1 Introduction and Use Cases

Your client, Hypothetical Meals, is a large food company that produces a significant portion of the world’s food. They currently use a mishmash of spreadsheets and macros to manage food production, including inventory, logistics, sales, etc. They would like a unified system to replace these highly manual procedures. This system will serve the following use cases:

- The system will track ingredients, including vendors which can provide a given ingredient, cost information, and storage information (frozen, refrigerated, etc.). These details are provided by administrators.

- The system will allow authorized users to document orders for ingredients and to monitor how storage of ingredient stock compares to on-site storage capacity. Ordering is handled by managers or administrators. Ingredient ordering will be done using the “shopping cart” metaphor, with specific vendors being chosen at “check-out”. Orders are tracked from the time they’re placed until ingredient arrival.

- The system will provide reports on purchasing and ingredient use.

- Users will be able to bulk-import new ingredients and formulas from a simple text format.

- The system will track the production of foods by noting food formulas and allowing managers to record the production of food products according to these formulas. Such requests will provide the user with a list of specific ingredients that will be consumed, including lot numbers. Ingredients will always be consumed in FIFO order of acquisition, and the system will track partial use of ingredient lots (e.g., a sack of flour that’s 60% used by one run could later be fully consumed by the next run). Production is tracked from the start to completion.
The system will track ingredient amounts both in terms of storage (measured in sq.ft. based on the type of package) and its use in formulas (e.g., gallons of broth, pounds of potatoes, individual eggs):

- For storage purposes, each ingredient package can be reduced to an effective square footage requirement, storage footprint, which takes into account stacking/shelving.
- For formula purposes, each ingredient will have a customizable unit “native” to that ingredient, and the corresponding package will contain a number expressed in such units (e.g., a sack of potatoes may be 25 lb, a pail of broth may be 5 gallon, etc.).

All users will be able to log in using company single-sign-on. For our purposes, this means support for Duke NetID. Users may be marked as “managers” or “administrators” within the system.

Managers will have permission to perform the majority of the day-to-day operation of the system, while administrators will be able to override most of the rules of the system to correct erroneous situations. Unprivileged users will have read-only access to the system.

The system will provide reports on overall production.

A comprehensive transaction log will track all operations which permute the state of inventory, production, or user accounts.

Rather than treating ingredient stocks as a single quantity, the system will track individual ingredient lots as they are consumed and record the relationship between completed food product lots and the ingredient lots that went into them.

The system will allow production of intermediate products: products intended for use in other formulas rather than for sale to consumers. These will be tracked like ingredients and will occupy storage capacity per normal.

Users will be able to review records of completed productions, including lot numbers of the product as well as the input ingredients that created it.

Users will be able to produce a recall report, which identifies all products produced using a given ingredient lot, including transitively via intermediate products.

Users will be able to produce a ingredient freshness report, which outlines the average and worst-case time ingredients wait in inventory before being consumed in production.

IT administrators will be able to restore the state of the system from a robust backup system using a clearly documented procedure.

Rather than treating ordering as instantaneous, the system will track the lifecycle from order placement to ingredient arrival. Upon arrival, the user will be able to note the arrived ingredient’s lot number as assigned by the vendor.

Rather than treating production as instantaneous, the system will track the lifecycle from production start to completion. Upon completion, the system will generate a lot number to assign to the product.
The system will model a number of production lines which are responsible for carrying out production activities. The system will track details of this including which formulas can be made on which production lines and what production lines are idle or busy.

The system will provide reports on production line utilization.

The system will track the company stock of final products in its distributor network, sales of such products to customers, and the resulting revenue.

Users will be able to produce a profitability report based on ingredient costs versus final product sales.

Users will be able to produce a final product freshness report, which outlines the average and worst-case time final products wait in the distribution network before being sold.

2 Definitions

- **Ingredient**: A food product purchased by the company for use in production. Available from at least one vendor, typically more. A given ingredient will come in a specific package and temperature state.

- **Ingredient package**: Ingredients may come in a sack or pail (around 50 lbs), a drum (for liquids, around 500 lbs), a “supersack” (a large square sack that sits on a shipping pallet; around 2,000 lbs), or a truckload or railcar (for liquids, 50,000+ lbs).

