fulfillment, only considering the delivery as per 7 R's principle - the right product and/or service, the right quantity, the right condition, the right place, the right time, the right customer, and the right cost (APICS 2017). However, this measure limits the consideration of customer order changes to due dates and quantities in KPI measurement. This paper aims to study the changes in the delivery commits and quantities to identify different ways to measure commitment quality. This study provides transparency in measuring delivery commits and facilitates measurement flexibility for multiple commits. Furthermore, this paper explores multiple ways to measure the delivery commitments and proposes theoretical definitions and quantitative formulae, which are presented as a matrix. We further implement the matrix at Infineon with actual data and present the related results and discussion. The implementation and results from a global semiconductor manufacturer provide empirical evidence for various measurements for delivery commitments.

Section 2 of the paper presents a comprehensive review of the related work. In Section 3, definitions of commitment quality are introduced, and a standardized framework is proposed that provides a detailed discussion of various measurement levels. Section 4 illustrates the implementation of the framework and presents the results. Section 5 continues with a discussion of the results, and Section 6 concludes the paper and identifies the scope of future research.

2 RELATED WORK

In the field of supply chain management, the measurement and evaluation of a company's performance is essential for the assessment, control, and improvement of its operations. In this study, we propose using a matrix to accurately measure the accuracy of product deliveries based on different time steps. To this end, we conduct a literature review on delivery reliability and investigate various measurement methods. Handfield and Pannesi (1992) examine the impact of delivery speed and reliability on customer satisfaction in logistics management based on a survey of 91 manufacturing companies in the United States. In their study, the authors characterize delivery speed as the duration between when a customer order is received and when the final delivery is made. As for the definition of Delivery Reliability (DR), they adopt the one proposed by Hill (1989), which outlines it as the capability to deliver goods on or before the promised scheduled due date. The study's findings show that DR is more important than delivery speed regarding its impact on customer satisfaction. Furthermore, customers are more satisfied with reliable deliveries, even if they are not delivered as quickly as expected. The authors emphasize DR in logistics management since it greatly impacts customer satisfaction and can result in higher customer loyalty and repeated business. White (1996) contends that DR should be measured based on a company's ability to adhere to due dates. He presents several methods for measuring DR, such as perceived relative reliability or the percentage of on-time deliveries. Vachon et al. (2002) define reliability as "the ability of a firm to follow through on a commitment to a promised delivery date." According to Gunasekaran et al. 2004, performance measurement is essential for "setting objectives, evaluating performance, and determining the future course of actions." Sarmiento et al. (2007) analyze the relationship between DR, manufacturing capabilities, and new models of manufacturing efficiency. The authors argue that DR is a critical aspect of manufacturing efficiency and is closely related to the manufacturing capabilities of the organization. In this study, the authors adopt the definitions of delivery dependability provided by Leong et al. (1994) and Vickery et al. (1997). According to Leong et al. (1994), delivery dependability refers to the ability of a company to meet delivery schedules or promises. On the other hand, Vickery et al. (1997) define delivery dependability as the ability to meet quoted or anticipated delivery dates and quantities precisely. Forslund and Mattsson (2021) show in a survey of 224 purchasing managers in Swedish manufacturing companies that supplier flexibility is not being measured directly but rather measured in terms of DR which refers to orders delivered on confirmed or desired delivery dates. The survey also showed that 72% of suppliers measure DR based on the promised delivery date, while 28% consider it based on the desired delivery date, with the latter being seen as a better reflection of customer demands. Furthermore, the authors provided a broader definition of DR based on the point in the order-to-delivery process. They classify DR into four categories: Supplier DR at Order, Supplier DR after order confirmation, Supplier DR vs. confirmed delivery date, and Supplier DR at delivery vs. wished delivery date. While partially building upon Forslund and Mattson's (2021) study regarding delivery reliability, our research emphasizes CQ towards customers and its important levers to strengthen customer focus and keep commitments. Kamble and Gunasekaran (2020) emphasize the significance of DR, alongside various other performance measurements, in big-data-driven supply chains.

Additionally, the SCOR model, which aims to provide a standardized terminology for supply chain description, does not define DR. Instead, it uses the term "Reliability" as one of the core strategies to identify the performance of a supply chain. It defines it as "the ability to perform tasks as expected" (APICS 2017). In literature, other performance metrics, such as alpha, beta, and gamma service levels, are used to measure and evaluate a firm's performance in meeting customer demand. The alpha, beta, and gamma service levels are three different ways to measure the performance of a service. Alpha measures the likelihood of fulfilling all customer orders from available stock within a set time frame (Tempelmeier 2000). Beta measures the percentage of total demand promptly fulfilled from available stock. Gamma considers the number of backorders and the waiting times for those backordered demands, making it a measure that combines both time and quantity aspects of service performance. Although we included the alpha, beta, and gamma service levels in the literature review for the sake of completeness, it is worth noting that these performance measures are deemed less relevant in the context of our paper's focus on collaboration with customers.

