

**METHOD AND SYSTEM FOR SEASONAL PLANNING AND SCHEDULING APPROACH
USING MULTIPLE HORIZON FORECASTS FROM MONTE CARLO SIMULATION**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 63/490,884 filed March 17, 2023, the contents of which are incorporated in their entirety herein.

TECHNICAL FIELD

[0002] The present specification relates to inventory management, and more particularly, to a method and system for seasonal planning and scheduling approach using multiple horizon forecasts from Monte Carlo simulation.

BACKGROUND

[0003] Holding optimal amounts of inventory for a seasonal product based on demand uncertainty is important for companies to control inventory costs, while maintaining service level. As such, a need exists for improved methods of seasonal planning of inventory levels.

SUMMARY

[0004] In one embodiment, a method may include receiving historical data indicating demand for a product during a plurality of time periods within a plurality of previous years; determining a plurality of Gamma distributions comprising a best fit Gamma distribution for each time period among the plurality of time periods based on the historical data; performing a plurality of first simulations of the Gamma distributions for a first number of future time periods to generate a first estimated demand for each time period of the first number of future time periods for each of the plurality of first simulations; performing a plurality of second simulations of the Gamma distributions for a second number of future time periods to generate a second estimated demand for each time period of the second number of future time periods, the second number of future time periods being greater than the first number of future time periods; determining a first inventory amount of the product needed to satisfy the first estimated demand for each time period of the first number of future time periods in at least a first minimum percentage of the first simulations; determining a second inventory amount of the product needed to satisfy the second

estimated demand for each time period of the second number of future time periods in at least a second minimum percentage of the second simulations, the second minimum percentage being less than the first minimum percentage; and ordering a third inventory amount comprising a minimum of the first inventory amount and the second inventory amount.

[0005] In another embodiment, a computing device may include a processor configured to receive historical data indicating demand for a product during a plurality of time periods within a plurality of previous years; determine a plurality of Gamma distributions comprising a best fit Gamma distribution for each time period among the plurality of time periods based on the historical data; perform a plurality of first simulations of the Gamma distributions for a first number of future time periods to generate a first estimated demand for each time period of the first number of future time periods for each of the plurality of first simulations; perform a plurality of second simulations of the Gamma distributions for a second number of future time periods to generate a second estimated demand for each time period of the second number of future time periods, the second number of future time periods being greater than the first number of future time periods; determine a first inventory amount of the product needed to satisfy the first estimated demand for each time period of the first number of future time periods in at least a first minimum percentage of the first simulations; determine a second inventory amount of the product needed to satisfy the second estimated demand for each time period of the second number of future time periods in at least a second minimum percentage of the second simulations, the second minimum percentage being less than the first minimum percentage; and order a third inventory amount comprising a minimum of the first inventory amount and the second inventory amount.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The embodiments set forth in the drawings are illustrative and exemplary in nature and not intended to limit the disclosure. The following detailed description of the illustrative embodiments can be understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

[0007] FIG. 1 schematically depicts an example computing device, according to one or more embodiments shown and described herein;

[0008] FIG. 2 schematically depicts a plurality of memory modules of the computing device of FIG. 1, according to one or more embodiments shown and described herein;

[0009] FIG. 3 depicts example Gamma distributions, according to one or more embodiments shown and described herein; and

[0010] FIG. 4 depicts a flowchart of an example method for operating the computing device of FIG. 1, according to one or more embodiments shown and described herein.

DETAILED DESCRIPTION

[0011] The embodiments disclosed herein describe methods and systems for seasonal planning and scheduling approach using multiple horizon forecasts from Monte Carlo simulations. When supplying a seasonal product, that is a product that is used seasonally, rather than year-round, it may be difficult for a producer of the product to determine how much inventory to produce. If not enough inventory is produced, the producer may run out of product before the season ends and be unable to meet demand. However, if too much inventory is produced, the producer may be unable to sell all of the inventory before the end of the season, which may require the producer to incur the cost of storing the remaining inventory until the following season, or discarding the remaining inventory if it will expire or no longer be usable the following season. Estimating an amount of inventory needed may be particular difficult to predict if demand for the product has substantial variability over the course of a season or between seasons (e.g., if demand depends on weather or other unpredictable factors).

[0012] In embodiments disclosed herein, it is assumed that a Gamma distribution provides a relatively accurate probability distribution of the demand for a product, based on empirical studies. As such, historical data indicating past demand for a product during each week of a season over a plurality of previous years is used to determine a Gamma distribution to estimate demand for each week of the season. The determined Gamma distributions are then used to simulate demand for the product over both a short-term time horizon (e.g., the next few weeks), and a long-term time horizon (e.g., the rest of the season). An inventory amount needed to satisfy the demand over the short-term time horizon and/or the long-term time horizon may be determined for a certain confidence level based on the simulations. An appropriate amount of inventory may then be produced based on the needed inventory amount, as disclosed herein.