- **Temperature state**: The kind of storage a given ingredient requires to maintain food safety and/or freshness: either frozen, refrigerated, or room temperature. Ingredients should never be stored at a different temperature state than they come in.

- **Vendor**: A partner company that sells one or more ingredients.

- **Storage capacity**: The total amount the company can store for a given temperature state. For packages smaller than railcar/truckload, this is measured in square footage within the warehouse, refrigerator, or freezer (see storage footprint, below). Bulk ingredients in railcar or truckload have no maximum capacity as they are either kept in the original vessel or stored in special-purpose tanks.

- **Ingredient stock**: The total amount of a given ingredient owned and stored for use by the company. Measured in units specific to the ingredient (see native units, below). Each discrete lot is tracked independently.

- **Production run**: The act of consuming one or more ingredients to produce a product on a production line.

- **Storage footprint**: The square footage needed to store a given ingredient package, taking into account stacking and shelving. The footprint is based solely on the package, so the total footprint for an ingredient’s stock is calculated as the integer number of packages remaining (possibly including one partially consumed package) multiplied by the package’s footprint.
- **Native unit**: The unit of measure associated with an ingredient for production purposes. For example, potatoes may be measured in pounds, while broth may be measured in gallons. Ingredient packages provide a configurable number of native units of the ingredient.

- **Food product**: The result of a production run of a given formula. Measured in product units. Each production run’s output includes a unique lot number.

- **Product unit**: The indivisible output of production (e.g. a can of soup, a wrapped loaf of bread, etc.). The system does not track what specific form a product unit takes, only that it is an integer count resulting from a production run. This is a different, unrelated concept from native unit, defined above.

- **Formula**: The set of ingredients and their native unit quantities needed to produce a given food product in a specified quantity of product units. Each formula can only be run on certain production lines.

- **Manager**: A user with the “manager permission” who is able to order ingredients and perform production runs.

- **Administrator**: A user with the “administrator permission” who therefore has all manager rights plus the ability to override system rules to directly correct data, input new ingredients and formulas, and perform other core configuration operations.

- **Unprivileged user**: A user with neither of the above two permissions. Still able to read inventory status, read reports, etc.

- **Ingredient lot**: Some specific owned quantity of an ingredient from a single ingredient order. Identified by a user-provided lot number at ordering time. Identified by a user-recorded lot number on arrival from the vendor.

- **Intermediate product**: A food product created on a production line for use in a later production. These are not suitable for sale directly, but are instead tracked in a manner similar to ingredients. Lot numbers are assigned by the system on completion of the production.

- **Final product**: A food product created on a production line for packaging/sale to customer. Lot numbers are assigned by the system on completion of the production.

- **Recall report**: A report that ties given ingredient lot(s) or intermediate product(s) to all food products which were produced from it. Most commonly used in the event of a food safety investigation or recall.

- **Ingredient freshness report**: A report which shows the average and worst-case time ingredients wait in inventory before being consumed in production, both per-ingredient and company-wide.

- **Pending order**: An ingredient order that has been placed but has not yet arrived. No lot number is recorded yet.

- **Completed order**: An ingredient order that has arrived; inventory is updated and lot numbers are recorded at this time.
• **Production line**: A part of a production facility capable of producing a food product. Certain production lines can only make certain products, and a line can only make one product at a time. A production line that is in use is *busy*, otherwise it is *idle*.

• **Production in progress**: A production which has been started but not yet completed on a given production line. Includes lead time for equipment changeover and preparation as well as the actual production time (though this distinction is not tracked by this system). No lot number is assigned yet.

• **Completed production**: A production that is finished and the resulting products are available. Lot numbers are assigned at this time.

• **Utilization**: The fraction of the time a given production line is busy within a given time window.

• **Customer**: A store which resells our product to consumers, either directly (e.g. a grocery store) or after preparation (e.g. a restaurant).

• **Consumer**: Individuals who purchase and ultimately consume the food products. Not modeled in this system.

• **Distribution network**: The network of warehouses and partner companies that house final products before they are sold to customers. Not related to the inventory capacity for ingredients.

