CHAPTER 8 Operations Analytics

A LOOK BACK:

In Chapter 7, we introduced the role of marketing in business, the components of the marketing mix, and the questions that might arise in each component of the marketing mix. We defined marketing analytics and described how companies can use marketing analytics to gain actionable business intelligence. Using the SOAR model, we presented examples of marketing questions addressable using descriptive, diagnostic, predictive, and prescriptive data analytics; the sources of marketing data; and the key types of analytics employed.

A LOOK AT THIS CHAPTER:

In this chapter, we investigate how data analytics is applied to the operations function utilizing the SOAR model. We begin our discussion by introducing the role of operations in business, the three branches of operations (i.e., human resources, information technology, and supply chain), and the questions that might arise in each branch of operations that can be addressed through data analytics. Next, we investigate operations data sources and the specific analytics applied to address operations questions, including descriptive, diagnostic, predictive, and prescriptive analytics. We also introduce the respective tools and techniques that can be used in each type of data analytics and how the results of the analyses can be reported.

A LOOK AHEAD:

In Chapter 9, we apply the SOAR model to accounting analytics. We then work through the SOAR model by discussing examples of accounting questions addressable using data analytics, the sources of accounting data as well as the key types of analytics employed. We conclude by demonstrating how the results of accounting analytics can be reported.

{VIGNETTE}

Can you imagine being asked the following questions during a job interview?

Question 1: "A book has N pages, numbered the usual way, from 1 to N. The total number of digits in the page numbers is 1,095. How many pages does the book have?"

Question 2: "A man pushed his car to a hotel and lost his fortune. What happened?"

Believe it or not, your answer to these questions at one time impacted whether or not Google hired you as a new employee. However, that is no longer true thanks to one branch of operations analytics-human resource analytics. After analyzing data from tens of thousands of job interviews, analytics revealed that answering such "brainteaser questions" correctly did not predict long-term success in the company. Analytics also determined that GPAs and test scores were not good predictors of performance either-unless the applicant had just graduated. The results from human resource analytics caused Google to change its interviews to a structured behavioral approach, which focuses on past performance and behavior, asking questions like: "Describe a time when you were under a lot of pressure at work. How did you react?" As you will see from this example as well as others in the chapter, human resource analytics can help transform companies into higher performing organizations.

Just in case you are wondering, the answers to the questions above are:

Answer 1: "401 pages"

Answer 2: "He was playing Monopoly."

Sources: Gover, Ian. February 11, 2015. 5 Companies Using Big Data to Transform Human Resources. Available on-line at: https://www.geteverwise.com/human-resources/5-companies-using-big-data-to-transform-human-resources/, accessed on 06/26/2020.
Quotes from: Anonymous. December 24, 2011. Answers to Google Interview Questions. *The Wall Street Journal* (Online).

After reading this chapter, you should be able to:

LO8-1: Explain the role of operations and its three branches including human resources, information technology, and supply chain.
LO8-2: Describe representative operations questions addressable by data analytics, by branch of operations.
LO8-3: Enumerate potential internal and external sources of operations data.

LO8-4: Explain how descriptive analytics can be used to answer operations questions.
Lab 8-1 Descriptive Analytics using the Data Analysis Add-in (Excel)
LO8-5: Explain how diagnostic analytics can be used to answer operations questions.
Lab 8-2 Hypothesis Testing using the Data Analysis Add-in (Excel)
LO8-6: Explain how predictive analytics can be used to answer operations questions.
Lab 8-3 Process Control Chart (Tableau)
Lab 8-4 Forecasting (Tableau)
LO8-7: Explain how prescriptive analytics can be used to answer marketing questions.
Lab 8-5 Optimization using the Solver Add-In (Excel)
LO8-8: Characterize how operations analytics reports results.

(Comp: please insert in the margin: "LO8-1: Explain the role of operations and its three branches including human resources, information technology, and supply chain")

(LEVEL 1 HEADER) THE ROLE OF OPERATIONS IN BUSINESS

People think we got big by putting big stores in small towns. Really, we got big by replacing inventory with information. Sam Walton, Founder of WalMart

Operations turns inputs into goods and services that companies sell.

Formally, **operations** "makes sure the materials and labor, or any other input, [are] used in the most effective and efficient way possible within an organization – thus maximizing the output".[1] So, operations encompasses many processes including: (1) ordering raw materials; (2) scheduling production (including the labor); (3) designing processes to maintain quality and efficiency; (4) managing the workforce; and (5) integrating information technology (IT) throughout the processes. In other words, operations is "the backbone of business efficiency".[2]

[1] Source: Belyh, Anastasia. June 22, 2016. Operations Management: Definition, Principles, Activities, Trends. Available on-line at: https://www.cleverism.com/operations-management-definition-principles-activities-trends/, accessed 06/25/2020.
[2] Source: Leighton, Becky. May 9, 2020. Operations Management: The Backbone of Business Efficiency. Available on-line at: https://masterstart.com/blog/business/operations-management-the-backbone-of-business-efficiency/, accessed on 06/25/2020.

How do managers use operations? Sainsbury's, the second largest grocery chain in the UK, uses innovations in human resources to continuously generate profits, which is remarkable for an industry characterized by thin margins. Not only is the grocer known for its employee training academies, its human resources pioneered the "self-service style" of shopping that is growing in popularity across the globe. Domino's, the world's largest pizza delivery chain, uses IT operations to help ensure that the company's systems work properly and securely as half of its orders are now made digitally. IT operations is even more critical on its busiest day of the year, Super Bowl Sunday, when 2 million pizzas are ordered (most during a 45 minute window).[3] Walmart, the world's largest company based on revenue, developed one of the most technologically advanced supply chain systems that allows the company to know "at all times what products are needed, how much products are needed, and when these products are needed."[4] The system includes putting vendors in charge of managing their inventory electronically and cross-docking (i.e., needed inventory goes directly to stores without being stored in a warehouse).

In summary, operations is essential to the success of a business. Without operations, many companies would simply fail due to a lack of a quality product to sell.

(LEVEL 2) THE THREE PRIMARY BRANCHES OF OPERATIONS

[3] Source: Splunk. Revealing the Secret Sauce. Available on-line at: https://www.splunk.com/en_us/customers/success-stories/revealing-the-secret-sauce.html, accessed on 06/30/2020.

[4] Source: Rubin, Chad. January 4, 2020. Walmart Supply Chain 2020: Why It Continues to Dominate? Available on-line at: https://www.skubana.com/blog/walmart-leading-way, accessed on 06/30/2020.

In this chapter, we will examine three primary branches of operations, including human resources, IT operations, and supply chain.

Human resources is a branch of operations that focuses on managing and developing a company's workforce. Human resources encompasses all of the people employed by the company. Tasks include recruiting, hiring, compensating, and training employees as well as performance management. Historically, production equipment was considered to be the most valuable asset in a company. Now, however, some consider people as the organization's most valuable asset because of the knowledge and productivity that employees bring to the organization.[5] The importance of human capital (i.e., experience, knowledge, skills, creativity, social and personality attributes) will continue to increase as our current knowledge economy grows, making human resources play an increasingly important role in a company.

IT operations is a branch of operations that "is responsible for the smooth functioning of the infrastructure and operational environments that support application deployment to internal and external customers, including the network infrastructure; server and device management; computer operations; IT infrastructure library (ITIL) management; and help desk services for an organization."[6,7] In other words, IT operations is how the company manages its hardware, software, and IT support. For example, a company's policy about cloud computing, bring your own device, Internet of Things (IoT) (i.e., devices connected to the Internet), and machine-to-

[5] Source: VP legacies. December 9, 2019. 9 Reasons Why Your Employees Are Your Company's Most Valuable Asset. Available on-line at: https://vplegacies.com/9-reasons-why-your-employees-are-your-companys-most-valuable-asset/, accessed on 06/25/2020

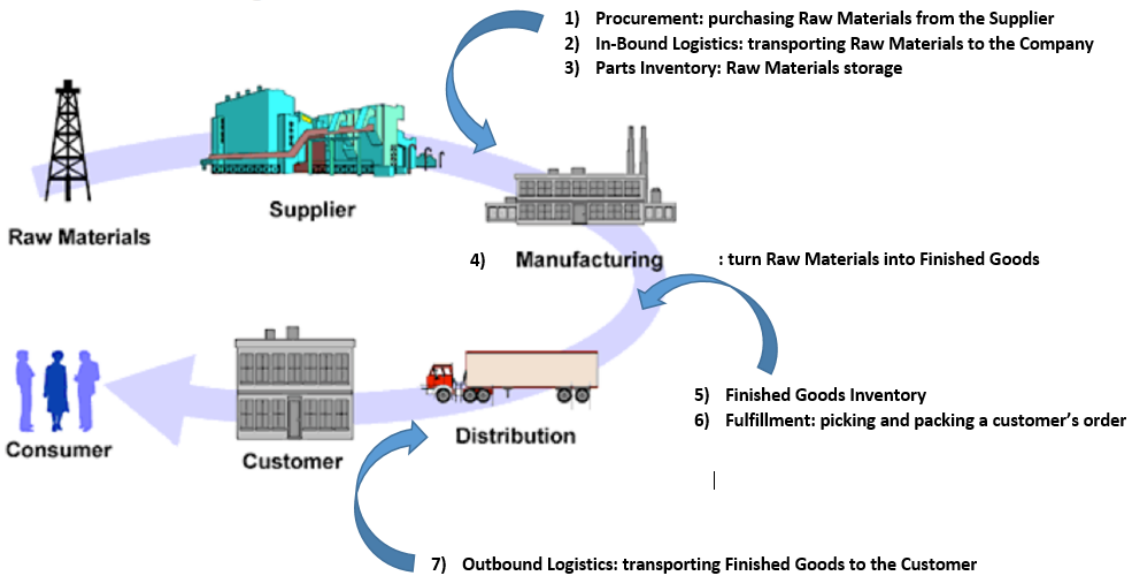
[6] Source: Hertvik, Joe. What Does IT Operations Management Do (ITOps)? Available on-line at: https://joehertvik.com/operations-management/, accessed 06/28/2020.

[7] IT Operations and IT Applications are typically separate in companies but there is overlap in the two different functions. In this chapter, we take a broad approach and include both.

machine communications are current decisions for IT operations. As we saw above, some claim people are an organization's most important asset, but others claim that data is an organization's most valuable asset. One thing is for sure, however, as data becomes increasingly important in the digital age, IT operations will become increasingly important in companies.

Supply chain is a branch of operations that is responsible for the production and distribution of a product (or service) to the final consumer. It includes all of the necessary processes to make the product including: obtaining raw materials, transforming raw materials into the finished product, transportation, and distribution. A company's supply chain is the network of entities that are involved in executing the process including: vendors, transportation companies, warehouses, distribution centers, and retailers. Supply chains are integral parts of most companies' business and are "essential to company success and customer satisfaction."[8] Accordingly, some people claim the networks established by the supply chain are an organization's most important asset, because without the networks it would be impossible to procure and distribute goods. Exhibit 8.1 shows an example of the seven steps in a supply chain.

[8] Source: Council of Supply Chain Management Professionals (CSCMP). The Importance of Supply Chain Management. Available on-line at: https://cscmp.org/CSCMP/Develop/Starting_Your_SCM_Career/Importance_of_SCM/CSCMP/Develop/Starting_Your_Career/Importance_of_Supply_Chain_Management.aspx?hkey=cf46c59c-d454-4bd5-8b06-4bf7a285fc65, accessed on 06/30/2020.



