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MASTER THESIS IN SAFETY ENGINEERING FOR TRANSPORT LOGISTICS AND PRODUCTION

Environmental Monitoring System in Food Transportation

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Environmental Monitoring System in Food Transportation

ABSTRACT

This thesis presents the development of a comprehensive simulation model aimed at optimizing hospital food preparation and delivery processes, specifically focusing on Malta Hospital. The objective is to enhance operational efficiency, ensuring that meals are prepared and delivered on time, while meeting patients' dietary requirements, which is critical for patient recovery and wellbeing. By examining each stage of the food service workflow, from production to ward delivery, the simulation identifies areas for improvement, focusing on inventory management, food quality, and streamlined operations.

Additionally, the thesis incorporates a real time temperature monitoring system within a logistics truck simulation, developed in the AnyLogic environment, to address temperature sensitive deliveries. The system monitors the internal truck temperature during deliveries, visualizing temperature fluctuations in real time and triggering automated warnings when temperatures exceed safe thresholds. A dynamic visual indicator—represented by green or red circles—provides instant feedback on whether the truck's temperature is within acceptable ranges. A graphical interface displays time versus temperature data, allowing operators to track delivery conditions across four daily trips between multiple destinations.

The simulation aims to demonstrate how real time environmental monitoring can be seamlessly integrated into logistics operations to safeguard temperature sensitive goods. By utilizing automated alerts, real time graphing, and data logging, the system enhances decision making for logistics operators. This model highlights the importance of temperature management in maintaining the integrity of perishable goods and presents a framework for optimizing delivery operations in temperature sensitive environments.

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Preethi Saravanan

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THE FOODFACTORY
CREATING TASTE

INTRODUCTION

The Food Factory is a culmination of over three decades of dedication, innovation, and growth in the catering industry, led by James Barbara. Since its inception in 1989, James Caterers Ltd, founded by James Barbara, has grown from a humble, one man operation producing and distributing homemade delicacies to one of Malta's largest and most esteemed catering companies. The Food Factory, which is the latest extension of this business, has set new standards of excellence, creativity, and efficiency in the industry, earning recognition both locally and internationally

Today, The Food Factory operates a state of the art central processing unit (CPU), equipped with the latest technology, making it the largest and most modern industrial catering facility on the island. This facility seamlessly integrates various independent food production units, ranging from healthcare catering, high volume bakery and pastry production, to specialized kitchens that cater to diverse dietary needs, including Halal meals. The facility is energy efficient, Grade A certified, and adheres to the stringent ISO 22000:2018 food safety standards.

As The Food Factory serves a diverse clientele, including airlines, hospitals, correctional centres, hotels, schools, nursing homes, and catering establishments, maintaining the quality and safety of food products during storage and transportation is crucial. Perishable goods such as fresh food and meals require consistent environmental conditions, particularly temperature control, to ensure they arrive at their destinations in optimal condition. Temperature sensitive items can be compromised during transit if the temperature exceeds certain thresholds, leading to spoilage and a loss of product integrity.

In response to these challenges, this thesis focuses on the design and implementation of a Real Time Temperature Monitoring and Tracking System within a truck logistics simulation. The system aims to simulate real world challenges associated with managing temperature sensitive deliveries. By monitoring, visualizing, and managing temperature fluctuations during transit, the model addresses key logistical problems faced by food delivery companies, ensuring the safe transport of goods.

This monitoring system is especially relevant to The Food Factory's operations, given the company's involvement in largescale food production and catering. With high volume services like Cook and Serve, Cook and Chill, and Cook and Freeze, it is vital that temperature sensitive products maintain their quality throughout the supply chain. Realtime temperature tracking will enable The Food Factory to maintain product quality and reduce spoilage, ensuring that food items reach clients — including airlines, hospitals, and retail outlets — in the best condition.

Through this project, The Food Factory can enhance its logistical capabilities by introducing smart monitoring technologies, ensuring efficient and safe transport of perishable goods.

Objectives

The primary objective of this model is to create a system that:

1. Monitors Realtime temperature inside the truck during transit.
2. Displays temperature fluctuations visually using dynamic elements (circles representing safe or unsafe conditions) and textual warnings.
3. Tracks truck movement across multiple destinations within a given timeframe.
4. Provides visual feedback and logs for decisionmakers to manage transport operations based on temperature conditions.