• **Profitability report**: A report comparing the sales revenue versus ingredient cost for each formula as well as overall for the company. Does not include other cost factors such as factory time, labor, etc.

• **Final product freshness report**: A report which shows the average and worst-case time final products wait in the distribution network before being sold to customers, both per-product and company-wide.

3 Requirements

*A note on requirements: No set of requirements is perfect, and that is certainly true here. I’m sure that contradictions, under-specified behavior, and unintended consequences will be revealed. Your overriding goal should be to produce a quality system; if you believe that goal would be better served if a requirement were altered or interpreted a certain way, ask about it, and get the conclusion in writing. The result may be a variance in a requirement for a specific team, or even modification of this requirements document for all teams. In short, if unsure, ask.*

Some requirements have attached an informal tip, clarification, or example – these do not alter the requirements themselves, but are meant to answer likely questions about a requirement.

1. Server

   1.1. Your software must have a server that supports an arbitrary number of users.

   1.2. During the install/setup process, a special user named “admin” is configured.
1.3. The system shall allow the use of the Duke NetID system to allow all users to login using their Duke credentials in addition to supporting locally created users. The special local “admin” account remains, and has administrator permission.

1.4. Any stored passwords must be kept in a secure manner (i.e., salted + hashed)

1.5. All communication between the clients and server must be encrypted.
   Tip: For web-based solutions, this means using HTTPS.

1.6. The server must maintain state in a persistent fashion.

1.7. For all views which show a potentially unbounded number of records, the response time of the interface shall not depend on the quantity of records.
   Tip: This implies some form of pagination so that only a finite number of records are retrieved at a time. Pagination can be explicit (page 1 of N) or implicit (infinite scrolling). Other UI solutions are likely also possible.

1.8. The system shall track permission level for each user: unprivileged, manager, and administrator. The special local “admin” user has implicit administrator permission. Permissions are strictly nested: managers can do anything normal users can, and administrators can do anything that managers can.

1.9. Users with administrator permission can create and delete “local” (non-NetID) user accounts.

1.10. Users with administrator permission can grant manager or administrator permission to any existing user (either NetID-based users or local users).

2. Vendor information management

   2.1. Administrators will be able to add, edit, or remove vendors. A vendor will be defined by a unique name, a free-form field for contact information, and a unique case-insensitive alphanumeric freight carrier code.

3. Inventory tracking functionality

   3.1. Administrators will be able to add or edit ingredients. An ingredient is defined as:
      • A unique name
      • The package the ingredient comes in, which is one of:
        – Sack (occupying 0.5 sqft of floorspace)
        – Pail (occupying 1 sqft of floorspace)
        – Drum (occupying 3 sqft of floorspace)
        – Supersack (occupying 16 sqft of floorspace)
        – Truckload (not occupying any floorspace)
        – Railcar (not occupying any floorspace)
      • The temperature state of the ingredient: frozen, refrigerated, or room temperature
      • The vendor(s) which can provide the ingredient (see req 2) and the price each charges per package
      • The native units of the ingredient (pounds, gallons, or a short custom string)
      • The number of native units that the package provides
3.2. Administrators will be able to remove ingredients. If an ingredient is listed in an existing formula, an appropriate error will be shown indicating the affected formula(s), and the removal will be aborted.

3.3. Administrators will be able to set the storage capacity for ingredients and intermediate products in each of the three temperature zones: freezer, refrigerator, and warehouse (room temperature), except for truckload/railcar ingredients, for which there is no tracked storage limit.

*Clarification:* Truckload/railcar ingredients are either stored in special-purpose tanks or left in their original vessel until use, so maximum capacity need not be tracked by this software.

3.3.1. Storage of ingredients other than truckload/railcar will be tracked in sqft of floorspace of the freezer/refrigerator/warehouse.

3.3.2. The system must enforce storage limitations when processing orders (see req 3.4) and production runs of intermediate products (see req 7).

3.3.3. Temperature states must always be respected; an ingredient may never be stored at another temperature state.

3.3.4. If the user tries to edit a capacity to a value below the current total inventory storage in that temperature state, an appropriate error will be shown and the operation will be prevented.

