Introduction to Operation Management

030 **Deliver**

2 Capacity management

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Capacity management

Capacity management entails comprehending the interplay between an operation's demand and supply and resolving any discrepancies between them. This involves predicting demand, evaluating the ability to provide products and services, and selecting appropriate strategies for managing both demand and supply in line with performance objectives and long-term strategies. Operations managers must juggle two opposing priorities: ensuring customer satisfaction by delivering services and products promptly, and maintaining efficiency by reducing the costs linked to surplus capacity. This balance is essential because capacity management impacts both revenue and expenses, thus affecting profitability (or the overall effectiveness of service delivery in non-profit settings).

We examine these competing priorities from a broad perspective. At this level, managers aggregate different products and services to gain a general understanding of demand and capacity. For example, a car rental company might assess demand and capacity in terms of "car rental days per month." Although this method does not account for the specific types of cars rented or the individual preferences of each customer, it provides a useful initial estimate.

Key questions
What is involved in managing capacity?
How is demand measured?
What techniques are employed to measure capacity?
How can demand be efficiently managed?
What approaches are utilized to manage the supply side?
How can operations evaluate the effects of their capacity management decisions?

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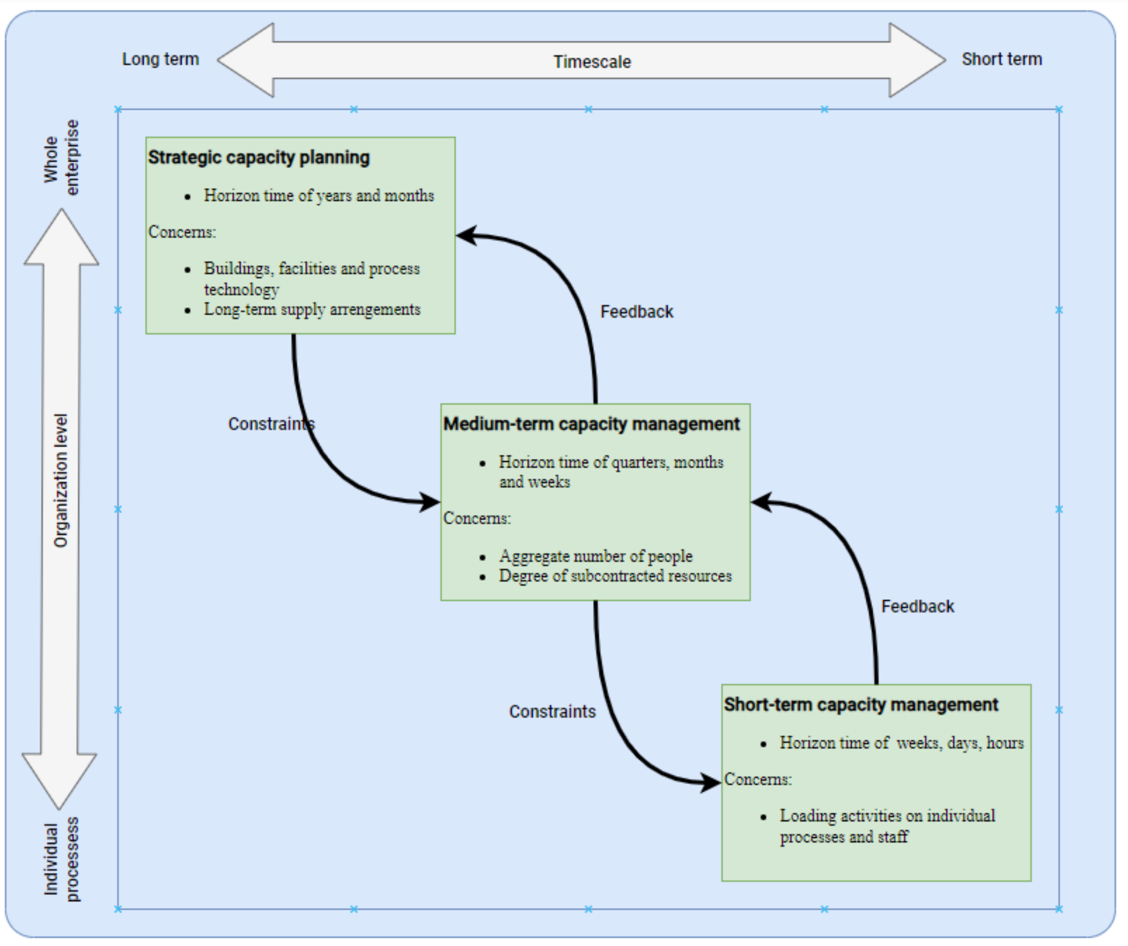
What is capacity management?