The temperature function integrated into the model calculates the current temperature in realtime, based on the simulated hour of the day. This function ensures that temperature data is accurately tied to the time, which is critical for understanding how environmental conditions may vary over a 24hour period.

Moreover, the model provides cyclical truck routes , where each truck completes four trips per day between four specific destinations. By ensuring the truck moves continuously and cyclically, the model reflects the regularity and predictability of logistics operations, making it easier to identify temperature trends and potential risks over time.

Purpose of the Model

The purpose of this model is twofold:

1. **Risk Management for Temperature Sensitive Deliveries:** The system provides a means to anticipate and address potential risks associated with fluctuating temperatures. By identifying when temperatures exceed safe thresholds (e.g., above 20°C), the system triggers visual and textual warnings, allowing logistics operators to take corrective actions before goods are compromised. This is particularly relevant in industries such as food and pharmaceuticals, where minor changes in temperature can have significant impacts on product quality and safety.
2. **Operational Optimization:** By simulating the truck's routes and tracking temperature data in real time, logistics managers can gain valuable insights into how temperature sensitive goods behave under varying environmental conditions. The system logs data on temperature changes, the number of trips, and the times at which these changes occur,

which can be used to refine future transportation strategies. The graphical interface included in the simulation presents a clear visual history of the temperature trends, making it easier for managers to understand the impact of environmental variables on their delivery operations.

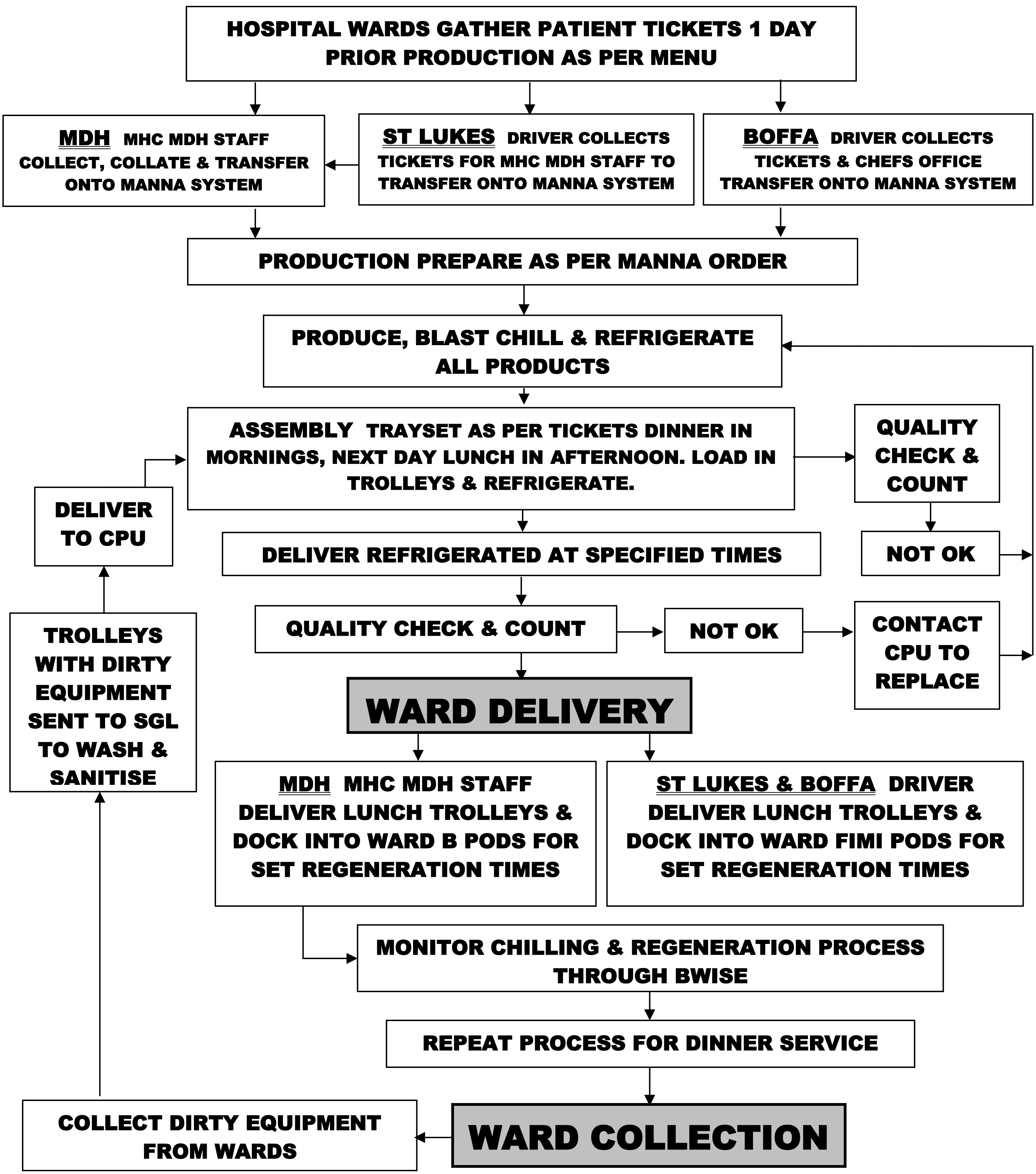
This model thus serves as a proof of concept for integrating smart monitoring technologies into logistics, allowing companies to mitigate temperature related risks and ensure the safe, efficient transport of goods. It demonstrates how automation , real time data monitoring , and visual feedback mechanisms can be applied to improve logistical decision making and reduce the risk of product spoilage during transport.