[0013] Turning now to the figures, FIG. 1 schematically depicts an example configuration of a computing device 100, according to the embodiments disclosed herein. The computing device 100 may comprise a variety of different types of devices (e.g., a local computing system, a cloud

computing system, and the like). The computing device 100 may perform the operations of the embodiments disclosed herein. In the illustrated example, the computing device 100 includes one or more processors 102, a communication path 104, one or more memory modules 106, a data storage component 108, and network interface hardware 110, the details of which will be set forth in the following paragraphs.

[0014] Each of the one or more processors 102 may be any device capable of executing machine readable and executable instructions. Accordingly, each of the one or more processors 102 may be a controller, an integrated circuit, a microchip, a computer, or any other physical or cloud-based computing device. The one or more processors 102 are coupled to a communication path 104 that provides signal interconnectivity between various modules of the computing device 100. Accordingly, the communication path 104 may communicatively couple any number of processors 102 with one another, and allow the modules coupled to the communication path 104 to operate in a distributed computing environment. Specifically, each of the modules may operate as a node that may send and/or receive data. As used herein, the term “communicatively coupled” means that coupled components are capable of exchanging data signals with one another such as, for example, electrical signals via conductive medium, electromagnetic signals via air, optical signals via optical waveguides, and the like.

[0015] Accordingly, the communication path 104 may be formed from any medium that is capable of transmitting a signal such as, for example, conductive wires, conductive traces, optical waveguides, or the like. In some embodiments, the communication path 104 may facilitate the transmission of wireless signals, such as WiFi, Bluetooth®, Near Field Communication (NFC) and the like. Moreover, the communication path 104 may be formed from a combination of mediums capable of transmitting signals. In one embodiment, the communication path 104 comprises a combination of conductive traces, conductive wires, connectors, and buses that cooperate to permit the transmission of electrical data signals to components such as processors, memories, sensors, input devices, output devices, and communication devices. Additionally, it is noted that the term "signal" means a waveform (e.g., electrical, optical, magnetic, mechanical or electromagnetic), such as DC, AC, sinusoidal-wave, triangular-wave, square-wave, vibration, and the like, capable of traveling through a medium.

[0016] The computing device 100 includes one or more memory modules 106 coupled to the communication path 104. The one or more memory modules 106 may comprise RAM, ROM,

flash memories, hard drives, or any device capable of storing machine readable and executable instructions such that the machine readable and executable instructions can be accessed by the one or more processors 102. The machine readable and executable instructions may comprise logic or algorithm(s) written in any programming language of any generation (e.g., 1GL, 2GL, 3GL, 4GL, or 5GL) such as, for example, machine language that may be directly executed by the processor, or assembly language, object-oriented programming (OOP), scripting languages, microcode, etc., that may be compiled or assembled into machine readable and executable instructions and stored on the one or more memory modules 106. Alternatively, the machine readable and executable instructions may be written in a hardware description language (HDL), such as logic implemented via either a field-programmable gate array (FPGA) configuration or an application-specific integrated circuit (ASIC), or their equivalents. Accordingly, the methods described herein may be implemented in any conventional computer programming language, as pre-programmed hardware elements, or as a combination of hardware and software components. The memory modules 106 are discussed in more detail below in connection with FIG. 2.

[0017] Referring still to FIG. 1, the example computing device 100 includes a data storage component 108. The data storage component 108 may store data used by the computing device 100, such as historical demand data, as disclosed herein. The data storage component 108 may also store other data used by the various components of the computing device 100.

[0018] Still referring to FIG. 1, the computing device 100 comprises network interface hardware 110 for communicatively coupling the computing device 100 to the external computing devices, such as computing devices that store historical demand data. As such, the network interface hardware 110 may send data to and/or receive data from various external computing devices. The network interface hardware 110 may comprise a wired and/or wireless connection to one or more external computing devices. In other examples, the network interface hardware 110 may be send data to and/or receive data from other computing devices.

[0019] The network interface hardware 110 can be communicatively coupled to the communication path 104 and can be any device capable of transmitting and/or receiving data via a network. Accordingly, the network interface hardware 110 can include a communication transceiver for sending and/or receiving any wired or wireless communication. For example, the network interface hardware 110 may include an antenna, a modem, LAN port, Wi-Fi card, WiMax card, mobile communications hardware, near-field communication hardware, satellite

communication hardware and/or any wired or wireless hardware for communicating with external computing devices.