While there is a large amount of literature on this topic, there is no agreed definition of these metrics, so a clear and concise definition is needed to aid accurate interpretations and applications.

The related work section has shown that the accurate measurement of customer deliveries is done in various ways, and no clear definition is available. Hence, we use the term CQ for all forms of reliability measurements. The developed CQ matrix provides a unified approach to measure delivery commitments in a unified metric for all types of industries by clearly defining all the steps and dates of an order, different scenarios, etc. By harmonizing these elements, the CQ matrix encapsulates a holistic approach, ensuring a unified framework that accommodates all industry types and their unique requirements.

3 COMMIT QUALITY AND VARIOUS LEVELS IN THE FRAMEWORK

In supply chain management, a commitment refers to a delivery promise made to customers. The ability to deliver orders within an agreed delivery window is called a CQ. Since each business operates within different characteristics of its supply chain, it is essential to recognize that a Business-To-Business (B2B) SC may differ in certain aspects from a Business-To-Customer (B2C) SC. Similarly, various industries have specific characteristics, such as those seen in semiconductor SCs, compared to e-commerce SCs, which are affected by factors like the used mode of transportation (e.g., air, sea, land). Therefore, establishing unambiguous reference and measurement standards for delivery commitments is vital. Building on the insights presented in Sections 1 and 2, it is evident that customers expect prompt responses to their orders, which have multiple commit dates, delivery times, and demand considerations. To address these complexities, we propose reference levels (as shown in Section 3.1) and measurement levels (as shown in Section 3.2) to categorize orders based on different measurement frequencies, granularities, and time periods.

3.1 Reference Levels

Reference Date:

The reference date is the considered due date to determine delivery commitments. The order must be delivered on or before the selected date while considering the delivery window to be deemed successful. A predetermined time frame in which the client can anticipate receiving their order is known as the delivery window. The First Commit Date (FCD), the Last Commit Date (LCD), and the Best Commit Date (BCD) are the three levels of reference dates we use to measure delivery commitments. The LCD is the most recent date committed, the BCD is the earliest date among the committed dates, and the FCD is the first date committed to the customer. When the order is delivered at any time during the delivery window, the commitment quality is met (e.g., between the 18th and the 22nd, as shown in Figure 1).

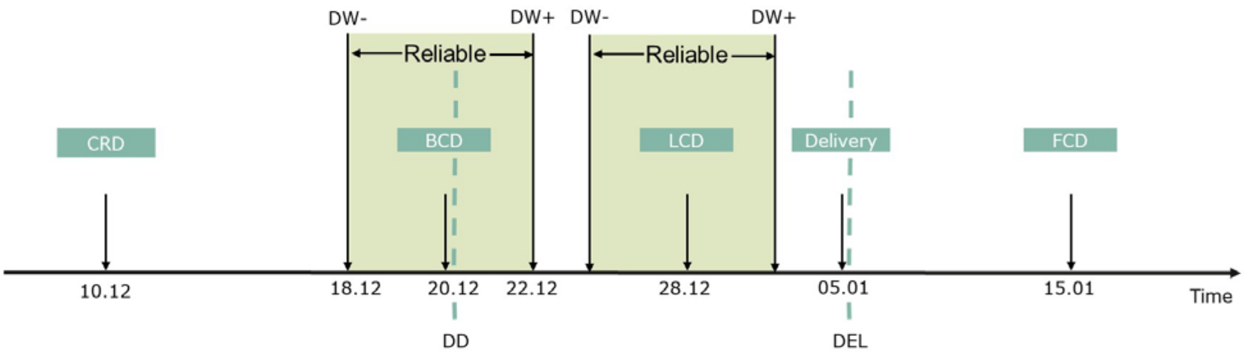


Figure 1: Levels of reference dates and reference time along with delivery window.

Reference Time:

The reference time is the moment at which the quality of a delivery commitment is evaluated. There are two levels of reference times: At the Due Date and Delivery (as shown in Figure 1). At Due Date, the delivery is assessed after the chosen reference date has passed, while at Delivery, the delivery is evaluated when the orders are shipped.

Reference demand:

The reference demand corresponds to a selected type when assessing the commitment quality. There are two levels of reference demand: Order (ORD) and Demand (DEM). Considering ORD, then deliveries are assessed for orders in a period (see Figure 2). Referring to DEM, deliveries are then evaluated for a specific period's demand volume. The key difference is that only backlogs (B) are considered at the ORD level. Backlog represents the build-up of unmet customer demand within a specific time period, which needs to be carried forward and considered as part of the demand in the subsequent period. Therefore, B is always equal to or greater than zero, indicating either unfulfilled demand or no backlog at all. In contrast, at the DEM level, orders from the current period, backlogs from the previous period, shipped orders (S), and pre-delivered orders (PD) from the current period are considered. Like B, the PD is always equal to or greater than zero. To calculate the Total Demand for a given period p, equation (1) is used, considering either (a) the existence of a backlog or (b) the existence of pre-deliveries. The backlog and predelivery for a period p are calculated using equations (2) and (3).