Significance of the Study

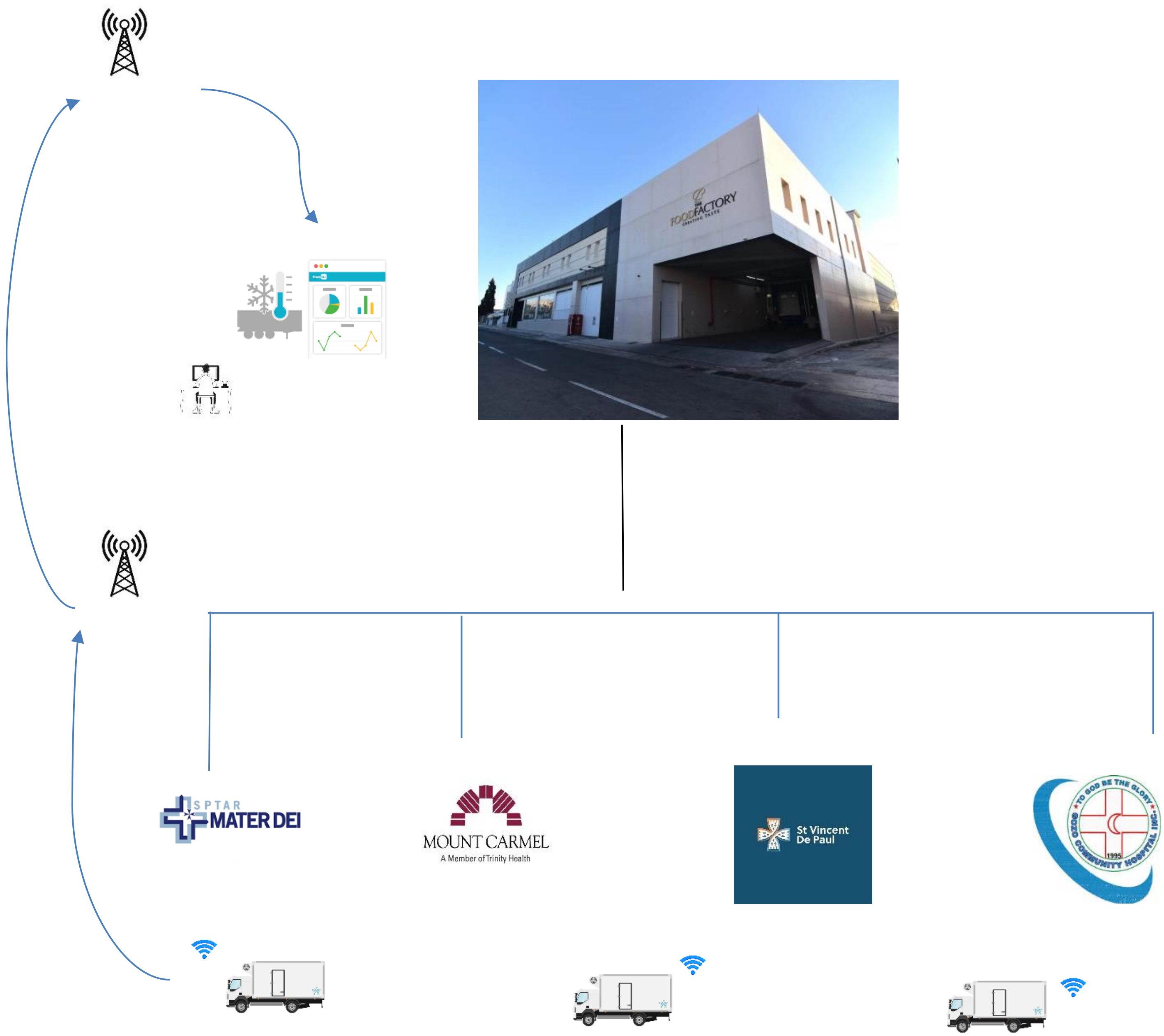
The significance of this project lies in its potential to revolutionize the way temperature sensitive deliveries are managed. By providing real time monitoring and alert systems, it ensures that operators can take proactive measures to safeguard goods. The data collected through this model can also inform future decisions, such as determining the best routes, ideal times for deliveries, and necessary adjustments to truck equipment to maintain optimal temperature conditions.