[0020] Referring now to FIG. 2, the one or more memory modules 106 of the computing device 100 include a historical data reception module 200, a historical data smoothing module 202, a Gamma distribution determination module 204, a short-term Gamma distribution simulation module 206, a long-term Gamma distribution simulation module 208, a needed inventory determination module 210, a current inventory determination module 212, and an inventory order module 214. Each of the historical data reception module 200, the historical data smoothing module 202, the Gamma distribution determination module 204, the short-term Gamma distribution simulation module 206, the long-term Gamma distribution simulation module 208, the needed inventory determination module 210, the current inventory determination module 212, and the inventory order module 214 may be a program module in the form of operating systems, application program modules, and other program modules stored in one or more memory modules 106. Such a program module may include, but is not limited to, routines, subroutines, programs, objects, components, data structures and the like for performing specific tasks or executing specific data types as will be described below.

[0021] The historical data reception module 200 may receive historical data indicating demand for a seasonal product over plurality of previous years. In the illustrated example, the historical data reception module 200 receives historical data associated with demand for aircraft deicer fluid, which has a seasonal demand during the winter and colder months of the year. However, in other examples, the historical data reception module 200 may receive historical data associated with other seasonal products.

[0022] The historical data reception module 200 may receive historical data indicating demand for a seasonal product during a plurality of previous years. The number of years of historical data received by the historical data reception module 200 may be equal to the number of years for which historical data is available. In the illustrated example, the product for which data is received is a seasonal product. As such, in the illustrated example, the historical data reception module 200 receives demand data for a plurality of previous years during the season for which demand exists (e.g., during the winter). However, in other examples, the historical data reception module 200 may receive year-round demand data for a plurality of previous years.

[0023] In the illustrated example, the historical data reception module 200 may receive historical data indicating demand for a seasonal product during each week of the season in a plurality of previous years (e.g., demand during each week of the winter of 2022, demand during each week of the winter of 2021, demand during each week of the winter of 2020, and so on). In other examples, the historical data reception module 200 may receive historical data indicating demand for the seasonal product during other time periods during the season in a plurality of previous years (e.g., during each day of the season or each month of the season in previous years). In embodiments, a time period delineating the season during which demand exists for the seasonal product may be predefined (e.g., October 1-March 31). As such, the historical data reception module 200 may receive historical data for previous years during the predefined seasonal time period.

[0024] In the illustrated example, the historical data reception module 200 may receive historical data indicating demand at a plurality of locations, as disclosed herein. In embodiments, the seasonal product may be produced at a plurality of different factories or hubs, and each such hub may provide the product to customers within a certain geographical region. In the illustrated example, where the seasonal product is aircraft deicer fluid, the product may be provided to airports situated across the United States. In particular, a plurality of hubs that produce aircraft deicer fluid may each provide aircraft deicer fluid to specific airports within a particular geographic region. As such, the historical data reception module 200 may receive demand data within each such geographic region. Accordingly, future demand may be predicted for each geographic region, as disclosed herein. As discussed in further detail below, the historical data received by the historical data reception module 200 may be used to simulate future demand for the seasonal product, as disclosed herein.

[0025] Referring still to FIG. 2, the historical data smoothing module 202 may perform smoothing of the data received by the historical data reception module 200, as disclosed herein. As discussed above, the historical data reception module 200 may receive historical data indicating the demand for a seasonal product during each week of the season (e.g., winter). That is, the historical data reception module 200 may receive demand data for the first week of the season during a plurality of previous years, the second week of the season during the plurality of previous years, the third week of the season during the plurality of previous years, and so on for each week of the season associated with the seasonal product. As discussed in further detail below, a Gamma distribution may be determined for each week of the season, based on the

received historical data. As such, each Gamma distribution may indicate a probability distribution of demand for the seasonal product during a particular week of the season.

[0026] However, using historical data to generate a Gamma distribution for each week of the season may not be the most accurate way to utilize the historical data, particularly if there is a limited amount of historical data (e.g., a relatively small number of previous years for which demand data exists). In particular, it may be preferable to utilize historical data from multiple weeks (e.g., one or more weeks before and one or more weeks after a particular week) to determine a Gamma distribution for each week of the season. In the illustrated example where the seasonal product is aircraft deicer fluid, demand tends to increase during extreme weather events (e.g., snow storms).

[0027] Such extreme weather events tend to be concentrated in time. As such, if a snow storm occurs during week 7 of the season in year 1 of the historical data and week 8 of the season in year 2 of the historical data, it may be predicted that future snow storms, and a subsequent increase in demand, are likely to occur during week 7 or 8 of the season in future years. Thus, it may be more accurate to consider a moving average of demand for each week based on the historical data, when determining a Gamma distribution, rather than simply using the historical data for each week of the season separately. This may help to smooth out variability of demand over different years. In the illustrated example, the historical data smoothing module 202 determines a 3-week moving average for each week for which historical data is received by the historical data reception module 200. However, in other examples, the historical data smoothing module 202 may determine a moving average for a different period of time for each week for which historical data is received by the historical data reception module 200. In still other examples, the historical data smoothing module 202 may utilize other methods to smooth the data received by the historical data reception module 200.