$$(a)\ DEM(p) = ORD(p) + B(p-1)\ (or)\ (b)\ ORD(p) - PD(p-1) \tag{1}$$

$$B(p) = \max\left(0, (DEM(p) + B(p-1)) - (S(p) + PD(p-1))\right) \tag{2}$$

$$PD(p) = \max\left(0, S(p) + PD(p-1) - (DEM(p) + B(p-1))\right) \tag{3}$$

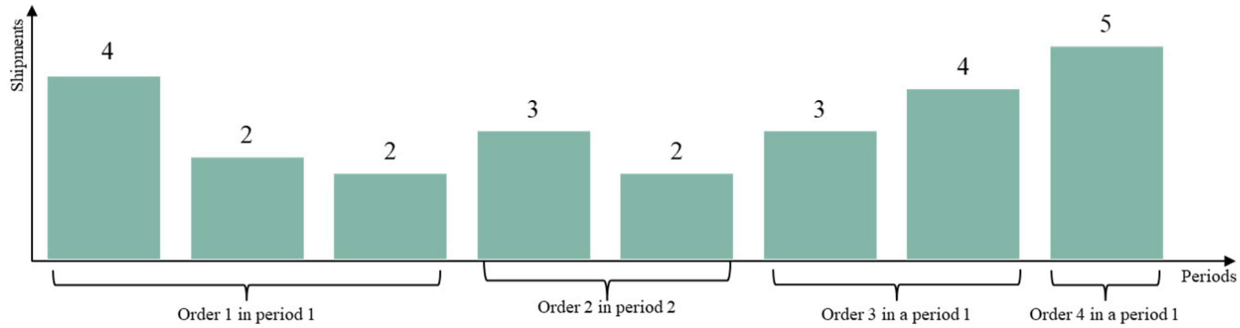


Figure 2: Order level.

3.2 Measurement Levels

Measurement Frequency:

The measurement frequency is a crucial factor in assessing the CQ of a SC, as it defines how often such assessment takes place. Two types of measurement frequency exist: Once (O) and Until Delivery (D). Measuring once means the deliveries are evaluated once at the selected reference date and measurement period. Measuring Until Delivery involves assessing deliveries regularly over a selected period until the order is successfully delivered. Therefore, we define the measurement frequency as follows: Let F represent the measurement frequency. It can take two possible values, $F \in \{O, D\}$.

Measurement Granularity:

The measurement granularity is a vital aspect of evaluating the CQ of a supply chain, and it determines the level at which such evaluations take place. Two levels are considered: Shipment and Delivered Volume (see Figure 3). Since orders often consist of multiple shipments, shipment evaluates the CQ at the level of each shipment. In contrast, delivered volume measures the CQ based on the total volume of pieces delivered. Thus, we define the measurement granularity as follows: Let G represent the measurement granularity. It can take two possible values, $G \in \{Shipment, Delivered\ Volume\}$. A Semiconductor Industry majorly requires full order deliveries. Partial deliveries may make the delivered quantities non-usable. Therefore, considering the importance of full deliveries, Figure 3 shows CQ as 0 when the entire order is not delivered. We further elaborate on partial deliveries in section 4.3

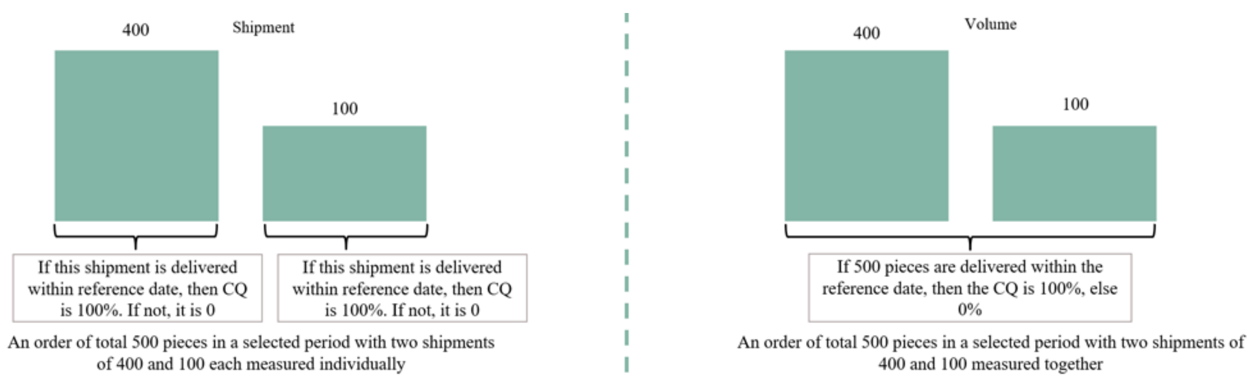


Figure 3: Levels of measurement granularity.