3.3.5. As native units of an ingredient are consumed by production, the system will compute the number of packages remaining, including a partially used package. This is used to compute the storage footprint of the ingredient in total. In other words, 

\[
remaining\ packages = \left\lceil \frac{remaining\ native\ units}{native\ units\ per\ package} \right\rceil
\]

and 

\[
total\ storage\ footprint = remaining\ packages \times package\ storage\ footprint.
\]

3.4. Managers shall be able to log orders of ingredients from vendors.

3.4.1. This is done using a shopping cart metaphor, where the user adds ingredients to cart, can edit quantities or remove items in cart, and finally “check out”.

3.4.2. Orders which would exceed storage capacity must be denied with an appropriate error message.

3.4.3. Successful orders shall immediately log the ingredient into the inventory.

3.4.4. The system shall track money spent on ingredients for use in reporting (see req 4).

3.4.5. The specific vendors for the order will be chosen during the final “check out” stage; the user will be able to conveniently choose a vendor per ingredient with the default being the least expensive for each ingredient.

3.4.6. **During the check-out process** When an order is marked completed, the date and time of the ordered ingredient lots should be noted. Further, the user will be able to optionally record the lot number of each purchased package. UI features should make it easy for the user to apply the same lot number to all packages of an ingredient in an order, or to apply different lot numbers to subsets of packages.

3.4.7. On successful check-out of an order, the order will tracked as *pending*.

3.4.8. Managers shall be able to view a list of pending orders, including all tracked details.

3.4.9. Managers shall be able to select an order and indicate that it is now *completed*, meaning the ingredients have arrived. Lot numbers are assigned at this time per req 3.4.6, and the inventory is updated.
3.5. Users shall be able to browse the inventory.

3.5.1. All ingredients shall be summarized in an efficient manner.
3.5.2. The user should be able to search by ingredient name and filter based on temperature state and/or package.
3.5.3. The quantity of each ingredient will be tracked in native units for production purposes and sqft for storage purposes.
3.5.4. The user shall be able to view a detail page for any given ingredient showing all tracked information for it.
3.5.5. Administrators shall be able to directly edit ingredient stock quantity to correct errors; this operation shall be logged clearly in the system log (see req 8). This also includes intermediate product stock.
3.5.6. At a high level, the system will show ingredient stock in total, but must be able to show specific lots owned on request. There is no need to distinguish at a finer granularity than ingredient lots (e.g., the package level).
3.5.7. The inventory browsing provisions above dealing with ingredients also apply to intermediate products.

4. Reporting

4.1. Spending report: Users shall be able to view a report of ingredient spending which indicates total spending on each ingredient to date, both overall and only for ingredients used in production.

4.2. Production report: Users shall be able to view a report of production which indicates total number of units of each formula produced to date, including the total ingredient cost that went into product.

4.3. Recall report: Users shall be able to select a previously or currently owned lot of ingredient/intermediate and view a report of all food products which were produced from it, including transitively via intervening intermediate products. The report should display all information known of all related entities (names, dates, lot numbers, etc.).

4.4. Ingredient freshness report: Users should be able to view a report which shows the average and worst-case duration of time for which ingredients and intermediate products wait in inventory before being consumed in production. The report should break down per-ingredient as well as overall.

4.5. Production efficiency report: Users should be able to specify a time span and produce a report showing utilization of all production lines over that timespan. The average utilization over all lines should also be shown.

4.6. Profitability report: Users should be able to view a report of all final products showing, for each, the number of units sold, average per-unit wholesale price, the wholesale revenue (units_sold * average_wholesale_price), total ingredient cost (similar to the production report), total profit (revenue – cost), per-unit profit (total_profit/units_sold), and profit margin (revenue/cost as a percentage). The report should also show a summary of total revenue, total cost, and total profit across all products.
4.7. **Final product freshness report**: Users should be able to view a report which shows the average and worst-case duration of time for which final products wait in the distributor network inventory before being sold. The report should break down per-product as well as overall.