At last, this study contributes to the broader field of smart logistics and supply chain management , demonstrating how technology can be used to enhance the safety and efficiency of delivery operations.

MALTA HOSPITALS PROCESS



IMPLEMENTED FUNCTION:



Logistics and Distribution System for Temperature-Sensitive Food Delivery

This diagram represents the logistics framework for the distribution of temperature-sensitive food products from a central Food Factory to four major healthcare institutions: Mater Dei Hospital, Mount Carmel Hospital, St. Vincent de Paul Residence (SVPR), and Gozo General Hospital. The system depicted highlights the critical components of temperature control, real-time monitoring, and the role of technology in ensuring the safe and efficient delivery of food across multiple destinations.

1. Central Food Factory as a Manufacturing & Distribution Hub:

At the core of the distribution network is the Food Factory, which serves as the central hub for producing, processing, and dispatching food. The image of the factory reflects its role in preparing meals that are sent out for delivery to various hospitals. The facility likely operates under strict food safety guidelines, ensuring that all food prepared and stored here meets health regulations before distribution.

From a logistics perspective, the factory must manage inventory, ensure proper packaging of temperature-sensitive goods, and coordinate with transportation units. In the context of healthcare, the timeliness and quality of food are crucial for patient recovery and staff nourishment, necessitating the need for an efficient and reliable supply chain.

2. Real-Time Temperature Monitoring and Control

A key feature illustrated in the diagram is the emphasis on temperature control during transportation. This is visually represented by the icon displaying a thermometer and data graph. In food logistics, maintaining the proper temperature is essential, especially when dealing with perishable goods intended for consumption in healthcare settings.

To achieve this, the trucks are equipped with temperature sensors that continuously monitor the internal environment of the delivery vehicles. These sensors send real-time data back to a central monitoring system, ensuring that the food remains within safe temperature limits throughout the transportation process. This feature is critical for maintaining the quality of the food and preventing spoilage, especially in cases where meals must meet specific dietary and health standards for patients in hospitals.

The temperature data can be analysed and visualized, allowing operators to track trends and respond to any issues that may arise during transit, such as fluctuations in the truck's cooling system. Such technology ensures that corrective actions can be taken before the food is compromised, improving the reliability of the distribution network.

3. Communication and Tracking Systems

The image includes several communication and tracking systems denoted by wireless symbols, including towers and Wi-Fi symbols next to the delivery trucks. These elements suggest that the trucks are equipped with communication devices that relay their position and status back to the logistics team in real-time.