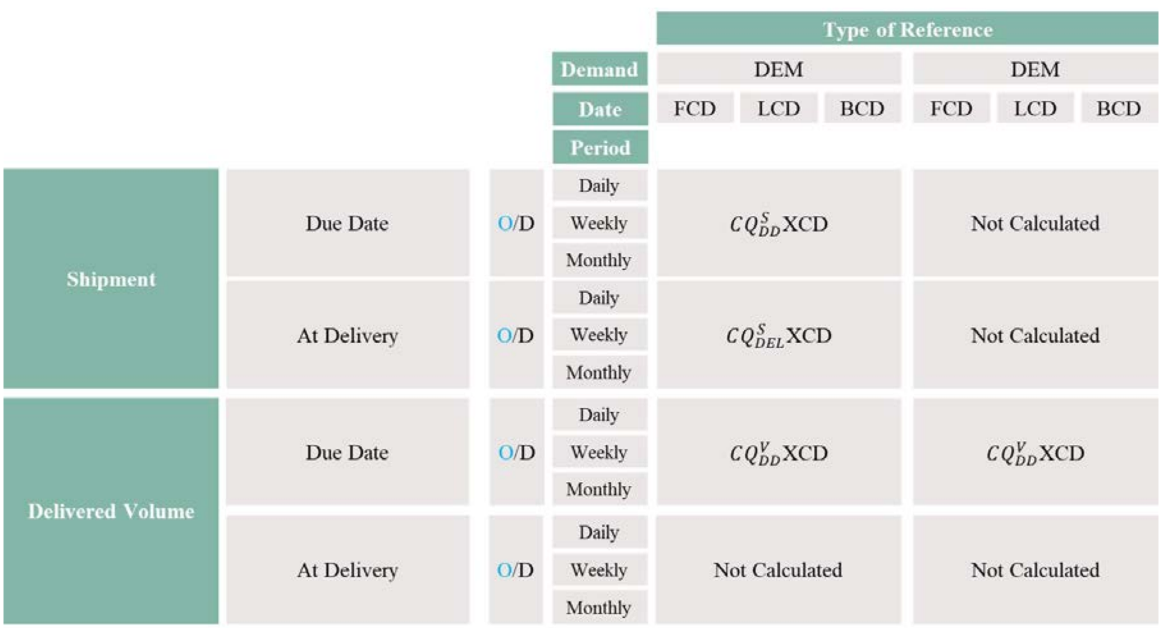
Measurement Period:

A measurement period is vital in supply chain management systems as it enables periodic data reporting (Gulledge 2008). It is combined with the reference demand, measurement frequency, and measurement granularity levels, as they require a time frame. For the reference demand, a period is utilized in both the ORD and DEM levels (see Figure 2). In the measurement frequency level, a period is employed to measure the CQ once during the selected period and until delivery are selected period intervals. In the measurement granularity level, a period determines a consolidated value, such as a daily/weekly/monthly consolidation of all shipments/delivered volumes. Thus, we define the measurement period as follows: Let P represent the measurement period. It can take several possible values, $P \in \{\dots, Day, Week, Month, \dots\}$.

3.3 Commit Quality Matrix

In this study, we present the CQ matrix (see Figure 4) as a framework for calculating the CQ of an SC. This matrix consolidates all the aspects discussed at various levels and provides a comprehensive summary. To simplify the use of the reference dates in the matrix, we refer to XCD, where X can be either (F)irst, (L)ast, or (B)est. The CQ of a supply chain can be measured at both shipment and delivered volume levels. In each of these levels, the measurement can be carried out at any date between the Due Date or Delivery. Additionally, a shipment can be measured at Due Date or Delivery once (O) or until delivery (D). When considering delivered volume, the measurement period is considered wherever valid.

The matrix offers a comprehensive view of the referent and measurement levels for delivery commitments discussed in Section 3. This framework provides the much-needed flexibility to select a CQ measurement that aligns with the changing needs of industries. As discussed in Section 2, the research gap is addressed by introducing the matrix, which serves as a standard framework for various CQ measurements.



				Type of Reference					
			Demand	DEM			DEM		
			Date	FCD	LCD	BCD	FCD	LCD	BCD
			Period						
Shipment	Due Date	O/D	Daily / Weekly / Monthly	CQ_{DD}^{S}XCD			Not Calculated		
	At Delivery	O/D	Daily / Weekly / Monthly	CQ_{DEL}^{S}XCD			Not Calculated		
Delivered Volume	Due Date	O/D	Daily / Weekly / Monthly	CQ_{DD}^{V}XCD			CQ_{DD}^{V}XCD		
	At Delivery	O/D	Daily / Weekly / Monthly	Not Calculated			Not Calculated		

Figure 4: Commit quality matrix.