5. Documentation

5.1. **Developer guide**: A document shall be provided which orients a new developer to how your system is constructed at a high level, what technologies are in use, how to configure a development/build environment, and how the database schema (or equivalent) is laid out.

5.2. **Deployment guide**: A document shall be provided which describes how to install your software entirely from scratch. It should start by describing the platform prerequisites (e.g. Linux distro, required packages, etc.), then mechanically describe every step to deploying your system to production readiness.

5.2.1. In addition to covering how to install the system with “stock” default data, the procedure to install the system from scratch using backed up data should also be included (i.e., disaster recovery).

5.3. **Backup admin guide**: A document shall be provided which explains the backup solution so that a system administrator unfamiliar with your software could configure it from scratch, restore the database to any given backup, and test a backup for validity. See req 9.

6. Bulk import facility

6.1. Administrators shall be able to import new ingredients into the system by means of a text-based import (CSV, JSON, or other simple plaintext format). **The customer is accepting proposals on the format.**

6.2. The import interface shall include documentation as to the import format.

6.3. The import action shall only occur if the entire input is free of name conflicts or otherwise problematic issues; if such issues arise, the precise nature of the error should be presented to the administrator in enough detail that it can be corrected.

6.4. Administrators shall be able to import new formulas into the system by means of a text-based import (CSV, JSON, or other simple plaintext format). **The customer is accepting proposals on the format.**

7. Production modeling

7.1. Administrators shall be able to add/edit/delete/view formulas within the system. A formula consists of:
   - A unique name
   - A long-form description/notes field
   - One or more \{ingredient,quantity\} tuples, where the quantity is specified in floating-point native units
• The integer number of units of product this formula will produce
  The meaning of ‘unit’ for a food product depends on the product (cans, bags, bushels, etc.),
  but this distinction need not be modeled by this software for final products. For final products,
  a food product unit is a different concept from an ingredient native unit. For intermediate products,
  this number is in native units.

• Whether the formula is for a final product or an intermediate product. If an intermediate product,
  the formula will further indicate some attributes similar to ingredients (see req 3.1):
  – The package the intermediate product comes in; the options are the same as for ingredients.
  – The temperature state of the ingredient; the options are the same as for ingredients.
  – The native units of the intermediate product (pounds, gallons, or a short custom string).
  – The native units per package.\footnote{Added 2018-04-04. This was previously omitted, which was an oversight.}

• The set of production lines capable of producing the product

7.2. Managers shall be able to initiate production of a food product as follows:

7.2.1. The manager will select the formula and input the number of units that will be made.
  This value defaults to the product unit count listed in the formula and must be an integer greater
  than this default.

7.2.2. Before committing to production, the manager will be shown a list of the quantities of
  ingredients and intermediate products to be consumed as compared to the current inventory stock.

7.2.3. If the required ingredients are not present in full in inventory, the user will be alerted
to this and production will not be allowed to proceed. However, the manager should be prompted
with the option to automatically add to the ordering cart the difference between required ingredients
and current stock. If an intermediate product is needed but not present in inventory, an
descriptive error will be shown to indicate this. The manager will also select a compatible production
line from those currently idle. The UI should make clear the list of compatible production lines and show,
for those that are busy, what is currently being produced on them. If no compatible production
lines are available, an appropriate error should be shown.

7.2.4. If the production is feasible and confirmed by the manager, ingredient stocks will be
appropriately consumed. The quantity of ingredient consumed will be based on how much is called
for in the formula scaled by how many units past the base amount are to be produced. At this time,
the production is in progress. It can be marked complete from the production list (req 7.3) or the
production line view (req 7.4.5).
  Example: If a tomato soup formula makes 200 units using 10 gallons of tomato paste
  and the manager requests to make 300 units, then 300/200 * 10 = 15 gallons would
  be consumed.

7.2.5. If the formula is for an intermediate product, there must be sufficient storage capacity
of the correct type for the completed intermediate product. If not, an appropriate
error message should be shown and production disallowed.
7.2.6. Ingredient and intermediate product lots should be consumed in First-In-First-Out (FIFO) order to optimize freshness based on order/production date. The system should track partial use of ingredient lots/packages (e.g., a sack of flour that's 60% used by one run could later be fully consumed by the next run).