[[Insert Exhibit 8.1 here]]

Exhibit 8.1 Sample Supply Chain with Entities and the 7 Steps
Adapted from: Vorhies, William. 2015. Predictive Analytics in the Supply Chain. Available on-line at: https://www.datasciencecentral.com/profiles/blogs/predictive-analytics-in-the-supply-chain, accessed on 07/01/2020.

(Comp: please insert in the margin: "LO8-2: Describe representative operations questions addressable by data analytics, by branch of operations.")

(LEVEL 1 HEADER) SPECIFYING THE OPERATIONS QUESTION

This chapter examines three different types of analytics. First, **HR analytics** (a.k.a., people analytics, workforce analytics, and talent analytics) is "the systematic identification and quantification of the people drivers of business outcomes, with the purpose to make better decisions."[9] HR analytics helps companies attract, manage, and retain employees to increase company efficiency and profitability by helping to hire/assign the right employee with the right skill

[9] Source: van den Heuvel, Sjoerd and Tanya Bondarouk. 2016. The Rise (and Fall) of HR Analytics. Available on-line at: https://research.utwente.nl/en/publications/the-rise-and-fall-of-hr-analytics-a-study-into-the-future-applica, accessed on 06/26/2020.

set to the right job at the right compensation level. Second, **IT operations analytics** (ITOA) analyzes company data from various applications, devices and IT infrastructure to instantly identify, solve, and predict IT issues. IT operations analytics helps companies deliver the right IT services at the right quality level with the right level of security. Third, **supply chain analytics** analyzes company data to improve supply chain planning, efficiency, and effectiveness. Thus, supply chain analytics helps companies deliver the right product at the right time at the right place.

Put simply, they are all data driven approaches to making decisions. All three are designed to create actionable insights. All three branches of operations analytics begin with a question. And, given the different functions and responsibilities, each branch will have different types of questions that are potentially answerable by data. Exhibit 8.2 provides examples of detailed operations questions both by analytics type (e.g., descriptive, diagnostic, predictive, and prescriptive) as well as by the three main branches of operations: human resources, IT operations, and supply chain.

Data Analytics Type	**Operations Branch**		
	Human Resources	**IT Operations**	**Supply Chain**
Descriptive: What happened? What is happening?	How many employees does the company have (i.e., headcount)? What is the headcount in each department? What is the employee turnover rate? On average, how long do employees work for the company?	What is the average transaction response time? What is the average end user response time for a specific application? What is the application error rate?	Which vendors are the top suppliers (in terms of dollars and units)? How many B2B transactions did the company have last month? How much inventory is currently on hand? What is the average supplier lead time (to deliver)?
Diagnostic: Why did it happen? What are the	How has headcount changed from the past year?	Why did average transaction response time increase?	Why did quantity used per product change? Why has inventory on hand changed?

reasons for the past results?	Why has employee turnover rate increased? Why has candidate conversion rate fallen?	Why did the application error rate go up/down? How/Why has application performance changed?	Why did product quality increase/decrease?
Predictive: What will happen in the future? What is the probability something will happen? Is it forecastable?	Which employees have the highest probability of leaving? Which new hires will perform the best? Which teams will underperform due to a skills gap?	Which system will have performance issues? Which system will have security issues? If a breach occurs, what will happen to response time? Cart checkouts?	What will product demand be in two years? What happens to costs if the company increases/decreases order quantities? Which machine will break down?
Prescriptive: What should we do based on what we expect will happen? How do we optimize our performance based on potential constraints?	How many employees does the company need to staff during the holidays? What is the proper way to onboard and train a new hire based on preexisting experience and skills? Where should employees be positioned in a store to improve sales?	Which solution will solve a current systems problem? Which solution should be automatically executed to prevent a systems problem? Based on our company's risk tolerance level, how should our systems be setup?	Where should manufacturing plants and warehouses be located? What is the best route to deliver products? Which vendor should be used to meet lead time and quality KPIs? Which solution will solve a current machine breakdown?

[[Insert Exhibit 8.2 here]]

Exhibit 8.2 Operations Data Analytics Type and Different Types of Operations Questions by the Three Main Branches of Operations (Human Resources, IT Operations, Supply Chain)

Progress Check:

1. What is the difference between IT operations and supply chain?
2. Give two examples of operations questions asked by human resources that can be answered with human resource analytics.
3. Give an example of a supply chain question associated with predictive analytics.

(Comp: please insert in the margin: "LO8-3: Enumerate potential internal and external sources of operations data.")

(LEVEL 1 HEADER) OWN THE DATA: WHAT OPERATIONS DATA IS AVAILABLE? A DISCUSSION OF OPERATIONS DATA SOURCES

To be number one, you need to generate innovation. The only way to drive that innovation is based on data.

Alex Padilla
Domino's

There certainly is a lot of data available that can help address operations questions. This section details possible sources of operations data, including human resource data, IT operations data, and supply chain data.

(LEVEL 2 HEADER) HUMAN RESOURCES DATA

Human resources data is potentially created even before a person applies for a position with a company. If a person has an account on LinkedIn or posts a resume on a jobsite (e.g., indeed.com, monster.com), companies have access to this data to help select qualified applicants for open positions. Even more data is potentially available if a person officially applies for a position, sits for an interview, or has accessible (and therefore harvestable) social media data. Potential data includes education, demographics, work history, certifications, personality and behavioral traits, and special skills as well as likes and dislikes.

Once a person becomes an employee, human resources collects data about an employee across the company. As expected, companies maintain attendance records, training completed, performance evaluations, and work/job assignment as well as salary and promotion history. But, companies collect a lot more data than just those items. Human resources may survey employees to get feedback about employee satisfaction, morale, and engagement (i.e., how valued employees feel by the company) to help predict turnover. To improve the employee experience, questions may be also asked about the company's communications, employee's

experience with the company (identifying areas of improvement), company's culture (i.e., actions, beliefs, values), employee motivation, and reasons for leaving (i.e., exit interview).[10]

Companies may also collect and analyze the employee data trail. As employees do their jobs they use computer systems, operate office/factory machinery, open and close doors, walk around the company, and interact with other employees and customers. Employees' interactions with the computer system can be captured using keylogging software, activity logs, and automatic screenshots. Companies may also use employee emails to/from to determine how employees across the company interact. Finally, companies may use **telemetry**, which is collecting data at remote points (possibly by a digital employee badge) and automatically transmitting the data to monitoring equipment. Telemetry allows companies to determine where employees spend their time, where they go, what they do, and how long they interact with other employees and customers. Exhibit 8.3 shows an example of a telemetry system.

[[Insert Exhibit 8.3 here]]

Exhibit 8.3 Sample Telemetry System

[10] Bhat, Adi. 10 Amazing Human Resource Survey Questions. Available on-line at: https://www.questionpro.com/blog/human-resource-survey-questions/, accessed online on 07/02/2020.

Source: https://trackking.in/wp-content/uploads/2016/06/employee-tracking-system-1030x343.jpg

To help manage human resource data, companies may use a **human resource management (HRM) system**. HRM systems store all of the collected human resource data in one place. They help automate human resource processes and compliance with laws and regulations. It is typically part of the company's ES (see chapter 7 for a discussion about ERPs and ESs). Having a centralized repository of human resource data improves data quantity and quality and streamlines the human resource analytics process.

(LEVEL 2 HEADER) IT OPERATIONS DATA

IT operations collects data from a wide variety of IT operations tools and devices to help monitor system performance as well as service performance (i.e., incident response) (all with the goal of improving both!). System performance data focuses on applications, devices, and operating systems. Typical system performance data includes: logs of usage, performance metrics (e.g., level of usage, response time), data breaches, and network (a.k.a. wire) data. Service performance data focuses on the help desk, change management, and incident response to IT problems. Typical service data includes: incident-related data, service/support ticketing (i.e., all service desk interactions with customers and employees), and service metrics (e.g., response time). Data includes streaming, real-time data as well as historical data.[11]

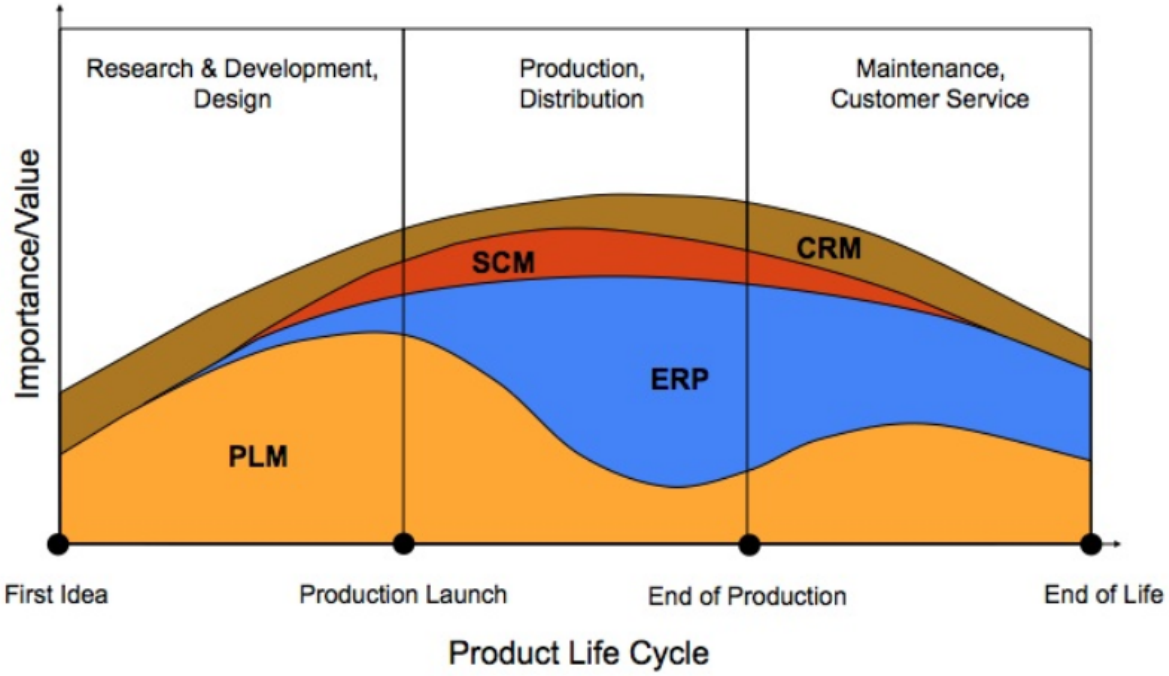
(LEVEL 2 HEADER) SUPPLY CHAIN DATA

The supply chain is all about the product and all the processes required to procure the raw materials to deliver the product to its final destination. Therefore, more data sources tend to

[11] For more information, please see: https://www.ibm.com/cloud/learn/aiops, and https://www.gartner.com/en/documents/3892967/market-guide-for-aiops-platforms

be used by supply chain analytics than other types of company analytics. Traditionally, ESs/ERPs were used to conduct transactions with supply chain partners (i.e., vendors and retail/wholesale customers).[12] **Supply chain management (SCMs) systems** are integrated modules for ESs/ERPs specifically designed to handle the supply chain. SCM software "tracks and executes company processes, including design, procurements, manufacturing, production, distribution, and order fulfillment." In other words, SCMs can help forecast demand, order (raw material) inventory to avoid stockouts, track the raw materials from shipping through the manufacturing process, monitor warehouse storage, and track shipping to the final customers. Some companies also use warehouse management systems to manage detail warehouse operations. Moreover, some companies link the SCM system with the CRM system to gain a total company perspective with the goal of boosting customer experience and satisfaction. As seen in Exhibit 8.4, CRM, ERP, and SCM all play an important role in a product's life cycle (Note: PLM is product lifecycle management).