Capacity management involves understanding the nature of demand and supply (capacity) and working to reduce the gaps between them, balancing the dual priorities of customer satisfaction and resource efficiency. These decisions are made within the operational constraints, such as supplier capabilities, staff availability, and other factors. As a result, each capacity decision is shaped by higher-level constraints. On the other hand, short-term decisions provide important insights for planning over longer periods.

Previously, we examined long-term capacity decisions related to the structure and scope of operations, as well as short-term capacity decisions involving task allocation, sequencing, and resourcing. Now, we focus on the medium-term aspects of capacity management. This involves making decisions within the physical capacity limits set by the operation's long-term capacity strategy. Medium-term capacity management usually involves assessing demand forecasts over a 2 to 18-month period, during which planned output can be modified, such as by changing the number of hours resources are used. However, in practice, forecasts are rarely completely accurate, requiring adjustments to demand changes that occur over shorter periods, known as short-term capacity management. For example, hotels and restaurants face unexpected and seemingly random demand fluctuations from night to night, but they also know from experience that certain days are generally busier than others.



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Objectives for Capacity Management Performance

The choices made by operations managers when developing their capacity plans impact various performance aspects:

- Costs: These are influenced by the relationship between demand and capacity. If capacity exceeds demand, it can lead to underutilization and higher unit costs.
- Revenues: These are also affected by the demand-capacity balance, but in the opposite manner. Ensuring capacity meets or exceeds demand at any given time guarantees that all demand is met, preventing revenue loss.
- Working Capital: This is impacted if an operation opts to build up inventory of finished products before demand arises. While this can satisfy demand, the organization must finance the inventory until it is sold.
- Quality of Services: This may suffer if a capacity plan involves significant fluctuations, such as hiring temporary staff. New staff and disruptions to routine operations can increase the likelihood of errors.
- Speed of Response: This can be improved by intentionally providing extra capacity to prevent queues or by building up product inventories.
- Dependability of Supply: This is influenced by how closely demand levels approach capacity. As demand nears the operation's capacity limit, the ability to handle unexpected disruptions diminishes.
- Flexibility: Particularly volume flexibility, is enhanced by having surplus capacity. If demand and capacity are balanced, the operation may struggle to accommodate unexpected demand increases.

A Framework for Capacity Management

Capacity management involves a series of activities. The process typically begins with the demand side by measuring (forecasting) demand for services and products over various time periods. This step involves choosing from a variety of qualitative methods (such as panel discussions, Delphi technique, and scenario planning) and quantitative methods (like time series and causal models) to enhance the accuracy of demand predictions.

The second step focuses on the supply side, where the capacity to deliver services and products is assessed. This involves considering the effects of factors such as product mix, time frame, and output specifications.

The third step involves exploring ways to manage demand through techniques like demand management and yield management.

The fourth step is about managing the supply side by determining the appropriate average capacity level. This involves deciding whether to maintain a constant capacity (level capacity plan) or to adjust capacity according to changing demand patterns (chase capacity plan).

Finally, operations managers need to understand the implications of different capacity management decisions on both the demand and supply sides of the framework.