[0028] Referring still to FIG. 2, the Gamma distribution determination module 204 may determine a plurality of Gamma distributions, as disclosed herein. A Gamma distribution is a two-parameter family of continuous probability distributions. A Gamma distribution may be defined by a shape parameter k and a scale parameter θ . FIG. 3 shows a plurality of example Gamma distributions having different shape parameters and scale parameters. In the example of FIG. 3, the x-axis represents a number of occurrences of some event (e.g., a demand for a product), and the y-axis represents a probability.

[0029] As discussed above, in embodiments, it is assumed that demand for a seasonal product may be represented by a Gamma distribution. That is, the probability distribution representing demand for the seasonal product during any week of the season may be approximated by a Gamma distribution. Furthermore, the demand for the product during each week of the season may be approximated by a different Gamma distribution (e.g., having different values for the shape parameter k and/or the scale parameter θ). Accordingly, in embodiments, the Gamma distribution determination module 204 may determine the shape parameter k and the scale parameter θ for a plurality of Gamma distributions based on the data received by the historical data reception module 200 or the data generated by the historical data smoothing module 202, as disclosed herein.

[0030] As discussed above, the historical data reception module 200 may receive demand data for a seasonal product for a plurality of previous years. In particular, the historical data reception module 200 may receive data indicating demand for the seasonal product during each week of the season during the plurality of previous years. Thus, the Gamma distribution determination module 204 may determine parameters of a Gamma distribution for each week of the season based on the historical data. For example, if the historical data reception module 200 has received 10 years of historical demand data, then the Gamma distribution may determine a Gamma distribution for each week of the season based on the 10 years of historical demand data. For example, the Gamma distribution determination module 204 may determine a Gamma distribution that indicates demand for the seasonal product during the first week of the season based on the historical data for the first week of the season during each of the 10 years of historical demand data. The Gamma distribution determination module 204 may determine a Gamma distribution that indicates demand for the seasonal product during the second week of the season based on the historical data for the second week of the season during each of the 10 years of historical demand data. The Gamma distribution determination module 204 may similarly determine a Gamma distribution indicating demand for the seasonal product during each week of the season based on the historical data for each week of the season during each of the 10 years of historical demand data. In some examples, the Gamma distribution determination module 204 may determine Gamma distributions based on the data generated by the historical data smoothing module 202 (e.g., moving-average demand data) rather than the raw data received by the historical data reception module 200.

[0031] In embodiments, the Gamma distribution determination module 204 may determine parameters for a Gamma distribution to best fit the appropriate data (e.g., the historical data associated with a particular week of the season). In some examples, the Gamma distribution determination module 204 may determine a shape parameter k and a scale parameter θ that produces a Gamma distribution for a particular week of the season having a least squares error as compared to the historical data for that week of the season. For example, the Gamma distribution determination module 204 may consider an initial shape parameter k and scale parameter θ and determine a sum of the squares of the difference between the Gamma distribution having the initial shape parameter k and scale parameter θ and the historical data for the appropriate week of the season. The Gamma distribution determination module 204 may then vary the shape parameter k and the scale parameter θ to minimize the sum of the squares to determine the best fit Gamma distribution. In other examples, the Gamma distribution determination module 204 may utilize other methods to best fit historical data for a particular week of the season to a Gamma distribution.

[0032] As discussed above, the Gamma distribution determination module 204 may utilize historical demand data for a plurality of previous years to determine a plurality of Gamma distributions, with each Gamma distribution representing a probability distribution indicating demand for the seasonal product during a particular week of the season. As such, the Gamma distribution determination module 204 may determine a different Gamma distribution for each week of the season. In some examples, the Gamma distribution determination module 204 may determine different Gamma distributions for different geographic regions. For example, the Gamma distribution determination module 204 may determine a different Gamma distribution for each week of the season for each geographic region for which historical demand data is received by the historical data reception module 200. The determined Gamma distributions may be used to determine how much of the seasonal product to produce, as discussed in further detail below.

[0033] Referring back to FIG. 2, the short-term Gamma distribution simulation module 206 and the long-term Gamma distribution simulation module 208 may simulate one or more Gamma distributions determined by the Gamma distribution determination module 204 over a short-term time horizon and a long-term time horizon, respectively, as disclosed herein.