4 IMPLEMENTATION AND RESULTS

4.1 Measurement Approach by Orders

In evaluating a supply chain's CQ, it is crucial to consider both the received and delivered orders. This involves the calculation of the CQ based on an order cycle, utilizing the shipment approach measured at Due Date with a reference date (XCD) as per equation (4). If a shipment is delivered within the reference date, its CQ is 100%. Otherwise, it is 0% until it is delivered. Shipments with a 0% CQ are added to the backlog, which affects the CQ calculation depending on the chosen measurement granularity. The measurement at this level can be further consolidated on a daily, weekly, monthly, or any other required period.

$$CQ_{DD}^{S}XCD = \frac{Total\ shipments\ delivered\ within\ reference\ date}{Total\ shipments\ delivered + Total\ shipments\ in\ backlog}$$
measured at any date between Due Date and at Delivery (4)

Evaluating the CQ of a SC per shipment at Delivery within a reference date (XCD) follows a similar approach to the earlier method. However, there is no consideration of backlog over a period. This is due to the measurement carried out only upon the delivery of the shipment. A shipment is assigned a 100% CQ if delivered within the reference date and 0% if the delivery surpasses the reference date. The calculation of this approach is given by equation (5).

$$CQ_{DEL}^{S}XCD = \frac{Total\ shipments\ delivered\ within\ reference\ date}{Total\ shipments\ delivered}$$
measured only at Delivery dates (5)

When measuring the CQ of a SC based on delivered volume, a period (p) is considered, as shown in Figure 3. This approach considers the entire order, which may consist of multiple shipments, and considers any backlog from previous periods. The calculation is performed using equation (6).

$$CQ_{DD}^{V}XCD = \frac{Volume\ of\ order\ delivered\ (p)}{Total\ volume\ of\ order + Backlog(p-1)}$$
measured at any date between Due Date and at Delivery (6)

Calculating CQ for delivered volumes is not possible at Delivery. This is because the volume approach considers a period for the calculation, whereas calculating at the point of delivery only pertains to the delivered orders.

4.2 Measurement Approach by Demand Period

To measure the CQ, it is necessary to consider the orders received and delivered within a given demand period (p) (see Figure 4). The measurement of the CQ by demand period is carried out exclusively at Due Date for delivered volume since the entire order is considered within this period. Equation (7) provides the calculation for the CQ by the demand period.

$$CQ_{DD}^{V}XCD = \frac{Total\ Demand\ fulfilled(p)}{Total\ Demand\ quantity\ (p) + Backlog\ Demand\ (p-1))}. \quad (7)$$

4.3 Implementation of the Matrix

To apply the CQ matrix in a practical setting, an order tracking tool has been developed in collaboration with a semiconductor manufacturer, which takes the order management (OM) data and calculates the CQ. This tool selects the relevant data fields based on domain knowledge. It identifies changes in Commitment Received Date (CRD), Forecasted Commitment Date (FCD), and Quantity (QTY) for each order line item. A unique identifier (UI) is created for each line item by concatenating the Order_ID and Line_Item. BCD and LCD are calculated for each line item based on the changes in commit dates and order quantities. CQ is then calculated at various levels of the matrix (see Figure 4) and presented as a percentage. An example of the CQ calculations using data from Table 1 is shown in Figure 5, where three orders are considered, with Orders 2 and 3 having multiple line items with different behaviors. Order 1 has a total quantity of 1000, Order 2 has 10500, and Order 3 has 130. Line item 2 in Order 2 is not delivered within the reference date but beyond 30.01.2022. In Section 5, we further discuss Order 2. Line item 2 in Order 3 is not delivered. All the orders are delivered within LCD, surpassing BCD. Deliveries at BCD make the CQ measured at FCD and LCD 0, and therefore, to have room for discussion between various measurements, the orders are considered to be delivered within LCD.

Table 1: CQ calculations for order shipments.

Order No	Order_ID	Line_ Item	QTY	FCD	LCD	BCD	Delivery date
1	1117371280	1	1000	18.01.2022	23.01.2022	05.01.2022	23.01.2022
2	1117371281	1	500	13.01.2022	25.01.2022	08.01.2022	23.01.2022
		2	10000	18.01.2022	23.01.2022	05.01.2022	not delivered
		2	10000	18.01.2022	23.01.2022	05.01.2022	30.01.2022
3	1117371282	1	100	25.01.2022	18.01.2022	11.01.2022	17.01.2022
		2	30	25.01.2022	21.01.2022	13.01.2022	not delivered