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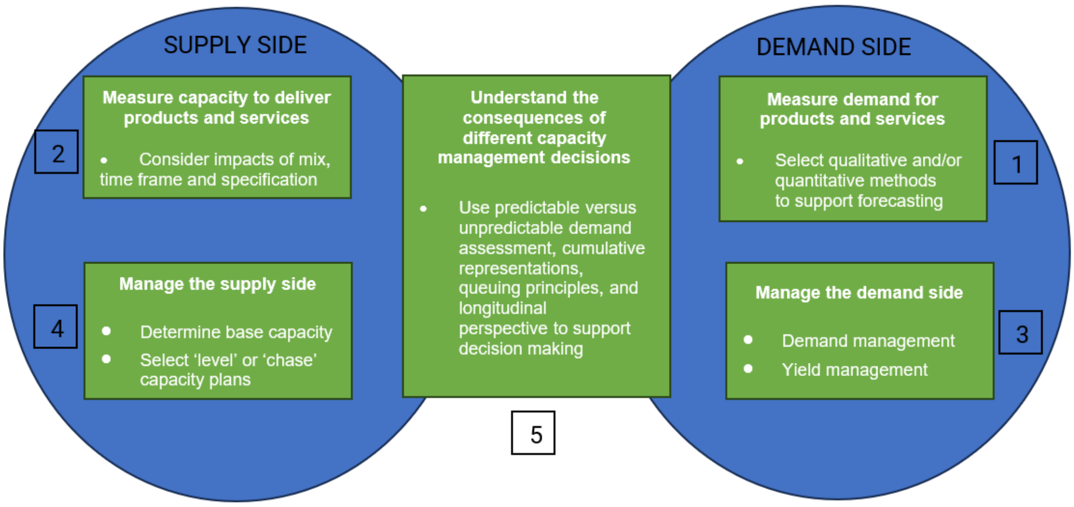
SUPPLY SIDE
2
Measure capacity to deliver products and services
• Consider impacts of mix, time frame and specification
4
Manage the supply side
• Determine base capacity
• Select 'level' or 'chase' capacity plans
Understand the consequences of different capacity management decisions
• Use predictable versus unpredictable demand assessment, cumulative representations, queuing principles, and longitudinal perspective to support decision making
5
DEMAND SIDE
Measure demand for products and services
• Select qualitative and/or quantitative methods to support forecasting
1
Manage the demand side
• Demand management
• Yield management
3

How is Demand Measured?

The initial step in capacity management is to comprehend the demand patterns for products and services across various time frames, such as hourly, daily, weekly, monthly, or annually. While recognizing whether demand is increasing or decreasing is a helpful starting point, it is not sufficient on its own. Understanding the rate of change is crucial for effective business planning. For instance, a law firm may need to determine when its growing business will require an additional partner. Since hiring a new partner could take several months, the firm must forecast when it will reach that point and plan when to initiate its recruitment process.

Qualitative Approaches to Forecasting

Managers often rely on qualitative methods, which draw on judgment and past experience, to predict demand. Three widely used techniques are the panel approach, the Delphi method, and scenario planning.

Panel Approach: Similar to panels of sports analysts who predict outcomes, groups of politicians, business leaders, stock market analysts, banks, and airlines gather to forecast demand. These panels function like focus groups, encouraging open discussion. While the collective input of multiple individuals can be advantageous, reaching a consensus can be challenging, and sometimes the most vocal or influential voices dominate (known as the bandwagon effect). Although this method is more reliable than relying on a single person's opinion, it still carries the risk of collective error.

Delphi Method: This is perhaps the most recognized method for generating forecasts using expert opinions. It is a more structured approach that minimizes the biases of face-to-face meetings. Experts participate in a survey, and their responses are analyzed and anonymously summarized for all participants. Experts are then asked to reconsider their initial forecasts based on the feedback and arguments from others. This iterative process continues until a consensus is reached or the range of decisions is narrowed. A refinement of this method involves assigning weights to individuals and their suggestions based on factors like experience, past forecasting success, and peer evaluations. Challenges with this method include designing an effective questionnaire and selecting a suitable panel of experts.

Scenario Planning: This approach is used for situations with high uncertainty, typically in long-term forecasting, and also involves a panel. Panel members are tasked with creating a range of future scenarios. Each scenario is then discussed, considering the associated risks. Unlike the Delphi method, scenario planning does not aim for consensus but rather explores a variety of options, with the goal of avoiding undesirable outcomes and pursuing the most favorable ones.

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Quantitative Approaches to Forecasting

Managers often opt for quantitative methods to predict demand, with two primary approaches being time series analysis and causal modeling techniques.

Time Series Analysis: This method involves examining historical patterns of behavior to predict future trends. By analyzing past data, managers can identify patterns and use them to forecast future demand.