7.2.7. Upon successfully logging a production run, the system should record the production and annotate it with a generated lot number. The lot numbers of all ingredients and intermediate products should be noted and tied to the production run.

7.2.8. For completed production runs of intermediate products, the product should be added to the inventory, at which time it functions as an ingredient and is available for consumption by other formulas.

7.2.9. For completed production runs of final products, the product should be added to the distributor network inventory for eventual sale to customers (see req 10).

7.3. Users should be able to browse completed and in-progress productions.

7.3.1. The view should be able to be filtered by timespan or product name search. The view should also be filterable to show only completed or only in-progress productions.

7.3.2. For each product, the user should be able to view the product lot number and the lot numbers of its constituent ingredients/intermediates.

7.3.3. Managers should be able to select a production and mark it completed, viewing the resulting lot number (req 7.2.7) and causing the product to enter the appropriate inventory (req 7.2.8 for intermediates and 7.2.9 for final products).

7.4. The system will model production lines.

7.4.1. Administrator will be able to add, edit, or remove production lines. A production line is defined as:
- A unique name
- A multi-line description field, optional
- A mapping to zero or more formulas that the production line is capable of supporting

7.4.2. Managers will be able to update the mapping between formulas and production lines; this should be possible either from a view of the formula (by indicating which production lines) or from a view of the production line (by indicating which formulas).

7.4.3. The system should disallow removal of a busy production line with an appropriate error message.

7.4.4. Users should be able to view the production lines, including what is currently being produced on each.

7.4.5. Managers should be able to select a busy production line and mark its production as completed, viewing the resulting lot number (req 7.2.7) and causing the product to enter the appropriate inventory (req 7.2.8 for intermediates and 7.2.9 for final products).

8. Global system logging
8.1. The system shall record a log of all actions undertaken in the system (i.e., any action that alters the system state, including inventory operations, production runs, user creation/deletion/modification, etc.). Log entries shall include the initiating user, the entities involved, the nature of the event, and the time and date. This includes corrective actions undertaken by administrators (per 3.5.5).

8.2. Managers shall be able to view this log.

8.3. The log view should allow searching by user, ingredient, and/or timespan.

8.4. Users consulting the log shall be able to navigate directly from a reference to an ingredient/product to the relevant detailed view (see reqs 3.5.4, 7.1).

8.5. Users should not be able to tamper with the log in any way, regardless of permission.

9. Backups: You must deploy a backup solution for your system’s database.

9.1. Backups shall be automatic and taken daily.

9.2. Backups shall be kept with a staggered retention (7 daily backups, 4 weekly backups, 12 monthly backups).

9.3. Backups must be stored on a separate system.

9.4. The backup system must require separate credentials to access.

9.5. The backup system should report on progress and alert on failure; this could be via email or another directed communication mechanism.

10. The system shall track the distributor network inventory (the inventory of completed final products ready to be sold to customers).

   Clarification: The distributor network inventory is separate from this system’s ingredient inventory. It represents a large network of warehouses and partners that distribute final products to customers. The system need not track a concept of maximum capacity for the distributor network inventory. Further, the system need not track lot numbers in the distributor network (this is handled by the distributors, not this system).

10.1. Users shall be able to view a list of unsold final products (i.e., those added to the distributor network inventory per req 7.2.9).

10.2. Managers shall be able to note sales of such products. The process will be as follows:

   10.2.1. Managers will be able to efficiently input quantities for a subset of the unsold items as well as per-unit wholesale prices for each (which could be zero for write-offs of expired goods).

   10.2.2. The manager will then submit the sale request, at which time a summary of the proposed transaction will be shown. This will display the selected products, quantities, unit prices, per-product subtotals ($quantity \times unit\_price$) as well as a grand total of revenue.

   10.2.3. The manager will be able to confirm or cancel the sale.

   10.2.4. On confirmation, the sold items will be removed from the distributor network and the revenue will be noted for the purposes of the profitability report (see req 4.6).
10.2.5. To facilitate the Final Product Freshness Report, the system must internally track lots with respect to their production time and sell final products to customers in FIFO order. ²