[12] EDI was used to exchange information between partners.



[[Insert Exhibit 8.4 here]]

Exhibit 8.4 Flow Graph of CRM, ERP, and SCM
Source: Ammann, Steve. August 12, 2011. The PLM State: A Flow Graph of PLM, CRM, SCM and ERP during Product Life. Available on-line at: https://www.zerowait-state.com/blog/a-flow-graph-of-plm-crm-scm-and-erp-during-product-life/, accessed on 07/03/2020.

In addition to this structured internal data, companies are also harnessing data where it is generated in the supply chain (e.g., warehouses, delivery trucks, machines, and store shelves) using a variety of different sensors (a.k.a., telemetry). For example, using radio-frequency identification (RFID) companies can immediately track/count inventory in warehouses and stores without requiring a bar code scanner or line of sight. Internet of Things (IoTs) sensors[13] can automatically generate and send metrics to the cloud in real-time. For example, companies can perform real-time monitoring of delivery trucks determining location, stops, speed, and

[13] Note RFID may be used in IOTs.

even the temperature of the cargo. This technology can also be used to monitor company assets, like trucks and machines, for maintenance needs.

Companies may also want to augment their internal supply chain data with external data. For example, weather and traffic data may be used to help determine delivery times, reroute delivery trucks, or predict customer demand. In addition, consumer feedback on social media can also be used as an input to demand forecasts as well as product features and design. Data about retail/wholesale/end customers' and suppliers' financial health and ability to continue as business is critical information for demand planning as well as continuing raw materials acquisition. Pricing data about raw materials and other inputs can be used to help determine product prices and forecasted profit. Finally, data about changing governmental rules and regulations can also help make sure that the company's supply chain is in current compliance.

Progress Check:

4. Identify sources of internal data that can be used for operations analytics.
5. Identify sources of external data that can be used for operations analytics.

(Comp: please insert in the margin: "LO8-4: Explain how descriptive analytics can be used to answer operations questions.")

(LEVEL 1 HEADER) ANALYZE THE OPERATIONS DATA

(LEVEL 2 HEADER) DESCRIPTIVE OPERATIONS ANALYTICS

As you recall, descriptive analytics simply describe or summarize the past. They help highlight the characteristics and features of a dataset by summarizing a large amount of data into an easy to understand format. They do not include any assumptions or future estimates/predictions. Thus, descriptive analytics help us understand the *actual* data and what

has already happened. A wide variety of summarization and statistical techniques as well as simple visualizations are examples of what might be employed as part of descriptive operations analytics.

(LEVEL 3 HEADER) Statistical and Summarizations Techniques for Descriptive Analytics

Summarization and statistical techniques are used to address basic questions of "What happened?" or "What is happening?" These techniques characterize, summarize, and organize data and are generally all found in spreadsheet software like Microsoft Excel. For example, counts, totals, sums, averages, subtotals, minimums, maximums, pivot tables (to summarize), standard deviations, and ratios are all examples of descriptive analytics techniques that can be completed using Excel. In addition, analysts can use tools such as Excel to create simple graphs/visualizations like histograms, bar charts, and pie charts. Exhibit 8.5 provides examples of statistical techniques that can be used in descriptive analytics for the different branches of operations.

Statistical Technique to Perform Descriptive Analytics	Use	Example of Type of Operations Question It Addresses
Counts	Show how frequently an attempt occurs	How many new employees were hired during the year? How many times did the website crash during the last month? How many times did the company stockout (i.e., run out) of inventory?
Totals, sums, averages, subtotals	Summary measures of performance	How many total employees work for the company? What is the average response website time? What is the average supplier lead time?

Minimums, maximums, medians, standard deviations	Summary measures of dispersion	Which employee has the lowest salary? Which employee spends the most time on the companies ES? Which supplier has not complied with required delivery times the most?
Graphs : bar charts, histograms	Summary visualization	How many employees are assigned to each location? What is the average number of users on each system for the month? What is the average lead time for each supplier?
Pivot tables	Flexible way to summarize large amounts of data	What is the total number of employees by month? What is the total number of users by each system? By month? What is the number of error free orders by day?
Ratios	Compares two numbers	What is the employee turnover rate for the year? What is the ratio of open versus completed service tickets? What is the supply chain **fill rate** (i.e., percent of customer orders satisfied by inventory on hand)?

[[Insert Exhibit 8.5 here]]

Exhibit 8.5 Statistical Techniques for Operations Descriptive Analytics

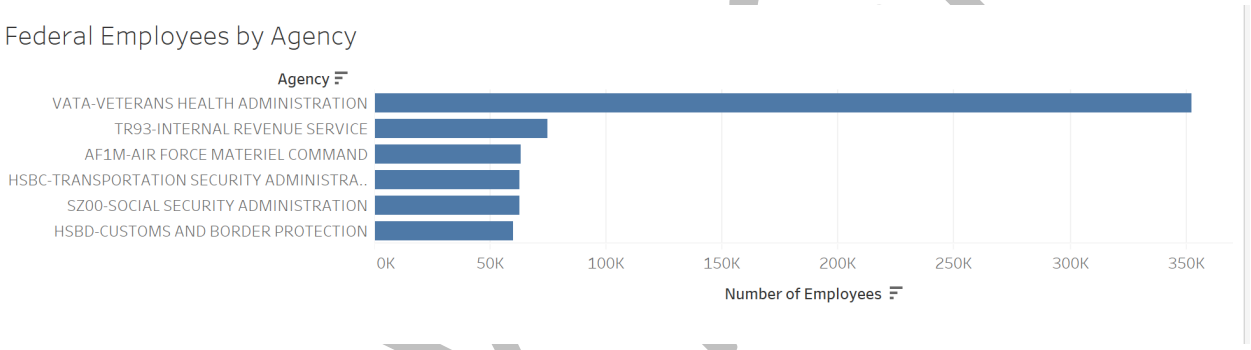
(LEVEL 3 HEADER) Example of Operations Descriptive Analytics: Headcount

Your workforce is your most valuable asset. The knowledge and skills they have represent the fuel that drives the engine of business – and you can leverage that knowledge.

Harvey Mackay

Descriptive analytics provide the basic statistics for operations data. Many governmental entities provide data about their operations on a website, typically called "open data." Using data from these websites, we can evaluate the operations of governmental entities. For example, using data from the U.S. government, we can answer the question: Which (U.S.)

federal agency employs the most number of employees? Exhibit 8.6 shows the top five federal agencies based on total number of employees, revealing that, by far, most of the federal employees work for the Veterans Health Administration (VHA), followed by the Internal Revenue Service (IRS), Air Force Material Command, Transportation Security Administration (TSA), Social Security Administration, and Customs and Border Protection.[14] Public and private companies can perform a similar analysis of headcounts by department, region, product, or some other relevant dimension.



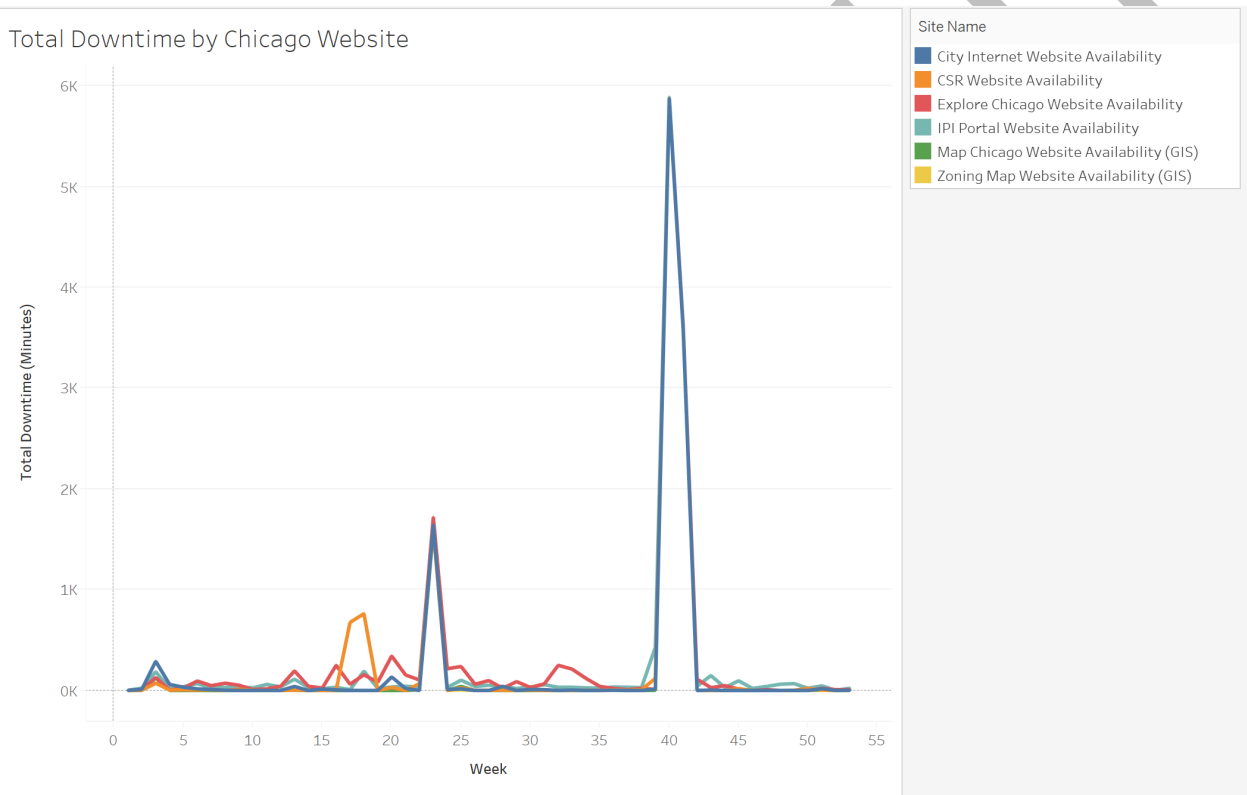
[[Insert Exhibit 8.6 here]]
Exhibit 8.6 Number of Employees by Federal Government Agency
Source: https://www.fedscope.opm.gov, accessed 07/18/2020.

(LEVEL 3 HEADER) Example of Operations Descriptive Analytics: Time Series Graph of Total Downtime

The City of Chicago maintains six websites (e.g., https://www.chicago.gov/city/en.html) to provide resources and information about the city. Chicago automatically checks the response times for the six websites to help ensure that all websites are properly working. Using 55 weeks of data from the Chicago Data Portal, we can answer the following questions: How many minutes of downtime do the websites experience each week? Does downtime vary over time?

[14] Note the Department of Defense has its own data available on the same website, but is not included in the data above.

As shown in Exhibit 8.7, all websites are generally responsive over the time period with the following exceptions: (1) during week 17, the CSR website experienced slow response times; (2) during week 23, all websites experienced slow response times; and (3) during week 40, all websites experienced *very* slow response times. Reasons for the slowdown should be investigated using diagnostic analytics. Public and private companies can perform a similar analysis of company websites.