Causal Modeling: This approach focuses on describing and assessing the cause-and-effect relationships between key variables. It helps managers understand how different factors influence demand, allowing for more informed predictions based on these relationships.

Time Series Analysis

Time series analysis is a forecasting method that analyzes patterns in time series data to predict future behavior. By identifying and removing variations caused by specific, assignable factors, it allows for more accurate extrapolation of future trends. Key techniques within time series analysis include:

- Simple Moving Average: This method calculates the average of a set number of past data points to smooth out short-term fluctuations and highlight longer-term trends.
- Simple Exponential Smoothing: This technique applies decreasing weights to past observations, giving more importance to recent data while smoothing out the series.
- Trend-Adjusted Exponential Smoothing: This approach extends simple exponential smoothing by incorporating a trend component, allowing it to adjust for trends in the data.
- Seasonal Models: These models account for regular, repeating patterns or cycles in the data, such as seasonal variations, to improve forecasting accuracy.

1. Simple Moving Average

The simple moving average (SMA) is a method used to smooth out short-term fluctuations and highlight longer-term trends in data by calculating the average of a fixed number of past data points.

$$[\mathrm{SMA}_t = \frac{1}{n}\sum_{i=0}^{n-1} X_{t-i}]$$

Where:

- (SMA_t) is the simple moving average at time (t).
- (n) is the number of periods over which the average is calculated.
- (X_{t-i}) is the data point at time $(t - i)$.

The formula calculates the average of the most recent (n) data points. By averaging these points, the SMA smooths out short-term noise and reveals underlying trends.

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In an automation manufacturing plant in Europe, the production output of robotic components is recorded daily. To identify the trend in production output, the plant manager uses a 7-day simple moving average. This helps in understanding whether production is increasing, decreasing, or stable over the week, allowing for better planning and resource allocation.

2. Simple Exponential Smoothing

Simple exponential smoothing is a forecasting technique that applies exponentially decreasing weights to past observations, giving more importance to recent data.

$$[S_t = \alpha X_t + (1 - \alpha) S_{t-1}]$$

Where:

- (S_t) is the smoothed statistic at time (t).
- $(X_t)$is the actual value at time (t).
- (α) is the smoothing constant $(0 < (\alpha) < 1)$.
- (S_{t-1}) is the smoothed statistic at time ($t - 1$).

The formula updates the smoothed value by combining the current actual value and the previous smoothed value, weighted by the smoothing constant (α). A higher (α) gives more weight to recent observations.

An automation manufacturer in Europe uses simple exponential smoothing to forecast the demand for its new line of industrial robots. By applying this method, the company can quickly adjust to changes in demand patterns, ensuring that production levels align with market needs without overproducing or underproducing.

3. Trend-Adjusted Exponential Smoothing

Trend-adjusted exponential smoothing, also known as Holt's linear trend model, extends simple exponential smoothing by incorporating a trend component, allowing it to adjust for trends in the data.

$$[S_t = \alpha X_t + (1 - \alpha)(S_{t-1} + T_{t-1})]$$
$$[T_t = \beta(S_t - S_{t-1}) + (1 - \beta) T_{t-1}]$$

Where:

- (S_t) is the smoothed value at time (t).
- (X_t) is the actual value at time (t).
- (T_t) is the trend factor at time (t).
- (α) is the smoothing constant for the level $(0 < (\alpha) < 1)$.
- (β) is the smoothing constant for the trend $(0 < (\beta) < 1)$.

The first formula updates the smoothed value by considering both the current actual value and the previous smoothed value adjusted by the trend. The second formula updates the trend component by considering the change in the smoothed values.

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A European automation manufacturer tracks the production of AI-driven assembly line equipment. By using trend-adjusted exponential smoothing, the company can account for both seasonal demand fluctuations and long-term growth trends, ensuring that production schedules are aligned with market trends.

4. Seasonal Models

Seasonal models account for regular, repeating patterns or cycles in the data, such as seasonal variations, to improve forecasting accuracy.

$$[Y_t = T_t + S_t + e_t]$$

Where:

- (Y_t) is the observed value at time (t).
- (T_t) is the trend component at time (t).
- (S_t) is the seasonal component at time (t).
- (e_t) is the random error component at time (t).