[0034] After determining a Gamma distribution representing an expected demand for a seasonal product during each week of the season, an appropriate Gamma distribution may be used

to estimate demand during a future week with some confidence level. However, simply estimating demand for a seasonal product for the upcoming week may be insufficient to determine an amount of product to produce or store. For example, the lead time to produce or otherwise procure additional product inventory may be greater than a week. As such, it may be desirable to predict demand for a product several weeks out when determining how much product to produce or procure. Furthermore, as discussed above, if inventory of a seasonal product remains at the end of the season, that product will most likely be unable to be sold until the following season. As such, costs may be incurred for the storage of the product until the following season. In addition, some seasonal products will not be usable the following season, and thus may go to waste. Accordingly, while it may be desirable to maintain sufficient inventory of a seasonal product to satisfy demand for the season, it may also be desirable to not have so much inventory that a large amount of product remains unsold at the end of the season.

[0035] Thus, in embodiments, the short-term Gamma distribution simulation module 206 may simulate Gamma distributions over a short-term time horizon (e.g., a few weeks in the future), while the long-term Gamma distribution simulation module 208 may simulate Gamma distributions over a long-term time horizon (e.g., the rest of the season). The results of these simulations may be used to determine how much product to produce, as disclosed herein.

[0036] The short-term Gamma distribution simulation module 206 may simulate a plurality of Gamma distributions determined by the Gamma distribution determination module 204 corresponding to the next several weeks. In some examples, the number of weeks for which simulations are performed may correspond to the number of weeks needed to produce or procure and deliver the seasonal product to a particular location. For example, if it takes three weeks to produce and deliver inventory to a particular location, the short-term Gamma distribution simulation module 206 may perform simulations of the Gamma distributions associated with the next three weeks of the season.

[0037] In one example, if simulations are run before week 4 of the season, for example, and it takes three weeks to produce and delivery inventory, then the short-term Gamma distribution simulation module 206 may performs simulations of the Gamma distributions associated with weeks 4, 5 and 6 of the season. In particular, a large number of simulations may be performed (e.g., 10,000 simulations), and each simulation may predict a demand for weeks 4, 5 and 6 of the season based on the simulation results. The simulations performed by the short-

term Gamma distribution simulation module 206 may be Monte Carlo simulations, wherein each simulation of a Gamma distribution comprises generating a random number and determining a demand based on the Gamma distribution and the generated random number.

[0038] The simulations of the Gamma distributions for weeks 4, 5 and 6 of the season may be performed together. That is, the first simulation may predict a demand for week 4 based on the Gamma distribution for week 4 and a first generated random number, a demand for week 5 based on the Gamma distribution for week 5 and a second generated random number, and a demand for week 6 based on the Gamma distribution for week 6 and a third generated random number. The three predicted demand levels (for weeks 4, 5 and 6) may be added together to determine a total demand for the seasonal product over weeks 4, 5 and 6 associated with the first simulation. A second simulation may then be performed in a similar manner to predict a demand for each of weeks 4, 5 and 6, and a total demand over all three weeks for the seasonal product associated with the second simulation. This may be repeated for the total number of simulations to be performed (e.g., 10,000 simulations). A total demand for the seasonal product for weeks 4, 5 and 6 (or another short-term time horizon) will then be determined for each of a plurality of simulations.

[0039] Once the total demand for the short-term time horizon is determined for each of a plurality of simulations, the computing device 100 may determine a demand level needed to satisfy a certain service level or confidence level, as disclosed in further detail below. For example, the computing device 100 may determine an amount of product inventory that satisfies the demand in 98% of the simulations to meet a 98% confidence level. This would be an amount of inventory that would have a 98% chance of satisfying demand for the next three weeks. However, a 98% confidence level or service level is merely exemplary, and in other examples, a different confidence interval may be used. The determination of the amount of product to be produced based on this inventory level is discussed in further detail below with respect to the needed inventory determination module 210.

[0040] Referring still to FIG. 2, the long-term Gamma distribution simulation module 208 may simulate a plurality of Gamma distributions determined by the Gamma distribution determination module 204 corresponding to each week for the rest of the season. The long-term Gamma distribution simulation module 208 may operate similarly to the short-term Gamma distribution simulation module 206, except that it simulates more Gamma distributions over a

longer time horizon. For each simulation performed by the long-term Gamma distribution simulation module 208, a total amount of inventory needed to meet the predicted demand for the entire rest of the season may be determined. After performing a large number of simulations (e.g., the same number of simulations as performed by the short-term Gamma distribution simulation module 206), the computing device 100 may determine an amount of product inventory that satisfies the demand for the rest of the season with some confidence level. This is discussed in further detail below with respect to the needed inventory determination module 210.

[0041] In some examples, the short-term Gamma distribution simulation module 206 and the long-term Gamma distribution simulation module 208 may simulate Gamma distributions associated with different geographic regions. In these examples, the Gamma distribution determination module 204 may generate one Gamma distribution for each geographic region for each week of the season, as discussed above. Thus, in these examples, each simulation performed by the short-term Gamma distribution simulation module 206 may simulate the Gamma distribution for each week over a short-term time horizon (e.g., the next three weeks) for each geographic region having a Gamma distribution. The short-term Gamma distribution simulation module 206 may then determine a total inventory needed to satisfy the predicted demand for every location in aggregate over the short-term time horizon.