[[Insert Exhibit 8.7 here]]
Exhibit 8.7 Total Downtime for Chicago Websites
Source: https://data.cityofchicago.org/Administration-Finance/Performance-Metrics-Innovation-Technology-Site-Ava/zfg3-p7xv, accessed 07/18/2020.

(LEVEL 3 HEADER) Example of Operations Descriptive Analytics: Ratios

Our last example of descriptive analysis is a variety of supply chain ratios for retail and wholesale trade companies (i.e., SIC is between 5100 and 5999) over the past decade.

Specifically, let's answer the following questions: How efficient is the supply chain? How responsive is the supply chain? How reliable is the supply chain?[15] To answer the first question about efficiency, we will calculate the following two ratios:

(1) the cash-to-cash or conversion cycle, which measures the length of time between a company paying the vendors and a company receiving cash from the customers. Obviously, the lower the ratio the better!
(2) asset turnover, which measures the sales revenue generated by the assets. The higher the ratio the better efficiency.

To answer the second question about responsiveness, we will calculate the inventory-to-sales ratio, which measures the inventory being carried to fulfill sales. To answer the question about reliability, we will calculate the inventory turnover ratio, which measures the number of times that inventory is sold during the year. Exhibit 8.8 presents the ratios generated using the Descriptive Statistics menu option of the Data Analysis Add-in for Excel. On average, the cash—to-cash conversion cycle is 172 days (basically half a year); each dollar of inventory generates two dollars of sales revenue; very little inventory is being held to cover sales; and inventory is completely sold approximately twice a year. The descriptive statistics also reveal that some of the ratios have great variability. A more in-depth analysis, perhaps by SIC code, would reveal even more information.

[15] These categories are from: Halo. 10 Supply Chain KPIs You'll Want Every Morning. Available at: https://halobi.com/blog/10-supply-chain-kpis-youll-want-every-morning/, accessed on 07/18/2020.

	Efficiency		Responsiveness	Reliability
	Cash-to-Cash Conversion Cycle	*Asset Turnover*	*Inventory -to-Sales Ratio*	*Inventory Turnover*
Mean	172.02	2.03	0.13	30.54
Standard Error	8.49	0.03	0.00	4.49
Median	127.03	1.72	0.10	6.90
Mode	100.39	0.20	0.00	227.58
Standard Deviation	496.84	1.65	0.18	262.57
Sample Variance	246,847.50	2.71	0.03	68,941.79
Kurtosis	833.91	58.24	257.62	2,216.82
Skewness	25.99	5.60	12.31	44.12
Range	19,043.19	26.80	5.21	13,751.35
Minimum	1.70	0.00	0.00	0.09
Maximum	19,044.89	26.81	5.21	13,751.44
Sum	588,637.42	6,944.91	451.24	104,499.80
Count	3422	3422	3422	3422

[[Insert Exhibit 8.8 here]]
Exhibit 8.8 Sample Supply Chain KPIs for Retail and Wholesale Trade Industries, 2009-2019
Source: Wharton Research Data Services (WRDS). Compustat North American Fundamentals-Annual. Accessed: 06/30/2020.

(LEVEL 3 HEADER) Examples of Descriptive Analytics in Operations: Key Performance Indicators (KPIs)

As you recall from chapter 7, an integral part of both descriptive and diagnostic analytics is key performance indicators (KPIs). KPIs are numerical metrics used to gauge company performance. The possible number of KPIs is endless. Each company determines which KPIs are the most crucial for the business and how they should be broken down (e.g., channel, product, region, and store). Below are examples of KPIs used in each branch of operations.

- Human resources
  - Absence rate and cost
  - Employee productivity
  - Employee job and benefits satisfaction

    - Internal promotion rate
    - (Involuntary and voluntary) turnover rate
    - Training effectiveness and cost per employee
    - Total employee cost (as a percentage of total costs)
    - New hire cost and 90 day failure rate
- IT operations
    - Open help desk tickets versus resolved tickets
    - Server and website downtime
    - Unsolved tickets per employee
    - Reopened tickets
    - IT support employees versus total employees
    - Server and website response time
    - Average resolution time
    - Server and website utilization rates
- Supply chain
    - Cash-to-cash cycle time (a.k.a., conversion cycle) and its components: days of payables, inventory, and receivables
    - On-time delivery to customer
    - Inventory to sales
    - Shipping cost and time
    - Perfect order delivery rate
    - Slow moving stock
    - Supplier on-time delivery and quality
    - Inventory turnover and carrying cost
    - Rate of product returns by customer
    - Back order rate

Lab Connection: Lab 8-1 provides step-by-step instructions on how we can use different features in Excel to generate descriptive analytics for supply chain KPIs.

Progress Check

6. What are days of payables, inventory, and receivables?

(Comp: please insert in the margin: "LO8-5: Explain how diagnostic analytics can be used to answer operations questions.")

(LEVEL 2 HEADER) DIAGNOSTIC MARKETING ANALYTICS

As you recall, diagnostic analytics helps to answer the questions: "Why did it happen?", "What are the reasons for the past results?", and "Can we explain why it happened?" In other words, diagnostic analytics attempts to identify the root cause (or the factor that initiated the chain of

events), which cannot often be uncovered by just performing descriptive analytics. Diagnostic analytics helps to evaluate the relations, patterns, and linkages between variables that might be related to an anomaly. This often requires combining multiple datasets and sometimes using external (not just historical) data.

(LEVEL 3 HEADER) Identifying anomalies/outliers

Often a first step in diagnostic analytics is to look for and identify unusual, unexpected results (i.e., an anomaly/outlier). Exhibit 8.9 details some anomalies by branch of operations and provides some possible explanations.

Branch of Operations	Expectation	Example of Anomaly	Possible Explanations for the Anomaly
Human Resources	Annual employee turnover will be 5%.	Annual employee turnover is 15%.	Company salaries are below the industry average.
IT Operations	Monthly server downtime will be 30 minutes.	The server downtime for the month of May was 2 hours.	A patch to fix server issues was not applied.
Supply Chain	Average freight cost per ton-mile is 18.8.	Average freight cost per ton-mile for September was 30.66.	More freight was shipped using (more expensive) airplanes instead of trucks.

[[Insert Exhibit 8.9 here]]

Exhibit 8.9: Examples of Anomalies by Operations Branch

Once the identified unexpected results have been identified, we can then investigate to understand exactly why the results occurred. As described in Chapter 7, root cause analysis (potentially with an Ishikawa Diagram) is often initially used to help understand what is driving the (unexpected) change. Additional techniques like those identified in Exhibit 8.10 below can

be used to find patterns or linkages in the underlying dataset or with an external dataset. Also, don't forget that the KPIs introduced in the descriptive analytics section are often also used in diagnostic analytics. The difference is that descriptive analytics would calculate a KPI at one point in time, while diagnostic analytics would see how the KPI changed over time.

Statistical Techniques to Perform Diagnostic Analytics	Use	Example of Type of Operations Question It Addresses
Summarization	Shows how totals vary at different levels of granularity (i.e., drill down, up, and through).	Why has employee turnover increased? Is it a companywide issue or localized?
Pivot table/Cross Tabulation	Groups variables to understand the relationships between them. Allows drill down and drill up.	What is the average resolution time for a systems problem in total and by each IT staff member?
Correlation	Extent to which variables are related to each other.	Is employee satisfaction related to customer satisfaction and sales revenue?
Regression	Examines whether there is a relationship between an independent input variable and dependent outcome variable.	What is the relationship between weather and demand?
Hypothesis Testing	Tests whether variables are significantly different.	Has the number of minutes of downtime for websites increased?
Process Control Chart	Determines whether a process is in control.	Why has the frequency of website slow response time increased?

[[Insert Exhibit 8.10 here]]

Exhibit 8.10: Diagnostic Analytics Techniques and Examples for Operations

(LEVEL 3 HEADER) Example of Diagnostic Analytics in Operations: Hypothesis Testing

Exhibit 8.8 presented some average supply chain KPIs during 2009-2019. Over the past decade, technology has permeated and transformed the supply chain making it reasonable to assume

that these ratios may have changed (and hopefully improved!) over time as technology increased the efficiency of the supply chain processes. To investigate if this is true, we want to answer the question: Have the supply chain KPIs changed over time?

To answer this question, we will perform hypothesis tests comparing the ratios from 2009 to those in 2019 using the t-test two sample (assuming unequal variances) menu option of the Data Analysis Add-in for Excel. Exhibit 8.11 presents the results of the hypothesis tests comparing the KPIs for cash-to-cash cycle, asset turnover, inventory-to-sales, and inventory turnover for 2009 and 2019. Let's look at the two tail test since we did not predict a specific direction with our question. Exhibit 8.11 shows that cash-to-cash cycle and asset turnover did decrease from 161 to 146 days and 1.9 to 1.74, respectively, but the decreases were not significant (meaning you can't say there was a change). However, both inventory-to-sales and inventory turnover significantly changed as the p-values are less than 0.05 (see the yellow highlights). Inventory-to-sales decreased from 0.16 to 0.12 indicating that the amount of inventory held (and associated costs) to fulfill sales decreased. Inventory turnover increased from 10.37 to 24.09 indicating that inventory is being sold faster in 2019 than in 2009 (and the supply chain has improved).

t-Test: Two-Sample Assuming Unequal Variances								
	Cash-to-Cash Cycle		Asset Turnover		Inventory-to-Sales		Inventory Turnover	
	2009	*2019*	*2009*	*2019*	*2009*	*2019*	*2009*	*2019*
Mean	161.04	145.65	1.90	1.74	0.16	0.12	10.37	24.09
Variance	10909.44	13874.45	0.85	3.06	0.01	0.01	452.76	2114.90
Observations	82.00	331.00	82.00	331.00	82.00	331.00	82.00	330.00
Hypothesized Mean Difference	0.00		0.00		0.00		0.00	
df	137.00		242.00		119.00		284.00	
t Stat	1.16		1.09		2.61		-3.97	
P(T<=t) one-tail	0.12		0.14		0.01		0.00	
t Critical one-tail	1.66		1.65		1.66		1.65	
P(T<=t) two-tail	0.25		0.28		0.01		0.0001	
t Critical two-tail	1.98		1.97		1.98		1.97	

[[Insert Exhibit 8.11 here]]

Exhibit 8.8 Sample Supply Chain KPIs for Retail and Wholesale Trade Industries, 2009-2019
Source: Wharton Research Data Services (WRDS). Compustat North American Fundamentals-Annual. Accessed: 06/30/2020.

While we did not find a significant difference for the overall cash-to-cash cycle, let's drill down to its components to see if any of them changed. So, we are going to answer the question: Have the KPIs for days of payables, inventory, and receivables changed over time? To answer this question, we compare the ratios from 2009 to those in 2019 using the t-test two sample (assuming unequal variances) menu option of the Data Analysis Add-in for Excel (just like above). Exhibit 8.12 presents the results. Only the days of inventory significantly changed dropping from 94.91 to 68.17, a 27 percent decrease. The results indicate that the time to pay vendors and receive cash from customers has not significantly changed from 2009 to 2019, but retail companies are holding inventory almost a third less time which should reduce inventory holding costs (i.e., insurance, storage, utilities).

t-Test: Two-Sample Assuming Unequal Variances						
	Days of Payables		Days of Inventory		Days of Receivables	
	2009	*2019*	*2009*	*2019*	*2009*	*2019*
Mean	40.89	45.11	94.91	69.17	25.23	31.38
Variance	582.35	3538.66	7459.03	5397.81	1699.00	1572.86
Observations	82.00	331.00	82.00	331.00	82.00	331.00
Hypothesized Mean Difference	0.00		0.00		0.00	
df	327.00		112.00		121.00	
t Stat	-1.00		2.49		-1.22	
P(T<=t) one-tail	0.16		0.01		0.11	
t Critical one-tail	1.65		1.66		1.66	
P(T<=t) two-tail	0.32		0.01		0.23	
t Critical two-tail	1.97		1.98		1.98	

[[Insert Exhibit 8.12 here]]

Exhibit 8.12: Hypothesis Tests for the Components of the Cash-to-Cash Cycle KPI
Source: Wharton Research Data Services (WRDS). Compustat North American Fundamentals-Annual. Accessed: 06/30/2020.