The formula decomposes the time series into trend, seasonal, and error components. By identifying and modeling these components, the model can accurately forecast future values that account for seasonal patterns.

An automation manufacturing company in Europe produces robotic components that experience seasonal demand fluctuations, such as increased orders during the lead-up to major industrial trade shows. By employing seasonal models, the company can predict these fluctuations and adjust production schedules accordingly. This ensures that they have sufficient inventory to meet peak demand periods without overproducing during slower times, optimizing both resource use and customer satisfaction.

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How is forecasting useful for operation management?

Forecasting is a critical tool for operations management, providing numerous benefits that enhance decision-making and efficiency across various aspects of an organization. Here’s how forecasting is useful:

Demand Planning: Accurate forecasts help operations managers anticipate customer demand, allowing them to adjust production schedules, manage inventory levels, and allocate resources effectively. This ensures that products and services are available when needed, minimizing stockouts and overproduction.

Resource Allocation: By predicting future demand, managers can allocate resources such as labor, materials, and machinery more efficiently. This helps in optimizing workforce scheduling, reducing idle time, and ensuring that resources are used where they are most needed.

Capacity Management: Forecasting aids in determining the necessary capacity to meet future demand. It helps in making informed decisions about whether to expand facilities, invest in new equipment, or adjust current operations to handle anticipated changes in demand.

Financial Planning: Forecasts provide insights into future sales and revenue, which are crucial for budgeting and financial planning. They help in setting realistic financial goals, managing cash flow, and making investment decisions.

Supply Chain Management: Accurate demand forecasts enable better coordination with suppliers, ensuring timely procurement of materials and components. This reduces lead times, minimizes inventory holding costs, and enhances the overall efficiency of the supply chain.

Risk Management: By anticipating future trends and potential disruptions, forecasting allows operations managers to develop contingency plans and mitigate risks. This proactive approach helps in maintaining stability and continuity in operations.

Strategic Planning: Forecasting supports long-term strategic planning by providing data-driven insights into market trends, customer preferences, and competitive dynamics. This information is vital for setting strategic objectives and identifying growth opportunities.

Customer Satisfaction: By ensuring that products and services are available when and where customers need them, forecasting helps in meeting customer expectations and enhancing satisfaction. This can lead to increased customer loyalty and a stronger market position.

Overall, forecasting is an essential component of operations management that drives efficiency, reduces costs, and supports strategic decision-making, ultimately contributing to the organization’s success.

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How is capacity measured?

The second aspect of capacity management involves understanding the nature of capacity, which refers to the ability to supply. Capacity is defined as the maximum level of value-added activity that a process can achieve over a certain period under normal conditions. This definition not only considers the scale of capacity but, more importantly, its processing capabilities. For instance, if a European automotive manufacturer invests in a new assembly line capable of producing 1,000 cars per month, this figure provides an idea of the scale but is not particularly useful for an operations manager. The manufacturer would focus on the output level, or processing capability, of the assembly line. If a standard model can be assembled every hour, the planned processing capacity might reach 24 cars per day. However, if each assembly takes four hours and two additional hours are needed for maintenance between shifts, the line might only produce 12 cars per day. Similarly, a test track might be fully occupied by vehicles undergoing quality checks during the day, handling only 50 cars daily. Alternatively, if used for shorter test drives and quick inspections, the track could accommodate up to 200 cars per day. Although measuring capacity might seem straightforward, it can be challenging to define clearly unless the operation is standardized and repetitive. For example, a robotic welding station designed to handle 60 car frames every three minutes has a capacity of 1,200 frames per hour. In such cases, an output capacity measure is appropriate because the output is consistent. However, for many operations, defining capacity is not as straightforward. When a wide range of outputs places varying demands on the process, output measures of capacity become less useful, and input capacity measures are often used instead. While almost every type of operation could use a combination of both input and output measures, in practice, most opt for one or the other.