[0042] The long-term Gamma distribution simulation module 208 may similarly simulate Gamma distributions for each location for each week over a long-term time horizon (e.g., the entire remaining season). The long-term Gamma distribution simulation module 208 may similarly determine a total inventory needed to satisfy the predicted demand for every location in aggregate over the long-term time horizon. By determining the inventory needed to satisfy the demand for every location in aggregate, inventory may be moved between geographic regions if one area is short of inventory but another area has excess inventory.

[0043] Referring still to FIG. 2, the needed inventory determination module 210 may determine an amount of inventory needed based on the simulations performed by the short-term Gamma distribution simulation module 206 and the long-term Gamma distribution simulation module 208, as disclosed herein. As discussed above, the short-term Gamma distribution simulation module 206 may determine an amount of inventory needed to satisfy demand over a short-term time horizon for each of a plurality of simulations and the long-term Gamma distribution simulation module 208 may determine an amount of inventory needed to satisfy

demand over a long-term time horizon for each of a plurality of simulations. Thus, in embodiments, the needed inventory determination module 210 may determine an amount of inventory needed to satisfy the demand over the short-term time horizon with a first confidence level, and may also determine an amount of inventory needed to satisfy the demand over the long-term time horizon with a second confidence level.

[0044] Because the long-term time horizon is further into the future than the short-term time horizon, the amount of inventory needed to satisfy demand over the long-term time horizon will necessarily be greater than the amount of inventory needed to satisfy demand over the short-term time horizon if the first confidence level is the same as the second confidence level. However, because there is greater uncertainty over the long-term time horizon than the short-term time horizon, the second confidence level associated with the long-term time horizon may be lower than the first confidence level associated with the short-term time horizon.

[0045] For example, the needed inventory determination module 210 may determine a first inventory amount needed to satisfy demand over the short-term time horizon with at least a 98% confidence level (e.g., an inventory level that satisfies demand in 98% of the simulations performed by the short-term Gamma distribution simulation module 206) and may determine a second inventory amount needed to satisfy demand over the long-term time horizon with at least a 90% confidence level (e.g., an inventory level that satisfies demand 90% of the simulations performed by the long-term Gamma distribution simulation module 208). Because the second confidence level is lower than the first confidence level, the inventory amount needed to satisfy the demand over the short-term time horizon may be greater than or may be less than the inventory amount needed to satisfy the demand over the long-term time horizon, depending on the specific confidence levels chosen, the length of the short-term and long-term time horizons, and the particulars of the Gamma distributions. While confidence levels of 98% and 90% were specified herein, it should be understood that in other examples, any other confidence levels may be chosen.

[0046] In embodiments, after the needed inventory determination module 210 determines a first inventory amount needed to satisfy demand over the short-term time horizon with a first confidence level and a second inventory amount needed to satisfy demand over the long-term time horizon with a second confidence level, the needed inventory determination module 210 may determine the smaller of the first inventory amount and the second inventory amount as the amount of inventory needed. This ensures that enough inventory will be available to satisfy either the

demand over the short-term time horizon or the long-term time horizon with the appropriate confidence levels. As such, selecting the lesser of the first and second inventory amounts as the amount of inventory needed may balance the desire to not run out of inventory before the season ends with the desire to not have too much inventory remaining at the end of the season. However, in some examples, the needed inventory determination module 210 may determine the larger of the first inventory amount and the second inventory amount as the amount of inventory needed.

[0047] Referring still to FIG. 2, the current inventory determination module 212 may determine the current amount of inventory on hand by the producer of the seasonal product. In the illustrated example, in which the seasonal product is aircraft deicer fluid, the fluid may be stored in one or more tanks that have sensors to monitor the amount of aircraft deicer fluid stored therein. As such, in these examples, the current inventory determination module 212 may receive tank telemetry data indicating how much aircraft deicer fluid is currently stored. However, in other examples, the current inventory determination module 212 may receive other types of data indicating the current inventory amount of the seasonal product.

[0048] Referring still to FIG. 2, the inventory order module 214 may order an amount of inventory of the seasonal product equal to the difference between the amount of inventory needed, as determined by the needed inventory determination module 210, and the amount of inventory on hand, as determined by the current inventory determination module 212. In some examples, the inventory order module 214 may transmit a request for the appropriate amount of the seasonal product to be produced (e.g., by a factory). In other examples, the inventory order module 214 may transmit a request for an appropriate amount of the seasonal product to be ordered or otherwise procured. This may cause the producer of the seasonal product to produce or procure enough inventory of the seasonal product to satisfy the predicted demand over either the short-term time horizon or the long-term time horizon, as discussed above. In some examples, the current inventory determination module 212 may be omitted, and the inventory order module 214 may simply order the amount of needed inventory determined by the needed inventory determination module 210.