In this section, we examine the obtained results from the matrix for different reference types, namely ORD and DEM. At the ORD level, the CQ is calculated per shipment at FCD, LCD, and BCD according to equation (4). At the shipment level for Due Date and FCD, the CQ is found to be 20%, as only one shipment (Order 3, Line item 1) is delivered within FCD out of the total of four shipments, including one backlog (Order 3, Line item 2). Although line item 2 of order 2 is in backlog, it is delivered before the end of the month and is considered in four deliveries. CQ calculated at the point of delivery does not consider the backlog, resulting in a CQ of 25%. Similarly, CQ calculated at the Due Date and LCD correspond to 60%, as three shipments are delivered within LCD (Order 1, Line item 1 in Order 2 and Order 3 respectively) out of the four delivered shipments, with one backlog (Order 3, Line item 2). At Delivery, the CQ is 75%. CQ for delivered volume at Due Date is calculated using equation (6). Line item 1 of Order 3 is the only volume delivered within FCD, and its CQ is 77%. For all other orders, CQ corresponds to 0 as there are no deliveries within FCD. CQ at LCD for Order 1 corresponds to 4.7%, as only 500 out of 10,000 are delivered within LCD. CQ for Order 3 is 77%, as 100 out of 130 are delivered within LCD. The consolidated CQ for delivered volume measured at Due Date and LCD is 30.28%. At the DEM level, the total delivered order volume is compared against the total demand for the selected period. In Table 1, a monthly demand period is assumed with no backlog from the previous demand period, where 100 out of the total demand of 10,730 are fulfilled at FCD, corresponding to a CQ of 0.93%, and 700 are fulfilled within LCD, resulting in a CQ of 6.5%.

				Type of Reference					
			Demand	DEM			DEM		
			Date	FCD	LCD	BCD	FCD	LCD	BCD
			Period						
Shipment	Due Date	O/D	Daily Weekly Monthly	20%	60%	0%	Not Calculated		
	At Delivery	O/D	Daily Weekly Monthly	25%	75%	0%	Not Calculated		
Delivered Volume	Due Date	O/D	Daily Weekly Monthly	12.8%	30.25%	0%	0.93%	6.5%	0%
	At Delivery	O/D	Daily Weekly Monthly	Not Calculated			Not Calculated		

Figure 5: Implementation of CQ-Matrix.

5 DISCUSSION

The discussion focuses on comparing different measurement levels introduced in Figure 4 and presented with data from Table 1 in Figure 5. Calculating the CQ at different levels in the matrix results in varying quantitative results, which we discuss in detail, highlighting the significance of choosing an appropriate measurement approach. Furthermore, the discussion also addresses the issue of whether a low CQ measurement is accurate or not. Handfield and Pannesi's (1992) study identified that an effective forecasting system is vital for achieving high CQ. Hence, forecast accuracy is crucial in measuring CQ, as Hallikas et al. (2002) reported. Customers often make forecasts based on a worst-case scenario to ensure supplier deliveries to avoid stock-out situations. However, inaccurate forecast accuracy can weaken CQ measurements (Hallikas et al. 2002). Thus, selecting a suitable measurement approach depends not only on the degree of CQ in each level in Figure 4 but also on the SC infrastructure of an organization and overall customer expectations.

The results of Figure 5 show that calculating the CQ at different levels for the same data results in different outcomes. The example data in Table 1 considers only orders delivered at LCD since measuring CQ for orders delivered at BCD gives a 100% score, as it is the earliest commit date. When FCD is less than LCD, measuring the CQ at FCD or BCD gives a 0% score, while measuring at LCD results in a 100% score, as the delivery surpasses FCD and BCD. Similarly, if FCD is greater than LCD, measuring at FCD or LCD gives a 100% score, while measuring BCD results in a 0% score since the delivery has surpassed BCD. Figure 5 shows that CQ measured at LCD (60%, 75%, 30.28%) is greater than that measured at FCD (20%, 25%, 12.8%) as most orders are delivered within LCD. Measuring at BCD is ideal since it reflects the earliest commit date, even though the score might be low. It is vital to measure CQ at BCD to showcase how well the SC is keeping up with commits, which can improve customer satisfaction. However, LCD serves as a contingency plan for orders with legally binding contractual penalty clauses to mitigate any losses resulting from non-deliveries at BCD. Therefore, we recommend prioritizing the reference dates in the following order: BCD, LCD, and FCD for the semiconductor industry.

The measurement approach employed in SC management can significantly impact the accuracy of the results obtained. One of the measurement approaches is the comparison between measuring at Due Date and at Delivery. Measuring at Due Date considers backlogs, whereas measuring at Delivery does not (see Order 2 in Table 1). As a result, the CQ at Due Date is less than at Delivery on the shipment level in Figure 5. This is because the backlogs are not considered when measuring at Delivery. In other words, undelivered shipments are not included in the calculation until delivery and are given a value of 0% when delivered outside the XCD. Measuring at Delivery is more suitable for highly customizable and low-supply products. However, it creates an unwanted positive impact by not considering backlogs. Thus, it does not provide an accurate picture of the situation for mass-produced items.

Regarding measuring at the order level, there are two methods: shipment and delivered volume. Measuring at the shipment level does not consider the order volume, whereas measuring for delivered volumes considers the actual volume of the order delivered from the total order volume. As a result, the CQ measured for order volumes (12.8%, 30.28%) is typically less than the shipment level (20%, 60%) (as seen in Figure 5). In the semiconductor industry, customers often expect full order delivery for certain products, and partial order deliveries may render the delivered parts unusable for their requirements. Thus, it is vital to prioritize orders with high volumes (QTY of Order 2, Line item 2 in Table 1) since non-deliveries of such orders could significantly reduce the CQ and negatively impact customer satisfaction.