Here's the table with the most used measure for each operation highlighted in bold:

Operation	Input Measure Capacity	Output Measure Capacity
Automotive Manufacturing	Number of assembly lines	**Number of cars produced per day**
Pharmaceutical Production	Volume of raw materials (litres)	**Number of batches produced per day**
Call Center	Number of available agents	**Number of calls handled per hour**
Restaurant	Number of tables or seats	**Number of meals served per day**
Data Center	Number of servers	**Data processed (terabytes) per day**
Hospital	Number of available beds	**Number of patients treated per day**
Retail Store	Floor space (square meters)	**Number of transactions per day**
Airline	Number of aircraft	**Number of passengers transported per day**

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Operation	Input Measure Capacity	Output Measure Capacity
Construction	Number of workers	**Square meters of building completed per month**
Software Development	Number of developers	**Number of software features delivered per month**

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How is the demand side managed?

How is demand managed in the European automotive industry? Demand patterns significantly impact how operations are conducted, prompting many manufacturers to try to influence them. This process, known as demand management, involves altering demand patterns to better align with available production capacity. This can be achieved by either boosting demand during off-peak times or limiting it during peak periods. Several strategies are employed to manage demand:

Price Adjustments: Modifying prices to reflect demand levels, such as offering discounts on certain car models during the off-season or increasing prices during peak buying periods like the end of the year.

Promotional Scheduling: Using promotions and advertising to stimulate demand during typically slow periods. For instance, car manufacturers might launch special promotions or financing deals to boost sales during the winter months when demand is usually lower.

Restricting Access: Limiting customer access to certain models or features to specific times, such as through exclusive pre-order systems for new car releases.

Service Level Variation: Adjusting service levels according to demand, allowing service quality to decline during high demand and improve during low demand periods, such as offering more personalized service during quieter times.

Developing Alternative Offerings: Creating products or services to utilize capacity during slow times. For example, automotive companies might focus on producing electric vehicles or hybrid models during periods of lower demand for traditional vehicles, or they might offer vehicle leasing options to maintain steady production levels.

In operations with relatively fixed capacities, like automotive manufacturing plants, maximizing revenue potential is crucial. Yield management is a strategy used to achieve this, involving various methods to optimize profit generation. This approach is particularly effective when capacity is fixed, the market is clearly segmented, services cannot be stored, are sold in advance, and the marginal cost of sales is low.

Automotive manufacturers exemplify these criteria, employing methods to maximize profit from their capacity. Overproduction might be used to offset potential demand fluctuations, though it risks excess inventory if demand does not meet expectations. By analyzing past sales data, manufacturers balance the risks of overproduction and underproduction. Additionally, price discounts are offered during slow periods to boost demand, such as offering lower rates on older models to clear inventory. Larger automotive groups may also sell discounted vehicles to third-party dealers, who then assume the risk and reward of finding customers.

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How is the supply side managed?

Managing the supply side involves ensuring that the production and delivery of goods or services align with demand while optimizing resources and minimizing costs. Here are some key strategies used to manage the supply side:

Inventory Management: Maintaining optimal inventory levels to meet demand without overstocking. This involves using techniques like just-in-time (JIT) inventory, where materials are ordered and received only as needed for production, reducing holding costs.

Supplier Relationships: Building strong relationships with suppliers to ensure reliable and timely delivery of materials. This can include negotiating favorable terms, establishing long-term contracts, and collaborating on quality improvements.

Production Planning: Developing efficient production schedules that align with demand forecasts. This includes capacity planning to ensure that production facilities can meet demand without excessive overtime or idle time.

Logistics and Distribution: Optimizing the transportation and distribution of goods to ensure timely delivery to customers. This can involve selecting the most efficient shipping methods, managing warehouse locations, and using technology to track shipments.

Technology and Automation: Implementing technology and automation to improve production efficiency and reduce costs. This can include using advanced manufacturing technologies, robotics, and data analytics to streamline operations.

Risk Management: Identifying and mitigating risks that could disrupt the supply chain, such as natural disasters, geopolitical issues, or supplier failures. This involves developing contingency plans and diversifying suppliers to reduce dependency on any single source.

Sustainability Practices: Incorporating sustainable practices into the supply chain to reduce environmental impact and meet regulatory requirements. This can include using eco-friendly materials, reducing waste, and improving energy efficiency.

By effectively managing these aspects, organizations can ensure a smooth and efficient supply chain that supports their overall business objectives.

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