While this analysis was performed on the entire retail industry, further analysis could include only companies that had data in both 2009 and 2019 using a paired two sample test of means. Similarly KPIs for human resources and IT operations could be analyzed over time.

Lab Connection: Lab 8-2 provides step-by-step instructions on how to perform a hypothesis test in Excel comparing the KPIs of different companies. Lab 8-3 provides step-by-step instructions on how to create another type of diagnostic technique, a process control chart, in Tableau.

Progress Check

7. What is the difference between KPIs used for descriptive analytics versus KPIs used for diagnostic analytics?

(Comp: please insert in the margin: "LO8-6: Explain how predictive analytics can be used to answer operations questions.")

(LEVEL 2 HEADER) PREDICTIVE OPERATIONS ANALYTICS

Predictive analytic answers the questions: "What will happen in the future?", "What is the probability something will happen" or "Is it forecastable?" The goal is to predict future performance using historical data and a user-specified algorithm, which is basically instructions on how to combine the data. So, unlike descriptive and diagnostic analytics, which describe things we know are true, predictive analytics describes things that possibly might happen.

In this chapter, we break predictive analytic techniques into four broad categories: (1) classification, (2) decision tree, (3) forecasting, and (4) regression.[16] Exhibit 8.13 outlines some predictive analytics techniques, how they are used, and an example of an operations question that can be addressed by the technique.

Statistical Techniques to Perform Predictive Analytics	Use	Example of Type of Operations Question It Addresses
Classification	Separates a dataset into two or more predefined "like" groups.	Which employees are more likely to perform well?
Decision Tree	Predicts a specific dependent variable based on a pathway that includes all action points with associated probabilities.	How well will a new hire perform?
Forecasting	Predicts future values based on past values of the same variable. Anticipates the behavior of many people/things on long timelines.	How many active users will be using a specific company system in two years?
Regression	Predicts a specific dependent variable outcome based on relationship between independent and dependent variables. Anticipates the	When will a specific machine break down?

[16] Decision trees can be used to create classification trees (for categorical data) and regression trees (for continuous data).

	behavior of one person/thing on a short timeline.	

[[Insert Exhibit 8.13 here]]

Exhibit 8.13: Predictive Analytics Techniques and Operations Examples

(LEVEL 3 HEADER) Example of Predictive Analytics in Operations: Forecasting and Regression

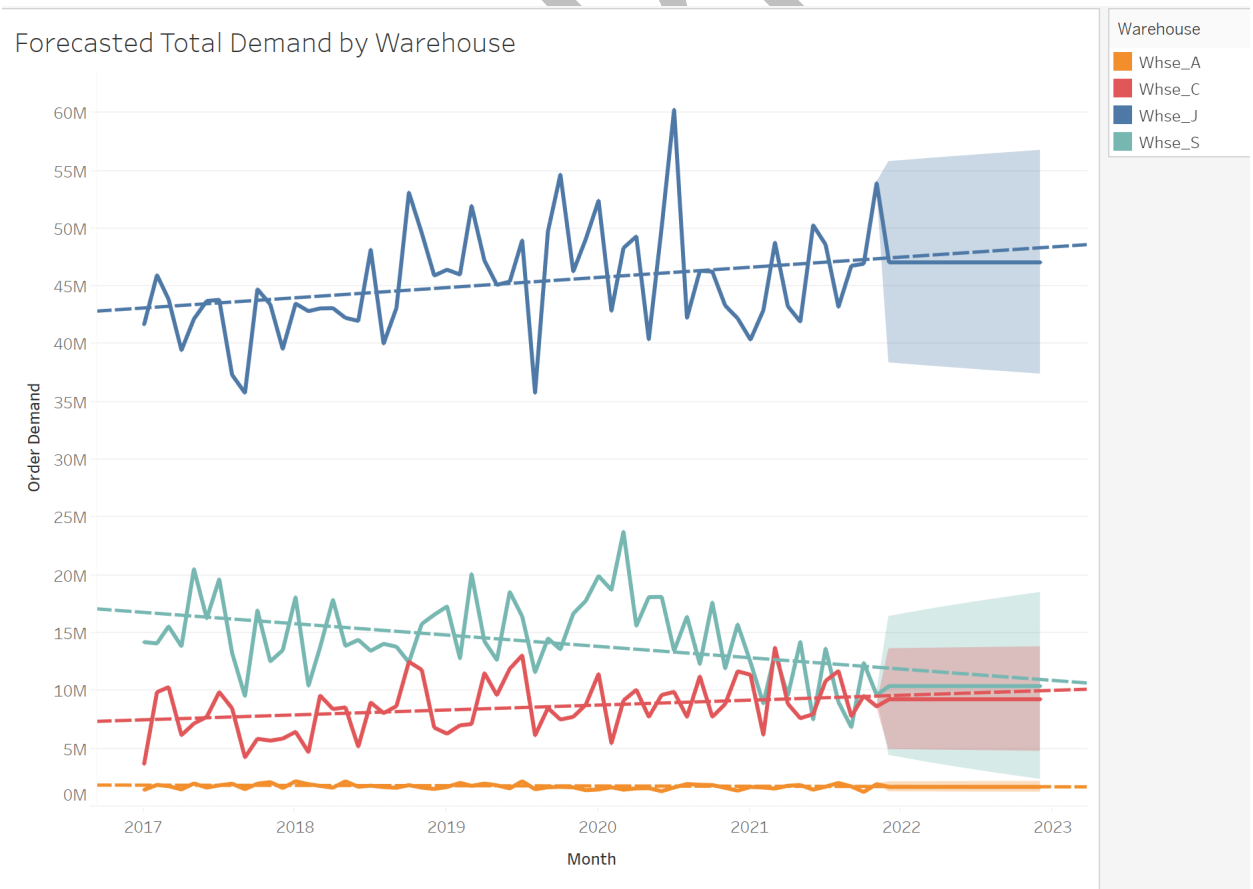
Forecasting and regression can be used to predict which employees are more likely to leave the company, which systems and machines require maintenance to prevent downtime, and forecast demand. Demand forecasts (of customer sales) are used in the supply chain management to help ensure that the right products are available to be properly delivered. Specifically, demand forecasts help prevent the overstocking and understocking of inventory, both of which can negatively impact revenue. In addition, demand forecasts can help companies plan for a wide variety of processes including production, purchases, and needed headcount.

Let's assume that a company has four warehouses that fulfill product orders for customers. Each warehouse is responsible for a different region. The company would like to forecast demand for the next year at each warehouse to determine how many workers are needed at each warehouse. The question we are answering in this analysis is: What is expected demand for 2022 at each warehouse?

Our data consists of a file that contains order date, quantity demanded, and warehouse location for 2017-2021[17]. First, we graph the current data in Tableau. Then, using the Forecast

[1717] This data was adapted from: https://www.kaggle.com/felixzhao/productdemandforecasting, accessed on 07/20/2020.

menu option under Analysis, Tableau generates a one year out forecast for expected demand at each warehouse. The forecast area is shaded to clearly differentiate it from the actual data. The band indicates a 95% prediction interval for the forecast. In other words, the Tableau model has determined that there is a 95% likelihood that estimated demand value will be within the shaded area. A narrower 90% confidence area or a wider 99% confidence interval can also be used. The dashed lines are the Tableau trend lines, showing the regression lines for the order demand based only on the past demand and date data (i.e., in other words no other independent variables are used to make a prediction about the order demand dependent variable). Exhibit 8.14 presents the Tableau visualization, while Exhibit 8.15 presents the Describe Forecast information available in Tableau.

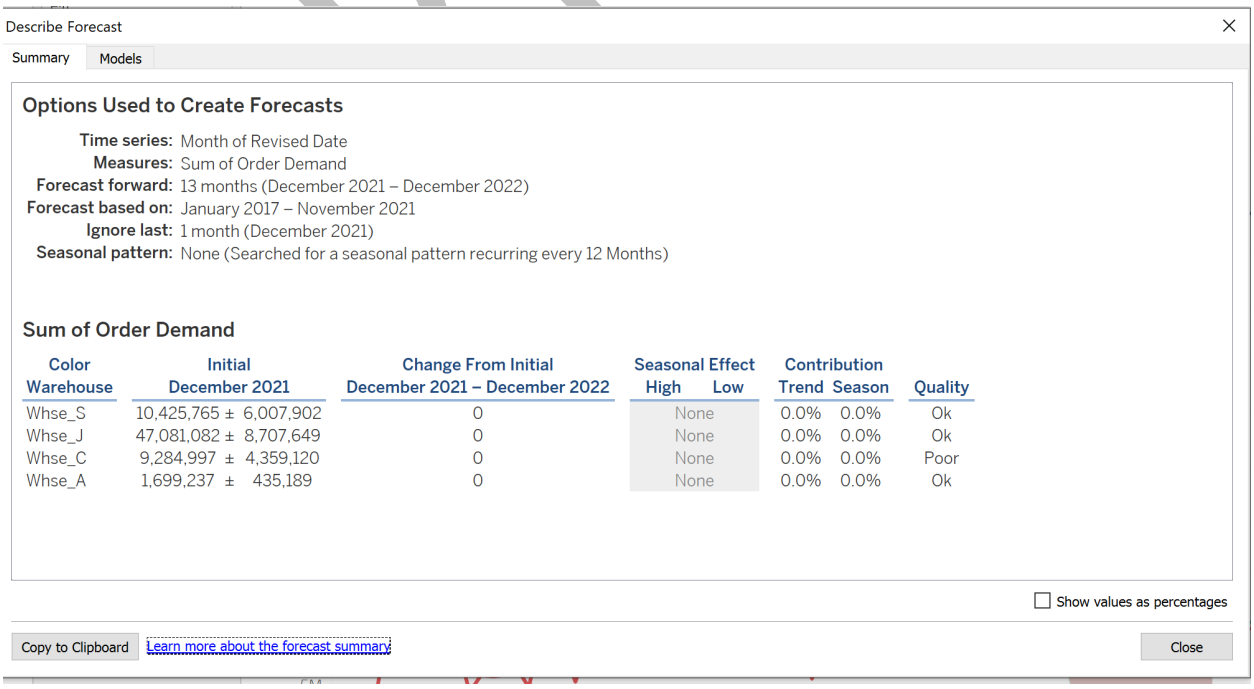


[[Insert Exhibit 8.14 here]]

Exhibit 8.14: Forecasted Demand in Tableau

The analysis shows that Warehouse J has much higher demand than the other warehouses, while Warehouse A has much lower demand than the other warehouses. In addition, demand at Warehouse J and Warehouse C seems to be trending slightly upwards while demand at Warehouse S appears to be falling. The estimated demand can be used to help determine the appropriate headcount needed at each warehouse in 2022. In addition, management may want to investigate why demand is decreasing at Warehouse S.