[0049] FIG. 4 depicts a flowchart of an example method for determining an amount of inventory of a seasonal product to order, which may be performed by the computing device 100. At step 400, the historical data reception module 200 receives historical data. As discussed above, the historical data received by the historical data reception module 200 may indicate demand for

a seasonal product during each week of the season associated with the seasonal product during a plurality of previous years. In some examples, the historical data reception module 200 may receive historical data associated with a plurality of locations or geographic regions.

[0050] At step 402, the historical data smoothing module 202 performs smoothing of the historical data received by the historical data reception module 200. In the illustrated example, the historical data smoothing module 202 determines a three-week moving average for the received historical data. However, in other examples, the historical data smoothing module 202 may determine a moving average over a different length of time, or may perform a different type of data smoothing.

[0051] At step 404, the Gamma distribution determination module 204 determines a Gamma distribution associated with demand for the seasonal product during each week of the season based on the historical data received by the historical data reception module 200. In some examples, the Gamma distribution determination module 204 may determine a Gamma distribution associated with demand for the seasonal product during each week of the season at within each of a plurality of locations or geographic regions.

[0052] At step 406, the short-term Gamma distribution simulation module 206 performs simulations of the Gamma distributions over a short-term time horizon in the future. In particular, as discussed above, the short-term Gamma distribution simulation module 206 may perform a plurality of simulations of the Gamma distributions for one or more weeks in the future using random number generation and Monte Carlo simulations and, for each simulation, may determine an inventory amount of the seasonal product needed to satisfy demand for the one or more weeks in the future.

[0053] At step 408, the long-term Gamma distribution simulation module 208 performs simulations of the Gamma distributions over a long-term time horizon in the future. In particular, as discussed above, the long-term Gamma distribution simulation module 208 performs a plurality of simulations of the Gamma distributions for each week remaining in the season using random number generation and the Monte Carlo method and, for each simulation, determines an inventory amount of the seasonal product needed to satisfy demand for the remainder of the season.

[0054] At step 410, the needed inventory determination module 210 determines an amount of inventory needed of the seasonal product. In particular, as discussed above, the needed

inventory determination module 210 may select the smaller of the inventory amount needed to satisfy the short-term time horizon, as determined by the short-term Gamma distribution simulation module 206, and the inventory amount needed to satisfy the long-term time horizon, as determined by the long-term Gamma distribution simulation module 208.

[0055] At step 412, the current inventory determination module 212 determines the current inventory of the seasonal product. As discussed above, in the illustrated example, the current inventory determination module 212 may receive tank telemetry data indicating an amount of aircraft deicer fluid stored in one or more tanks. However, in other examples, the current inventory determination module 212 may determine a current inventory of the seasonal product in other ways.

[0056] At step 414, the inventory order module 214 orders an inventory amount of the seasonal product. In one example, as discussed above, the inventory order module 214 may order an amount of the seasonal product equal to the difference between the amount of inventory needed, as determined by the needed inventory determination module 210, and the current inventory, as determined by the current inventory determination module 212. In other examples, the inventory order module 214 may simply order an amount of inventory determined by the needed inventory determination module 210.

[0057] It should now be understood that embodiments described herein are directed to a method and system for maintaining inventory of a seasonal product. Gamma distributions can be generated to represent expected demand for the seasonal product during each week of the season, based on historical demand data. These Gamma distributions may be used to simulate future demand for the seasonal product over both a short-term and long-term time horizon with difference confidence levels. By ordering enough product inventory to satisfy the lesser of these demand levels, embodiments disclosed herein may maintain an inventory level that balances the desire to maintain sufficient inventory to satisfy demand, while not maintaining excessive inventory at the end of the season.

[0058] It is noted that the terms "substantially" and "about" may be utilized herein to represent the inherent degree of uncertainty that may be attributed to any quantitative comparison, value, measurement, or other representation. These terms are also utilized herein to represent the

degree by which a quantitative representation may vary from a stated reference without resulting in a change in the basic function of the subject matter at issue.

[0059] While particular embodiments have been illustrated and described herein, it should be understood that various other changes and modifications may be made without departing from the spirit and scope of the claimed subject matter. Moreover, although various aspects of the claimed subject matter have been described herein, such aspects need not be utilized in combination. It is therefore intended that the appended claims cover all such changes and modifications that are within the scope of the claimed subject matter.