Measuring at the DEM level for delivered volume at Due Date is a complex process considering various factors, including current orders, backlogs from previous periods, pre-deliveries, and deliveries in the current period. As a result, measuring demand at the shipment level is impossible since this does not consider the total volume of orders. Similarly, measuring at the delivery level is not feasible since it considers only a specific period. In comparison, measuring at the DEM level allows for a more comprehensive understanding of order volumes. Planned demand is considered in this paper, as only confirmed orders are considered. Our analysis indicates that when all orders are considered as a single entity in the DEM period, the resulting CQ on the ORD level is lower than the CQ on the DEM level since the multiple orders are considered on the ORD level.

The proposed framework in this paper (see Figure 4) allows organizations to choose the measurement that best suits their SC processes and infrastructure. It also aims to standardize the CQ, enhancing transparency in delivery commitments. From a business perspective, we offer managers the flexibility to select an appropriate measurement for various scenarios in their SC with the CQ matrix. For example, customer-facing managers may opt for an ORD level measurement to gain a more granular view. In contrast, managers in decision-making roles requiring a high-level perspective can choose the DEM level measurement.

6 CONCLUSION AND OUTLOOK

This study has investigated the current methods used in SC management to measure delivery reliability, delivery performance, and customer satisfaction. A literature review has shown a need for suitable measures of delivery commitments and a clear and consistent definition of the involved metrics. To address this issue, we have proposed the Commit Quality Matrix (CQM), which provides a framework to measure the commitment quality of a SC along with its customizable reference levels (date, time, demand) and measurement levels (frequency, granularity, period). Furthermore, an order tracking tool was developed at Infineon that generates this matrix. In the results with real data, the choice of the levels of the matrix and their different outcomes were discussed. The framework provides a standard method to assess delivery performance and ensures customer satisfaction. Its flexibility allows it to meet different industries' specific needs, such as B2B or B2C. The framework provides the management with a comprehensive perspective on the various levels of measurement, enabling them to choose the one that best fits their particular infrastructure.

Although this paper limits the results to only the Monthly view, the proposed framework can significantly improve the accuracy and effectiveness of customer engagement efforts and become a widely adopted standard in the SC industry. By providing a transparent and standardized approach, organizations can more effectively allocate resources and focus on what truly drives engagement. The framework may need to be updated as SCs evolve. Moving forward, it is hoped that this framework will become widely adopted and contribute to the continued success of customer engagement efforts.

REFERENCES

APICS. 2017. *APICS Supply Chain Operations Reference Model SCOR Version 12.0*. http://www.apics.org/docs/default-source/scor-p-toolkits/apics-scc-scor-quick-reference-guide.pdf accessed 12th February 2023.

Blackhurst, J. V., K. P. Scheibe, and D. J. Johnson. 2008. "Supplier Risk Assessment and Monitoring for the Automotive Industry". *International Journal of Physical Distribution & Logistics Management* 38(2):143-165.

Chae, B. 2009. "Developing Key Performance Indicators for Supply Chain: An Industry Perspective". *Supply Chain Management* 14(6):422–428.

Cirtita, H., and D. A. Glaser-Segura 2012. "Measuring Downstream Supply Chain Performance". *Journal of Manufacturing Technology Management* 23(3):299–314.

Ehm, H., and T. Ponsignon. 2012. "Future Research Directions for Mastering End-To-End Semiconductor Supply Chains". In *Proceedings of the Automation Science and Engineering 2012 International Conference*, August 20th – 24th, Seoul, South Korea, 641–645.

Ehm, H., T. Ponsignon, and T. Kaufmann. 2011. "The Global Supply Chain is our New Fab: Integration and Automation Challenges". In *Proceedings of IEEE/SEMI Advanced Semiconductor Manufacturing 2011 Conference*, May 16th – 18th, Saratoga Springs, New York, United States of America, 1–6.

Forslund, H. and S.-A. Mattsson. 2023. "In Search of Supplier Flexibility Performance Measurement". *International Journal of Productivity and Performance Management*. 72(3):772-788.

Gulledge, T. and T. Chavusholu. 2008. "Automating the Construction of Supply Chain Key Performance Indicators", *Industrial Management & Data Systems*. 108(6):750-774.

Gunasekaran, A., C. Patel, and R. E. McGaughey. 2004. "A Framework for Supply Chain Performance Measurement". *International Journal of Production Economics*. 87(3):333-347.

Handfield, R.B. and R.T. Pannesi. 1992. "An Empirical Study of Delivery Speed and Reliability", *International Journal of Operations & Production Management*. 12(2):58-72.