Finally, Exhibit 8.15 presents a description of the forecast created by Tableau. No seasonality (i.e., a repeating pattern of variation over time) was detected for any of the warehouses. In addition, the quality of the forecasts was "OK" except for Warehouse C which is "Poor", indicating the forecast has more error. As more data becomes available for analysis, forecasts should become more accurate creating a "Good" quality.



[[Insert Exhibit 8.15 here]]
Exhibit 8.15: Forecasted Demand Description in Tableau

Lab Connection: Lab 4 provides step-by-step instructions on how to create a forecast in Tableau.

Progress Check

8. Why does the size of the band around the forecast change when the confidence interval changes?

(Comp: please insert in the margin: "LO8-7: Explain how prescriptive analytics can be used to answer operations questions.")

(LEVEL 2 HEADER) PRESCRIPTIVE OPERATIONS ANALYTICS

As you recall from Chapter 7, prescriptive analytics answers the questions: "What should we do based on what we will expect to happen?" and "How do we optimize our performance based on potential constraints?" While both predictive and prescriptive analytics make predictions about the future, prescriptive analytics recommends a course of action. Exhibit 8.16 identifies some prescriptive analytics techniques as well as examples of operations questions that each technique could answer.[18]

Statistical Techniques to Perform Prescriptive Analytics	Use	Example of Type of Operations Question It Addresses
Cash Flow Analysis	Evaluates future cash flows for potential investments or expenditures. It typically uses net present value (NPV) internal rate of return (IRR)	How many delivery trucks should the company purchase?
Goal Seek Analysis	What if analysis that determines the required input value(s) to get a	How many IT support staff are needed to resolve all IT tickets within 30 minutes?

[18] Optimization typically involves advanced techniques. Therefore, it is discussed in more detail in Chapter 11.

	desired output (backwards analysis).	
Optimization	The process of making something as effective as possible.	What is the optimal shipping route?
Scenario Analysis	What if analysis that examines the effect of changing *multiple* input variables at the same time on an outcome variable (typically, base/most likely, worst, and best cases).	What is the optimal inventory policy to maintain a specified item fill rate?
Sensitivity Analysis	What if analysis that examines the effect of changing *one* input on an outcome variable.	Which employees need to go to training to improve their productivity?

[[Insert Exhibit 8.16 here]]

Exhibit 8.16: Prescriptive Analytics Techniques and Operations Examples

(LEVEL 3 HEADER) Example of Prescriptive Analytics in Operations: Optimization

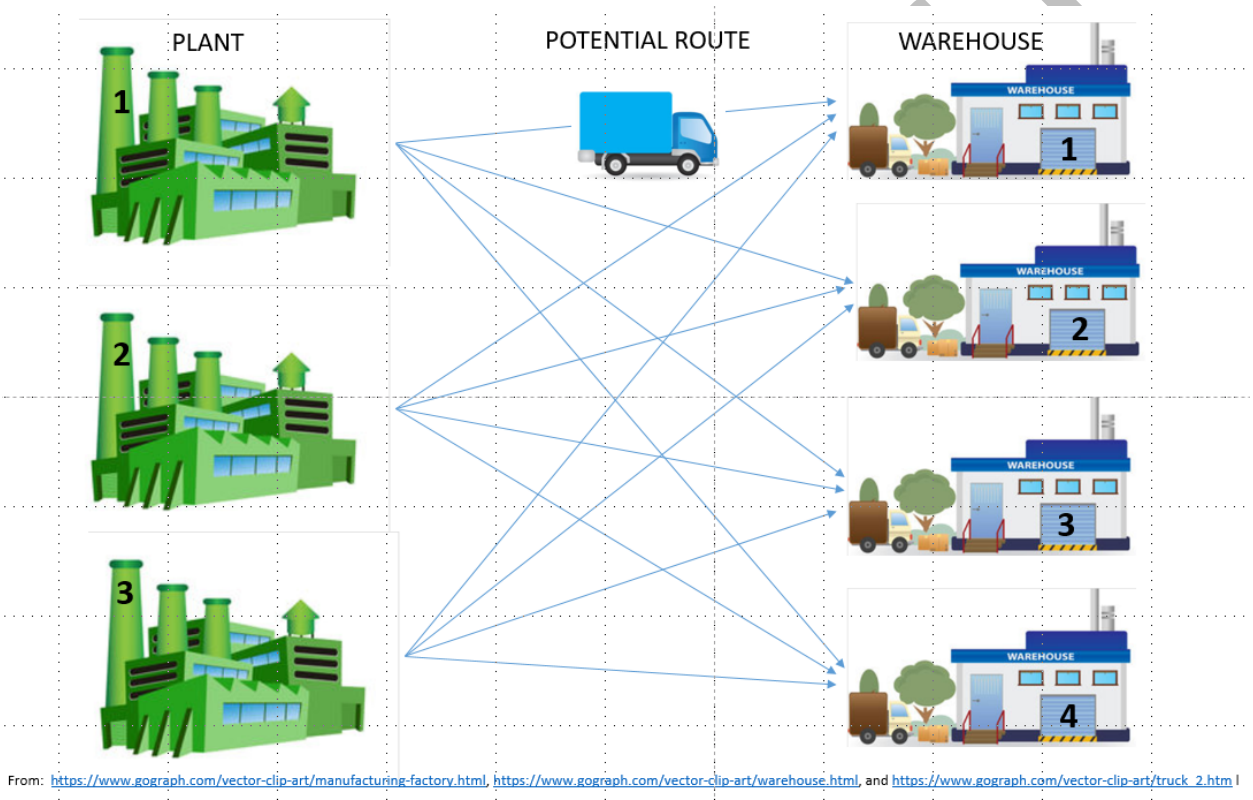
Optimization is the process of making something as effective as possible. In the supply chain, determining the best route to ship goods is important to control costs and deliver goods in a timely fashion. The tasks of determining the best shipping routes can be very complex. For example, UPS delivers over 21.9 million packages and documents a day using over 125,000 vehicles.[19] Walmart has 190 distribution centers[20] across the U.S. that support 4,753 U.S. stores and 599 Sam's Clubs.[21]

[19] UPS. 2019. UPS Fact Sheet. Available on-line at: https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=FactSheets&id=1426321563187-193, accessed 07/21/2020.

[20] MWPVL International Inc. 2020. Leadership in Global Supply Chain and Logistics Consulting. Available on-line at: https://mwpvl.com/html/walmart.html, accessed 07/21/2020.

[21] Walmart. 2020. Location Facts. Available on-line at: https://corporate.walmart.com/our-story/our-locations, accessed 07/21/2020.

Can you imagine trying to identify the best routes for all of the trucks for UPS or Walmart? We can't. So instead, let's look at a simplified example. Let's assume that a company manufactures one product in three manufacturing plants (Plant 1, 2, and 3), which supply four warehouses (Warehouse 1, 2, 3, 4). Exhibit 8.17 shows the potential shipping routes between the plants and warehouses.



From: https://www.gograph.com/vector-clip-art/manufacturing-factory.html, https://www.gograph.com/vector-clip-art/warehouse.html, and https://www.gograph.com/vector-clip-art/truck_2.htm l

[[Insert Exhibit 8.17 here]]
Exhibit 8.17: Possible Shipping Routes

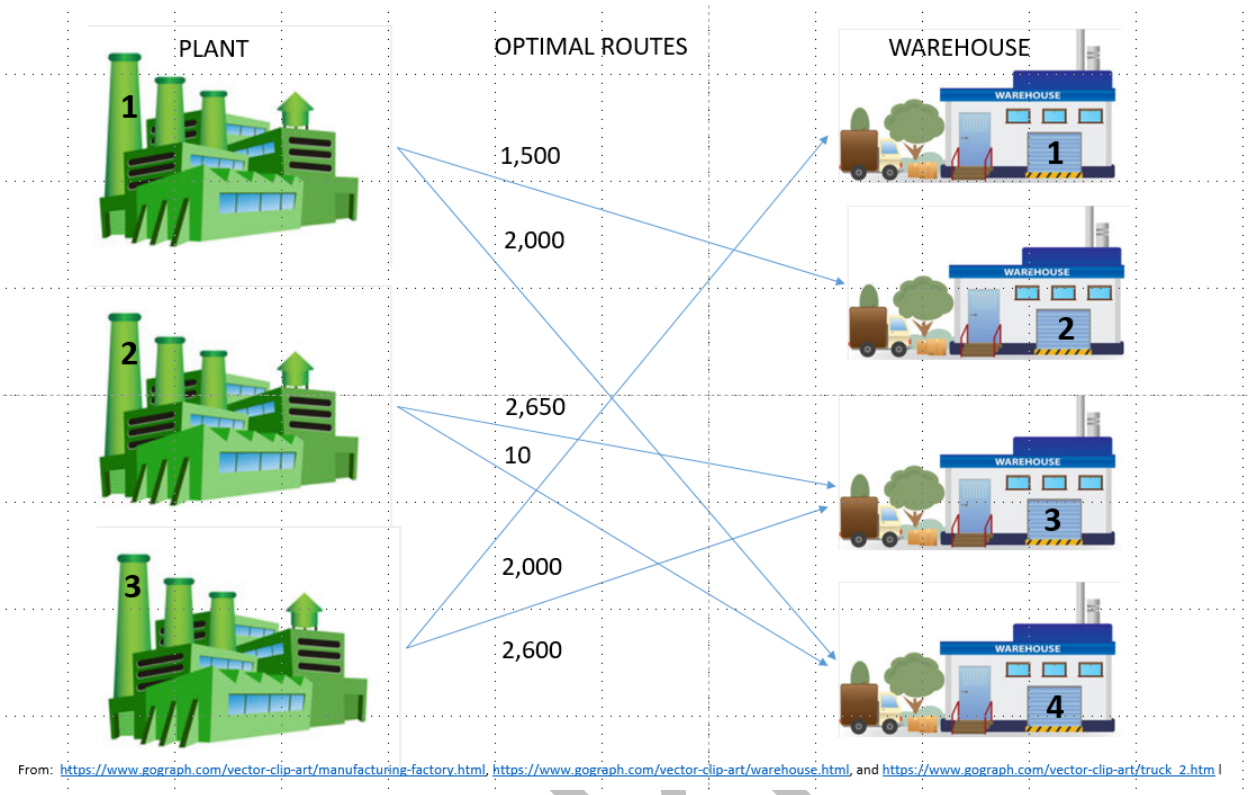
The per unit cost to deliver from one of the plants to one of the warehouses varies. Each warehouse plant has a maximum capacity to make a product (3500, 2750, and 4600). Each warehouse has its own customer demand for the product (2000, 1500, 5250, and 2100). The number of products that each plant can ship is less than or equal to its capacity. The number of products that each warehouse receives must be greater than or equal to its demand. The goal

is to minimize total shipping cost. Using the Solver Add-In for Excel, we can solve this problem. The result is shown in Exhibit 8.18.