CLAIMS

1. A method comprising:
 - receiving historical data indicating demand for a product during a plurality of time periods within a plurality of previous years;
 - determining a plurality of Gamma distributions comprising a best fit Gamma distribution for each time period among the plurality of time periods based on the historical data;
 - performing a plurality of first simulations of the Gamma distributions for a first number of future time periods to generate a first estimated demand for each time period of the first number of future time periods for each of the plurality of first simulations;
 - performing a plurality of second simulations of the Gamma distributions for a second number of future time periods to generate a second estimated demand for each time period of the second number of future time periods, the second number of future time periods being greater than the first number of future time periods;
 - determining a first inventory amount of the product needed to satisfy the first estimated demand for each time period of the first number of future time periods in at least a first minimum percentage of the first simulations;
 - determining a second inventory amount of the product needed to satisfy the second estimated demand for each time period of the second number of future time periods in at least a second minimum percentage of the second simulations, the second minimum percentage being less than the first minimum percentage; and
 - ordering a third inventory amount comprising a minimum of the first inventory amount and the second inventory amount.
2. The method of claim 1, wherein the second number of future time periods comprise the remainder of a season associated with the product.
3. The method of claim 1, wherein each time period of the plurality of time periods comprises one week.
4. The method of claim 1, further comprising:
 - smoothing the historical data to generate smoothed historical data; and
 - determining the plurality of Gamma distributions based on the smoothed historical data.

5. The method of claim 4, further comprising:
 - smoothing the historical data by determining moving averages of the demand for the product during the plurality of time periods within the plurality of previous years based on the historical data; and
 - determining the plurality of Gamma distributions based on the moving averages.
6. The method of claim 1, wherein the historical data indicates the demand for the product during the plurality of time periods within the plurality of previous years within a plurality of geographic regions.
7. The method of claim 6, further comprising determining the plurality of Gamma distributions comprising the best fit Gamma distribution for each time period among the plurality of time periods and for each geographic region among the plurality of geographic regions based on the historical data.
8. The method of claim 1, further comprising determining the plurality of Gamma distributions comprising the best fit Gamma distribution for each time period among the plurality of time periods based on the historical data using a least squares error method.
9. The method of claim 1, further comprising performing the plurality of first simulations of the Gamma distributions for the first number of future time periods using random number generation and Monte Carlo simulation.
10. The method of claim 1, further comprising:
 - determining a current inventory of the product;
 - determining a fourth inventory amount comprising a difference between the third inventory amount and the current inventory; and
 - ordering the fourth inventory amount.
11. The method of claim 10, further comprising:
 - receiving tank telemetry data indicating an amount of the product in one or more storage tanks; and

determining the current inventory of the product based on the tank telemetry data.

12. A computing device comprising a processor configured to:
 - receive historical data indicating demand for a product during a plurality of time periods within a plurality of previous years;
 - determine a plurality of Gamma distributions comprising a best fit Gamma distribution for each time period among the plurality of time periods based on the historical data;
 - perform a plurality of first simulations of the Gamma distributions for a first number of future time periods to generate a first estimated demand for each time period of the first number of future time periods for each of the plurality of first simulations;
 - perform a plurality of second simulations of the Gamma distributions for a second number of future time periods to generate a second estimated demand for each time period of the second number of future time periods, the second number of future time periods being greater than the first number of future time periods;
 - determine a first inventory amount of the product needed to satisfy the first estimated demand for each time period of the first number of future time periods in at least a first minimum percentage of the first simulations;
 - determine a second inventory amount of the product needed to satisfy the second estimated demand for each time period of the second number of future time periods in at least a second minimum percentage of the second simulations, the second minimum percentage being less than the first minimum percentage; and
 - order a third inventory amount comprising a minimum of the first inventory amount and the second inventory amount.
13. The computing device of claim 12, wherein the second number of future time periods comprise the remainder of a season associated with the product.
14. The computing device of claim 12, wherein each time period of the plurality of time periods comprises one week.
15. The computing device of claim 14, wherein the processor is further configured to:

smooth the historical data by determining moving averages of the demand for the product during the plurality of time periods within the plurality of previous years based on the historical data; and

determine the plurality of Gamma distributions based on the moving averages.

16. The computing device of claim 12, wherein the historical data indicates the demand for the product during the plurality of time periods within the plurality of previous years within a plurality of geographic regions.

17. The computing device of claim 16, wherein the processor is further configured to determine the plurality of Gamma distributions comprising the best fit Gamma distribution for each time period among the plurality of time periods and for each geographic region among the plurality of geographic regions based on the historical data.

18. The computing device of claim 12, wherein the processor is further configured to determine the plurality of Gamma distributions comprising the best fit Gamma distribution for each time period among the plurality of time periods based on the historical data using a least squares error method.

19. The computing device of claim 12, wherein the processor is further configured to perform the plurality of first simulations of the Gamma distributions for the first number of future time periods using random number generation and Monte Carlo simulation.

20. The computing device of claim 12, wherein the processor is further configured to:
determine a current inventory of the product;
determine a fourth inventory amount comprising a difference between the third inventory amount and the current inventory; and
order the fourth inventory amount.