By incorporating GPS tracking and wireless communication, the system ensures that each vehicle's progress can be monitored as it moves from the food factory to its respective healthcare destination. This provides several advantages:

- Route optimization: If there are any delays or changes in traffic conditions, the routes can be adjusted dynamically to ensure on-time deliveries.
- Real-time updates: Logistics managers can receive real-time updates on the status of each delivery, which is particularly important in ensuring the timely arrival of meals.
- Proactive issue management: If a truck deviates from its route or experiences issues

(e.g., vehicle breakdown or temperature control malfunction), the logistics team can react quickly by deploying a backup vehicle or rerouting existing deliveries.

The Wi-Fi symbols near the trucks imply that each vehicle is connected to the central monitoring system, ensuring that data on location, temperature, and delivery status is continuously updated and accessible for the stakeholders involved in the logistics process.

4. Healthcare Institutions as Final Destinations

The diagram shows four healthcare institutions as the primary destinations for the food deliveries. Each of these destinations represents a unique logistical challenge, given the specific dietary and operational needs of each facility.

- **Mater Dei Hospital:** As Malta's largest and most advanced hospital, Mater Dei requires a large volume of food deliveries daily to cater to patients, staff, and visitors. The hospital's size and patient demographics mean that food must be delivered frequently and in accordance with strict dietary guidelines to support patient care.
- **Mount Carmel Hospital:** Specializing in psychiatric care, Mount Carmel Hospital also requires specific food deliveries, often catering to the long-term needs of patients. The food provided must meet nutritional standards suited to individuals in mental health care, making timely and controlled deliveries essential.
- **St. Vincent de Paul Residence (SVPR**): This long-term care facility for the elderly is another critical destination in the network. Given the vulnerability of its residents, the food must be fresh and prepared to meet the dietary needs of the elderly. Any delays or issues in the supply chain could impact the health and well-being of these individuals, making efficient logistics management imperative.
- **Gozo General Hospital:** Located on the island of Gozo, this destination presents additional logistical complexity, as food deliveries must cross from the mainland to Gozo, potentially involving maritime transportation. This increases the risk of delays, and as such, the logistics system must ensure robust contingency plans are in place to manage the additional transportation stage effectively.

5. Delivery Network and Vehicle Management

The trucks used in the distribution process are depicted at the bottom of the diagram, and their placement near each healthcare institution suggests that deliveries are made directly from the food factory to the respective hospitals. Each truck is part of a fleet of temperature-controlled vehicles, ensuring that the food maintains its quality from the factory to the hospital.

Each vehicle is equipped with:

- Temperature sensors to monitor and maintain the correct temperature for perishable goods.
- GPS tracking and Wi-Fi communication to provide real-time updates on the vehicle's location and ensure timely deliveries.
- Data loggers that record the temperature history throughout the journey, ensuring

compliance with food safety regulations.

This direct delivery method minimizes handling and reduces the risk of food contamination or spoilage during transit. By using a fleet of dedicated vehicles, the system ensures that food can be delivered quickly and efficiently to each healthcare facility, maintaining the high standards necessary for patient care.