Network Transportation Problem									
Cost per unit delivery									
		Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4				
	Plant 1	1.80	1.86	1.88	1.75				
	Plant 2	1.26	1.46	1.10	1.22				
	Plant 3	1.18	1.92	1.12	1.92				
Recommended Shipping Model									
		Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4	Ship		Capacity	
	Plant 1	0	1500	0	2000	3500	<=	3500	
	Plant 2	0	0	2650	100	2750	<=	2750	
	Plant 3	2000	0	2600	0	4600	<=	4600	
								10850	Total
	Received	2000	1500	5250	2100				
		>=	>=	>=	>=				
	Demand	2000	1500	5250	2100	10850	Total		
Total Cost	14,594.09								

[[Insert Exhibit 8.18 here]]
Exhibit 8.18: Example of a Simple Transportation Optimization Problem

Based on the solution, Plant 1 should ship 1,500 units to Warehouse 2 and 2,000 units to Warehouse 4. Plant 2 should ship 2,650 units to Warehouse 3 and 100 units to Warehouse 4. Plant 3 should ship 2,000 units to Warehouse 1 and 2,600 units to Warehouse 3. The total cost for this shipping model is $14,594. Exhibit 8.19 visually shows the solution for our simplified example. UPS would just have 3,125 times more vehicles to route!



From: https://www.gograph.com/vector-clip-art/manufacturing-factory.html, https://www.gograph.com/vector-clip-art/warehouse.html, and https://www.gograph.com/vector-clip-art/truck_2.htm l

[[Insert Exhibit 8.19 here]]

Exhibit 8.19: Optimal Solution to the Simple Transportation Optimization Problem

If you select Sensitivity when you run the Solver, Excel automatically generates a Sensitivity Report, which can be used to help understand the recommended shipping model as well as help identify potential places to try and reduce costs. Exhibit 8.20 shows the Variable Cells portion of the Report. If a Final Value equals 0 (meaning nothing was shipped between the specified plant and warehouse), the Reduced Cost field indicates how much the cost per unit must decrease before the specified plant would ship to the specified warehouse in the Name field. For example, in order for Plant 1 to ship products to Warehouse 1, the per unit cost must drop by a little more than $0.12. In order for Plant 1 to ship products to Warehouse 3, the per unit cost must drop by almost $0.26.

Microsoft Excel 16.0 Sensitivity Report
Worksheet: [Book1]data
Report Created: 7/21/2020 11:27:08 AM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
C12	Plant 1 Warehouse 1	0	0.120483163	1.799534427	1E+30	0.120483163
D12	Plant 1 Warehouse 2	1500	0	1.86064162	0.119760924	1.86064162
E12	Plant 1 Warehouse 3	0	0.257810992	1.878392235	1E+30	0.257810992
F12	Plant 1 Warehouse 4	2000	0	1.745406041	0.120483163	0.119760924
C13	Plant 2 Warehouse 1	0	0.105901338	1.260314791	1E+30	0.105901338
D13	Plant 2 Warehouse 2	0	0.119760924	1.455764732	1E+30	0.119760924
E13	Plant 2 Warehouse 3	2650	0	1.095943432	0.105901338	0.496876011
F13	Plant 2 Warehouse 4	100	0	1.22076823	0.119760924	0.120483163
C14	Plant 3 Warehouse 1	2000	0	1.182175254	0.105901338	1.679051264
D14	Plant 3 Warehouse 2	0	0.554648271	1.91841388	1E+30	0.554648271
E14	Plant 3 Warehouse 3	2600	0	1.123705232	0.496876011	0.105901338
F14	Plant 3 Warehouse 4	0	0.673321623	1.921851653	1E+30	0.673321623

[[Insert Exhibit 8.20 here]]
Exhibit 8.20: Excel Solver Sensitivity Report

Lab Connection: Lab 5 provides step-by-step instructions on how to use Excel's Solver Add-in to minimize the cost of labor.

Progress Check

9. What is the optimization and why is it considered to be part of prescriptive analytics?

(Comp: please insert in the margin: "LO8-8: Characterize how operations analytics reports results.")

(LEVEL 1 HEADER) REPORT THE RESULTS

As noted in Chapter 6, there are numerous ways to report the results. In this chapter, we focus on **operations dashboards**, which are visual management tools that help track and monitor

KPIs to improve operations. Each company needs to decide not only what operations KPIs are important for success, but also the best way to present them on the dashboard. Separate dashboards (with appropriate KPIs) are typically created for human resources, IT operations, and supply chain.

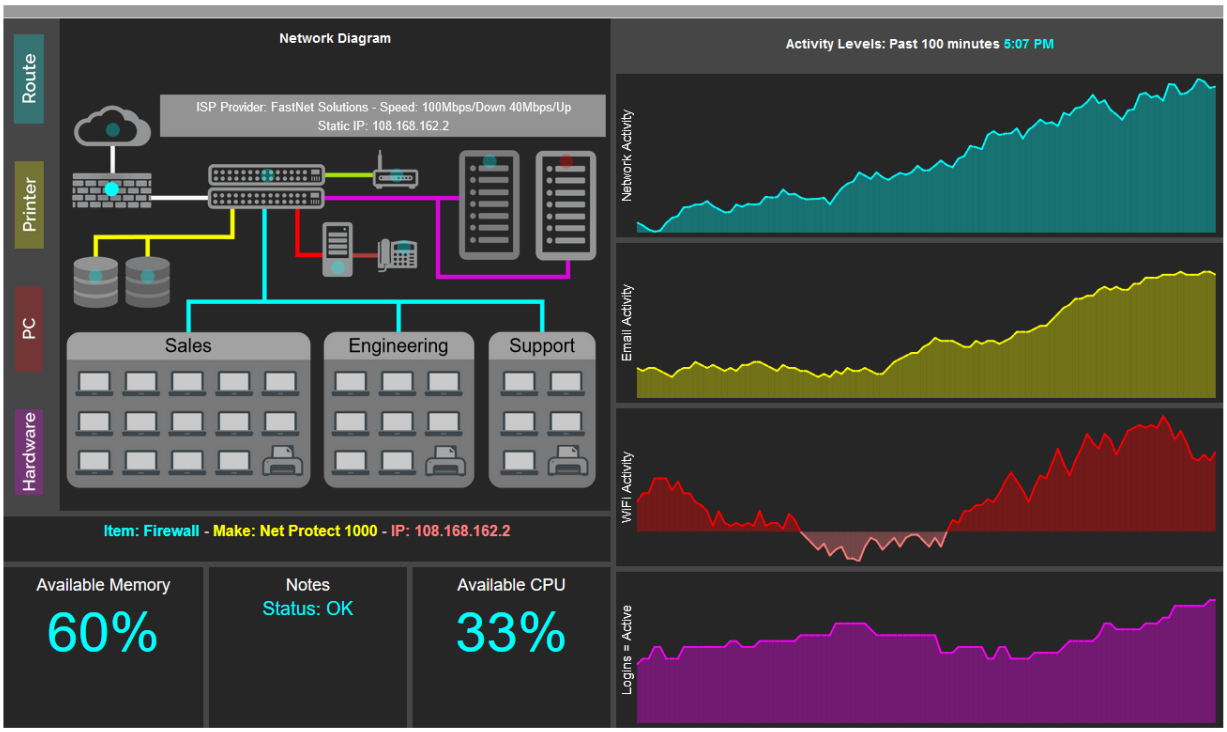
Exhibit 8.21 presents an example of an HR dashboard. The dashboard includes information about the recruitment activity, benefit expenses, headcount, occupational health expense, and staff absenteeism cost by month. Note that some of the KPIs are shown at a point in time (e.g., headcount) while others are shown over time (e.g., occupational health expense and staff absenteeism cost) or compared to prior years (e.g., recruitment activity and benefits expense).

[[Insert Exhibit 8.21 here]]

Exhibit 8.21: Sample HR Dashboard

Source: iDashboards. 2020. Human Resources – HR Reporting. Available on-line at: https://www.idashboards.com/dashboard-examples/human-resources-summary-dashboard/, accessed on 07/21/2020.

Exhibit 8.22 presents a sample IT operations dashboard for network resource monitoring. It shows the activity level for all of the network systems in the past 100 minutes as well as available memory and CPU, and overall status. Notice how the diagram on the left shows where the activity levels on the right are in the network using color coding. This is one of many potential IT operations dashboards. Others could potentially show IT services support (a.k.a., service ticket management), project management, cyber security, IT costs, and user IT engagement.

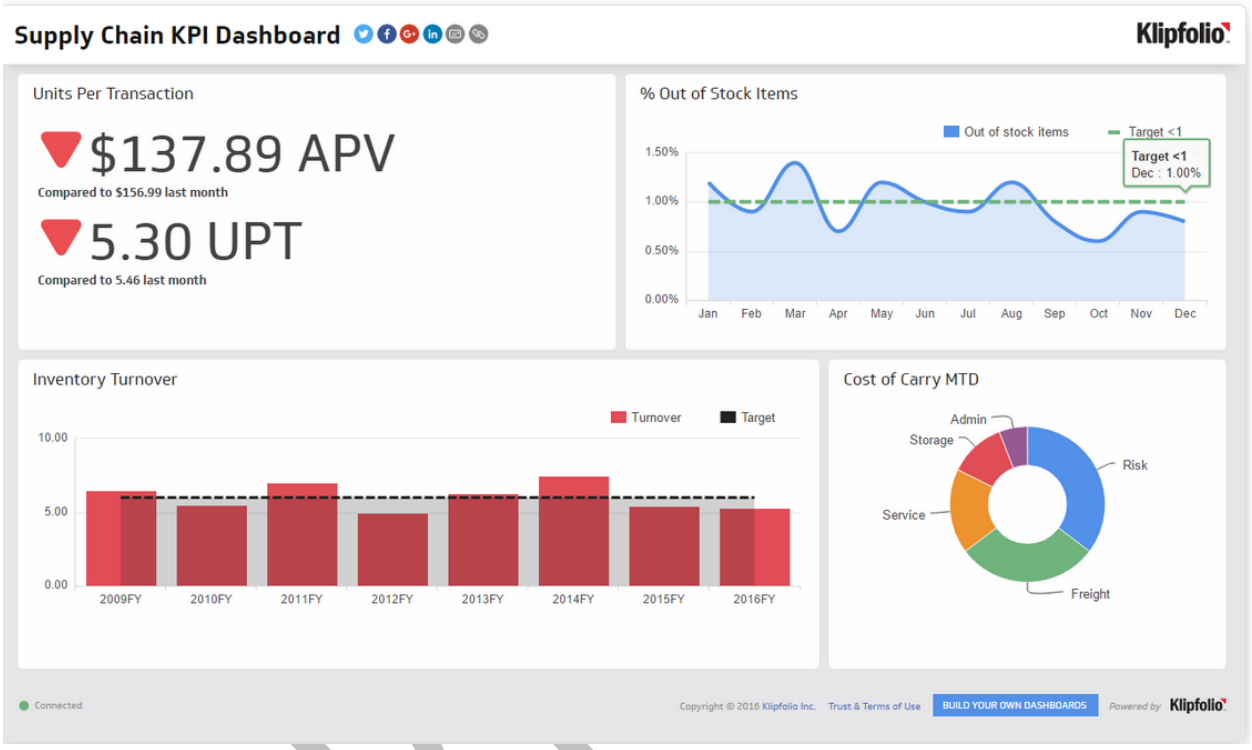


[[Insert Exhibit 8.22 here]]

Exhibit 8.22: Sample IT Operations Dashboard

Source: iDashboards. 2020. IT – Network Resource Monitoring. Available on-line at: https://www.idashboards.com/dashboard-examples/it-dashboard/, accessed on 07/21/2020.