Harland, C., R. Brenchley, and H. Walker. 2003. "Risk in Supply Networks". *Journal of Purchasing and Supply Management* 9(2): 51–62.

Hill, T. 1989. *Manufacturing Strategy Texts and Cases*. 1st ed. London: Red Globe Press.

Kamalahmadi, M., and M. Mellat-Parast. 2015. "Developing a Resilient Supply Chain Through Supplier Flexibility and Reliability Assessment". *International Journal of Production Research*, 54(1):302-321.

Kamble, S., and A. Gunasekaran. 2020. "Big Data-Driven Supply Chain Performance Measurement System: A Review Framework for Implementation". *International Journal of Production Research* 58(1):65-86

Khan, O., and B. Burnes. 2007. "Risk and Supply Chain Management: Creating a Research Agenda". *The International Journal of Logistics Management* 18(2):197–216.

Leong, G.K., D.L Snyder, and P.T. Ward. 1990. "Research in the Process and Content of Manufacturing Strategy". *Omega*. 18(2):109-22.

Radjou, N., L.M. Orlov, L. and T. Nakashima. 2002. "Adapting to Supply Network Change". *Forrester Research Inc*.

Sarmiento, R., M. Byrne, L. Rene Contreras, and N. Rich. 2007. "Delivery Reliability, Manufacturing Capabilities and New Models of Manufacturing Efficiency". *Journal of Manufacturing Technology Management*. 18(4):367-386.

Seitz, A., H. Ehm, R. Akkerman, and S.Osman. 2016. "A Robust Supply Chain Planning Framework for Revenue Management in the Semiconductor Industry". *Journal of Revenue and Pricing Management* 15(6):523–533.

Stewart, G. 1995. "Supply Chain Performance Benchmarking Study Reveals Keys to Supply Chain Excellence". *Logistics Information Management.* 8(2):38-44.

Supply Chain Council. 2017. Supply Chain Operations Reference (SCOR) Model Overview – Version 12.0. Accessed 16th January. 2023.

Tempelmeier, H. 2000. "Inventory Service-Levels in the Customer Supply Chain". *OR Spektrum*. 22:361–380.

Vachon, S., and R. Klassen. 2002. "An Exploratory Investigation of the Effects of Supply Chain Complexity on Delivery Performance". *IEEE Transactions on Engineering Management*. 49(3):218-230.

Vickery, S.K., C. Droge, and R.E. Markland. 1997. "Dimensions of Manufacturing Strength in the Furniture Industry", *Journal of Operations Management*. 15:317-30.

White, G.P. 1996. "A Survey and Taxonomy of Strategy-Related Performance Measures for Manufacturing". *International Journal of Operations & Production Management*.16(3):42-61.

AUTHOR BIOGRAPHIES

MADHURIMA VANGEEPURAM is a Master Thesis student in the Corporate Supply Chain Organization of Infineon Technologies AG, Munich. She received her Bachelor's in Information Technology and is currently pursuing M.Sc in Business Intelligence and Business Analytics at Hochschule Neu-Ulm University of Applied Sciences. Her research interests focus on order management and analytics. Her email address is madhurima.vangeepuram@student.hnu.de.

HANS EHM is Senior Principal Engineer at Supply Chain of Infineon Technologies AG. He has been in the semiconductor industry for four decades in multiple positions. He is heading the Supply Chain Innovations department at Infineon for more than a decade. His research interest is in Supply Chain Innovations. His email address is hans.ehm@infineon.com.

MARCO RATUSNY is a Ph.D. candidate in the Corporate Supply Chain organization of Infineon Technologies AG in Munich. He received his B. Sc. (2018) in Information Systems and Management and his M. Sc. (2020) in Stochastic Engineering in Business and Finance at the University of Applied Sciences Munich, Germany. His research interest is in demand planning and machine learning. His email address is marco.ratusny@infineon.com.

STEFAN FAUßER is a Professor of data analytics and course director of B.Sc in Data Science Management at the University of Applied Sciences Neu-Ulm, Neu-Ulm, Germany. He studied computer science at Ulm University and received his doctoral degree in 2015 from Ulm University. His research interests are machine learning, artificial Intelligence, and particularly speech emotion recognition. His email address is Stefan.Fausser@hnu.de.

STEFAN HEILMAYER is Principal Engineer at Supply Chain of Infineon Technologies AG and holds a master's in computer science from Technical University of Munich. He worked on various supply chain excellence projects and is currently the process owner of the Infineon mid-term supply chain planning process. His research interest is in Supply Chain modeling, simulation, and KPIs. His email address is stefan.heilmayer@infineon.com.

TOBIAS LEANDER WELLING is a Ph.D. candidate in the Corporate Supply Chain organization of Infineon Technologies AG in Munich. He received B.Sc. (2021) in Business Administration and Electrical Engineering and M.Sc (2023) in Business Administration and Electrical Engineering from RWTH Aachen University, Germany. His research interest is inventory management and machine learning. His email address is tobiasleander.welling@infineon.com.