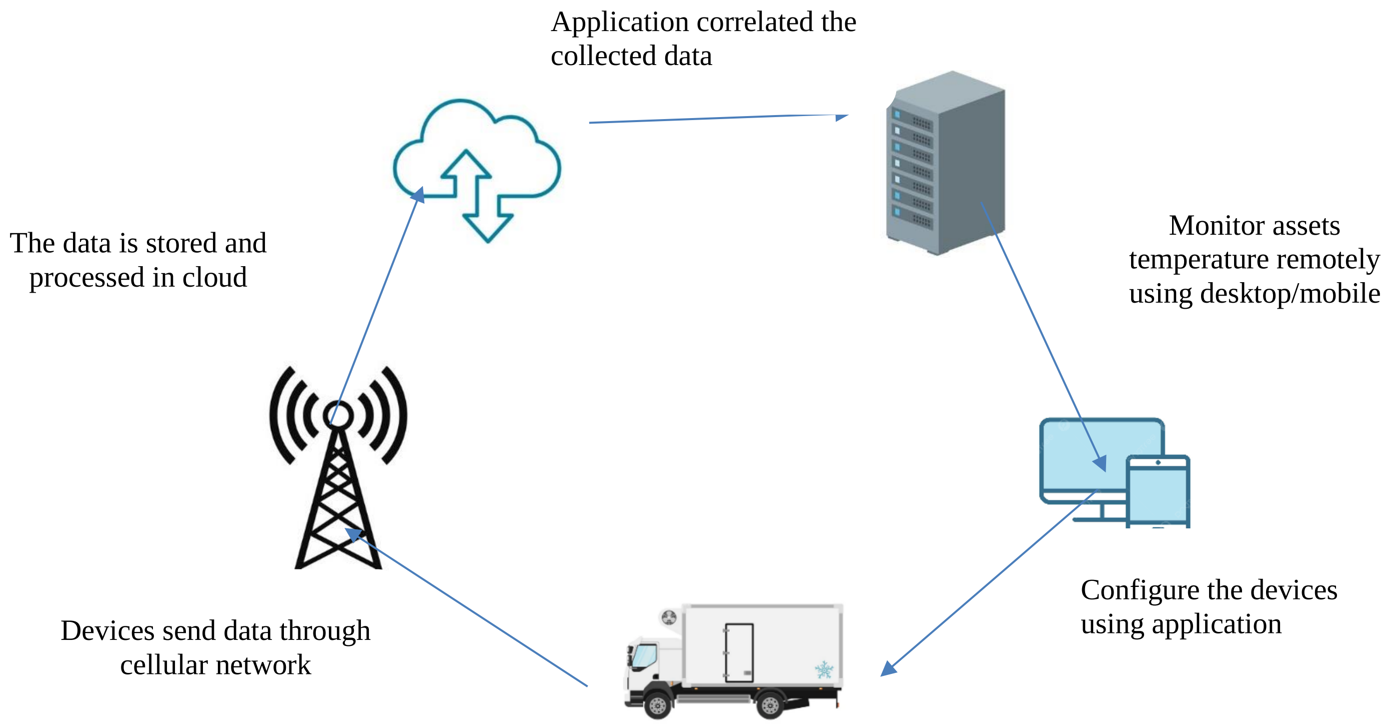
6. Efficiency and Redundancy in the System

The entire logistics network is designed to be highly efficient while also incorporating redundancy to handle any potential issues. For example, the real-time monitoring systems provide constant updates, allowing the logistics team to intervene if a problem arises (e.g., vehicle breakdown, route disruption, or temperature irregularities). Additionally, the use of multiple vehicles ensures that if one vehicle is delayed, another can be deployed to ensure timely deliveries.

By using technology to monitor, track, and optimize the delivery process, this system increases the overall reliability and efficiency of food distribution to hospitals, ensuring that even in complex environments, food is delivered in a timely manner and under safe conditions.

This diagram illustrates a sophisticated and technology-driven logistics system for delivering food from a centralized Food Factory to several healthcare institutions. Key elements such as real-time temperature monitoring, GPS tracking, and direct delivery are essential for ensuring the quality and safety of the food throughout the transportation process. By leveraging modern technology, the system can dynamically respond to challenges, optimize routes, and maintain product integrity, making it highly effective in the context of healthcare food distribution.

PROCESS FLOW:



IOT-Based Temperature Monitoring System for Food Logistics

This diagram illustrates an Internet of Things (IoT)-based system designed to monitor and manage temperature-sensitive assets, such as food, during transportation. The system ensures that the temperature is maintained within safe limits, and any deviations are detected and communicated in real-time. This network relies on a combination of cloud storage, mobile/desktop applications, and cellular networks for data transmission and monitoring.

1. Devices Send Data through Cellular Network

At the bottom of the diagram is a refrigerated truck that represents the primary temperature-sensitive asset in the logistics process. The truck is equipped with sensors that continuously monitor the internal temperature and communicate this data via a cellular network (illustrated by the transmission tower).

- Explanation: In a temperature-controlled logistics system, sensors within the truck record the temperature in real-time. These sensors are connected to the cloud using a cellular network, allowing the data to be transmitted continuously as the truck moves along its delivery route.
- Importance: Maintaining an optimal temperature is critical for ensuring that perishable goods (like food or medicine) are kept fresh during transportation. Any fluctuations beyond the accepted thresholds could compromise product safety and quality. The cellular network enables long-range communication, ensuring that data

is transmitted no matter where the truck is located.