Exhibit 8.23 shows a sample supply chain KPI dashboard. This dashboard includes the units per transaction (UPT) were 5.3 (a slight decrease from last month), average purchase value (APV), percent of out of stock items, inventory turnover, and cost of carrying the inventory. Other supply chain dashboard could present information about procurement, transportation, and warehouse operations.



[[Insert Exhibit 8.23 here]]

Exhibit 8.23: Sample Supply Chain Dashboard
Source: Klipfolio. 2020. Supply Chain KPI Dashboard. Available on-line at: https://www.klipfolio.com/resources/dashboard-examples/supply-chain/kpi-dashboard, accessed on 07/21/2020.

Progress Check

10. Why are dashboards good tools to present analytics?

(LEVEL 1 HEADER) SUMMARY

Operations analytics is used to answer operations questions. We specified the type of questions that can be addressed with both internal and external data across the three branches of operations. Next, there was a discussion of the data available to address operations questions. We also had a discussion of the different types of analytics that can be performed,

including descriptive, diagnostic, predictive and prescriptive analytics. The chapter concluded with examples of reporting the results using operations dashboards.

(LEVEL 1 HEADER) KEY WORDS

Fill rate - percent of customer orders satisfied by inventory on hand

Human resources - a branch of operations that focuses on managing and developing a company's workforce.

Human resource (HR) analytics – using people data to make better decisions.

Human resource management (HRM) system -stores collected human resource data in one place; and helps automate human resource processes and compliance with laws and regulations.

IT operations - how a company manages its hardware, software, and IT support.

IT operations analytics (ITOA) - uses company data from various applications and IT infrastructure to instantly identify IT issues as they occur.

Operations dashboards - visual management tools that help track and monitor KPIs to improve operations. Separate dashboards are typically prepared for human resources, IT operations, and supply chain.

Supply chain - a branch of operations that is responsible for the production and distribution of a product (or service) to the final consumer.

Supply chain management (SCM) system – stores collected supply chain data in one place; and helps automate supply chain processes and compliance with laws and regulations.

Telemetry - collecting data at remote points (possibly by a digital employee badge) and automatically transmitting the data to monitoring equipment.

(LEVEL 1 HEADER) ANSWERS TO PROGRESS CHECKS

1. Both are branches of the operations function. IT operations is how the company manages its hardware, software, and IT support. Supply chain is responsible for the production and distribution of a product (or service) to the final consumer. It includes all of the necessary processes to make the product including: obtaining raw materials, transforming raw materials into the finished product, transportation, and distribution.

2. Potential human resource questions addressable using analytics might include: “How has headcount changed from last year?” “Which new hires will perform best?” “How many employees does the company need to staff during the holidays?”
3. Potential supply chain questions addressable using predictive analytics might include: “What will demand be for a product?”, “What happens to costs if the company increase/decreases order quantities?”, and “Which machine will break down?”
4. Potential sources of internal data that can be used for operations analytics include data stored in human resource management systems, telemetry devices, computer logs, and supply chain management systems.
5. Potential sources of external data that can be used for operations analytics include LinkedIn, job websites, social media, weather, road conditions, and traffic patterns.
6. A KPI for supply chain is cash-to-cash cycle time, which is the total number of days from when the company pays the vendor to when the company receives money from the customer. It is the sum of the days of payables (the number of days it takes to pay vendors), days of inventory (the number of days a company holds inventory before it is sold), and days of receivables (the number of days until cash received from customer).
7. The difference is that descriptive analytics would calculate a KPI at one point in time, while diagnostic analytics would see how the KPI changed over time.
8. The size of the band around the forecast reflects the confidence interval associated with the forecast. For example, if you wanted to be only 10% confident in your forecast, then a very narrow confidence ban would be used because then your forecast would only have to fall within the band one out of ten times! So, 90 percent of the time your forecast would not be in that band. If you wanted to be 99% confident in your forecast, then a very wide confidence ban would be used because your forecast would have to fall within the band 99 out of 100 times! The wider band covers more potential forecasts increasing your odds of falling in the band.
9. Optimization process of making something as effective as possible. Optimization is a prescriptive analytics technique because it provides the answer to the question: “How do we optimize our performance based on potential constraints?”
10. There are many reasons why a dashboard is a good tool for presenting the results of analytics including: all information is gathered in one place; it provides instant access to critical information; KPIs can be automatically evaluated against a target; and summarizes a lot of data using easy to read visuals.

(LEVEL 1 HEADER) MULTIPLE CHOICE QUESTIONS

1. (LO8-1) Which of the following items is not part of operations?
    a. Advertising
    b. Integrating information technology

c. Ordering raw materials
d. Scheduling production

2. (LO8-3) What is collecting data at remote points and transmitting the data to monitoring equipment?
    a. Fill rate
    b. Operations dashboard
    c. Supply chain
    d. Telemetry
3. (LO8-3) CRM and SCM play an important role across the product life cycle?
    a. False
    b. True
4. (LO8-1, LO8-3) Which of the following statements about supply chain management systems (SCMs) is true?
    a. SCMs can be linked to the customer relationship management systems.
    b. SCMs are (usually) integrated modules of an enterprise systems
    c. SCMs includes the processes from procurement to delivering the goods to the customer.
    d. All of the above statements are true.
5. (LO8-4) "How many new employees were hired during the year?" is an example of a question that can be answered by:
    a. Descriptive analytics
    b. Diagnostic analytics
    c. Predictive analytics
    d. Prescriptive analytics
6. (LO8-5) "Why has the number of minutes of downtime for websites increased from last year?" is an example of a question that can be answered by:
    a. Descriptive analytics
    b. Diagnostic analytics
    c. Predictive analytics
    d. Prescriptive analytics
7. (LO8-6) "How many active users will be using the enterprise system in three years?" is an example of a question that can be answered by:
    a. Descriptive analytics
    b. Diagnostic analytics
    c. Predictive analytics
    d. Prescriptive analytics
8. (LO8-6) In Tableau, how are forecasts differentiated from the actual data?
    a. Bolded lines are used for forecasts

b. Dashed lines are used for forecasts
c. Different colored lines
d. Shading

9. (LO8-7) "Which employees need to go to training to improve their productivity?" is an example of what of a question that can be answered by:
    a. Descriptive analytics
    b. Diagnostic analytics
    c. Predictive analytics
    d. Prescriptive analytics
10. (LO8-7) To complete an optimization in Excel, which feature would you use?
    a. Data Analysis Add-in
    b. Forecast Sheet
    c. Solver Add-in
    d. What-if Analysis

(LEVEL 1 HEADER) DISCUSSION QUESTIONS

1. (LO8-1) Describe the role of operations in a company.
2. (LO8-3) A human resource management (HRM) system can be set up to include information about a (potential) employee from the person's public social media activity including likes/dislikes and tweets. Do you believe this is ethical for a company to collect this information? Why or why not
3. (LO8-3) How can telemetry be used by companies to gather information about employees? Do you believe that it is ethical for companies to use telemetry in this manner? Why or why not?
4. (LO8-3, LO8-4, LO8-5, LO8-6, LO8-7) Describe how companies can analyze the digital footprint left by employees.
5. (LO8-3, LO8-4, LO8-5) Assume that a company has standard operating hours of Monday through Friday, 8 a.m. to 5 p.m. What would be the concern if an employee was entering transactions at 3 a.m. on the weekend? How could this be determined?
6. (LO8-3) Why would a company want to link its SCM system with it CRM system?
7. (LO8-4, LO8-5) Let's examine the Dell computer order process. A customer places an on-line order for a computer and then pays for the order. After the order is placed and paid for, Dell orders the parts, vendors deliver the parts, the computer is assembled, and then shipped out. How does this process affect the cash-to-cash cycle for Dell?
8. (LO8-4, LO8-5) Why would a company want to evaluate the IT operations KPI of unsolved tickets per (IT service desk) employee? How could a company use a KPI equal to the number of unsolved tickets divided by the number of solved tickets.

9. (LO8-7) How could a sensitivity report for the Solver Add-In be used to improve shipping operations?

(LEVEL 1 HEADER) BRIEF EXERCISES

1. (LO8-1) Match the branch of operations (human resources, IT operations, and supply chain) to the example operations questions.

Example Operations Questions	**Branch of Operations**
How many minutes of downtime did the company website have last month?	
How many employees have been with the company less than 5 years? 1 year?	
What will product demand be in 5 years?	
What is the best shipping route to minimize cost? Delivery time?	
Why has application performance changed?	
How many employees does the company need to work on a holiday?	
Which machine needs maintenance to prevent downtime?	

2. (LO8-4, LO8-5, LO8-6, LO8-7) Match the analytics type (descriptive, diagnostic, predictive, and prescriptive) to the example operations questions.

Example Operations Questions	**Analytics Type** (Descriptive, Diagnostic, Predictive, or Prescriptive)
Why did the perfect order delivery rate change from last year?	
Which vendor is most likely to deliver on time?	
How many new machines should the company purchase?	
What is the perfect order delivery rate?	
Why did average delivery time increase?	
How many IT service desk employees are needed to resolve all IT tickets within 15 minutes?	

What is the internal promotion rate?	Descriptive

3. (LO8-3) Match the operations data to the branch of operations (human resources, IT operations, supply chain).

Example Operations Data	**Branch of Operations**
Performance evaluations	
Network statistics	
Demand forecasts	
LinkedIn account	
Shipping routes	
Delivery times	
IT service tickets open and closed	

(LEVEL 1 HEADER) PROBLEMS

1. (LO8-4, LO8-5, LO8-6, LO8-7) Match the analytics type (descriptive, diagnostic, predictive, and prescriptive) and branch of operations (human resources, IT operations, supply chain) to the analytics technique used.

Analytics Technique Used	**Analytics Type** (descriptive, diagnostic, predictive, or prescriptive)	**Branch of Operations** (human resources, IT operations, supply chain)
Total number of employees		
Forecast to estimate product demand in two years?		
Hypothesis test to see if server response time has increased.		
Optimization to schedule assembly line workers.		

Scenario analysis to determine the optimal fill rate.		
Regression to determine when a server breakdown.		
Count of employees by department		

2. (LO8-4, LO8-5, LO8-6, LO8-7) Match the analytics type (descriptive, diagnostic, predictive, and prescriptive) to the analytics technique used.

Analytics Technique Used	**Analytics Type** (descriptive, diagnostic, predictive, or prescriptive)
Optimization	
Forecasting	
Minimums	
Hypothesis Testing	
Classification	
Goal Seek	
Bar chart	

3. Match the Excel menu option (Data Analysis, Solver) to the analytics technique used.

Analytics Technique Used	**Excel Menu Option** (Data Analysis, Solver)
Optimization	Solver
t-test	Data Analysis
Regression	Data Analysis
Profit maximization	Solver
Cost minimization	Solver

4. (LO8-3) Companies may augment their SCM systems with a warehouse management system. Describe specific types of warehouse management questions that can be

answered using descriptive, diagnostic, predictive and prescriptive analytics (one question for each). Describe the techniques that could be used to address each of those questions.

5. (LO8-6) What is the difference between forecasting and regression?

(LEVEL 1 HEADER) LABS

Labs Associated with Chapter 8

8-1 (LO8-4) Descriptive Analytics using the Data Analysis Add-in (Excel)
8-2 (LO8-5) Hypothesis Testing using the Data Analysis Add-in (Excel)
8-3 (LO8-5) Process Control Chart (Tableau)
4-4 (LO8-6) Forecasting (Tableau)
8-5 (LO8-7) Optimization using the Solver Add-In (Excel)