2. Data Stored and Processed in the Cloud

Once the data is transmitted through the cellular network, it is stored and processed in the cloud (represented by the cloud icon in the diagram). The cloud acts as a central repository where all data is collected and made accessible for further analysis.

- Explanation: Cloud computing provides the infrastructure to store vast amounts of data collected from multiple trucks or devices. It also allows for real-time processing of this data, ensuring that any deviations from the ideal temperature are flagged immediately. Cloud storage is critical for ensuring that data is secure and can be accessed from anywhere, making it easy for logistics teams to monitor conditions from remote locations.
- Importance: Using the cloud provides scalability and flexibility. As more trucks or assets are added to the system, the cloud can easily scale to handle the additional data. The cloud also ensures that the data is safe, backed up, and available for further processing, such as trend analysis or compliance reporting.

3. Application Correlates the Collected Data

The next step involves an application (represented by the server icon) that processes and correlates the data collected from the sensors. This application performs analytics on the incoming temperature data, detecting patterns and generating reports for the logistics team.

- Explanation: The application acts as an intermediary between the raw data stored in the cloud and the end-users who need to monitor the system. It organizes the temperature data, correlates it with other variables (such as time, location, or truck identity), and provides valuable insights. For example, if a truck repeatedly experiences temperature fluctuations during a specific time of day, the application can flag this as a potential issue requiring attention.
- Importance: By processing the data and providing actionable insights, the application helps logistics teams make informed decisions. It ensures that potential problems are caught early, allowing teams to take corrective action before goods are compromised. The system also allows for the automation of reporting processes, making it easier to meet regulatory requirements for food safety.

4. Remote Monitoring of Assets Using Desktop/Mobile

Once the data is processed, the system allows users to monitor assets remotely using either desktop or mobile devices (represented by the computer and mobile device icons).

- Explanation: One of the core benefits of IoT-based systems is the ability to monitor assets from anywhere at any time. Logistics teams can access the temperature data, view trends, and receive alerts from their computers or mobile devices. This ensures that even if teams are not physically present, they can still maintain control over their assets and respond promptly to any issues.
- Importance: Remote monitoring provides flexibility and ensures that logistics

managers have full visibility over their assets regardless of their location. For example, if the temperature rises beyond the set threshold, a logistics manager can receive an alert on their phone, allowing them to take immediate action, such as rerouting the truck or adjusting the refrigeration system.

5. Configuring Devices Using the Application

The system also allows users to configure the devices remotely (represented by the mobile/computer icon pointing to the truck). This means users can adjust settings, thresholds, or operational parameters of the truck's temperature sensors through the application.

- Explanation: Device configuration is crucial in managing an IoT network. It allows logistics managers to make adjustments to the sensors without needing to access the truck physically. For instance, if the temperature range for a specific shipment needs to be changed (e.g., due to transporting a different type of product), the settings can be updated remotely through the application.
- Importance: The ability to reconfigure devices remotely enhances operational efficiency and minimizes the need for manual intervention. This reduces downtime and allows for real-time adjustments to meet changing logistical demands. Moreover, it ensures that all devices in the network are operating optimally and in line with regulatory standards.

Summary of the IoT-Based Temperature Monitoring System

The diagram showcases a complete IoT-based ecosystem that ensures the safety and integrity of temperature-sensitive goods during transportation. The system integrates several key components:

- Temperature sensors in the trucks that monitor internal conditions.
- Cellular networks that transmit the data to a central cloud server.
- Cloud storage and processing that ensures all data is securely stored and analyzed in real-time.
- Applications that correlate the data and provide actionable insights, enabling proactive responses.
- Remote monitoring and configuration capabilities that allow logistics teams to manage their assets from anywhere using desktop or mobile devices.

This system ensures seamless communication between assets and logistics teams, enabling better decision-making and ensuring that food and other temperature-sensitive products are transported safely and efficiently. The use of cloud storage, real-time data analysis, and remote monitoring significantly enhances the robustness and scalability of the logistics system.

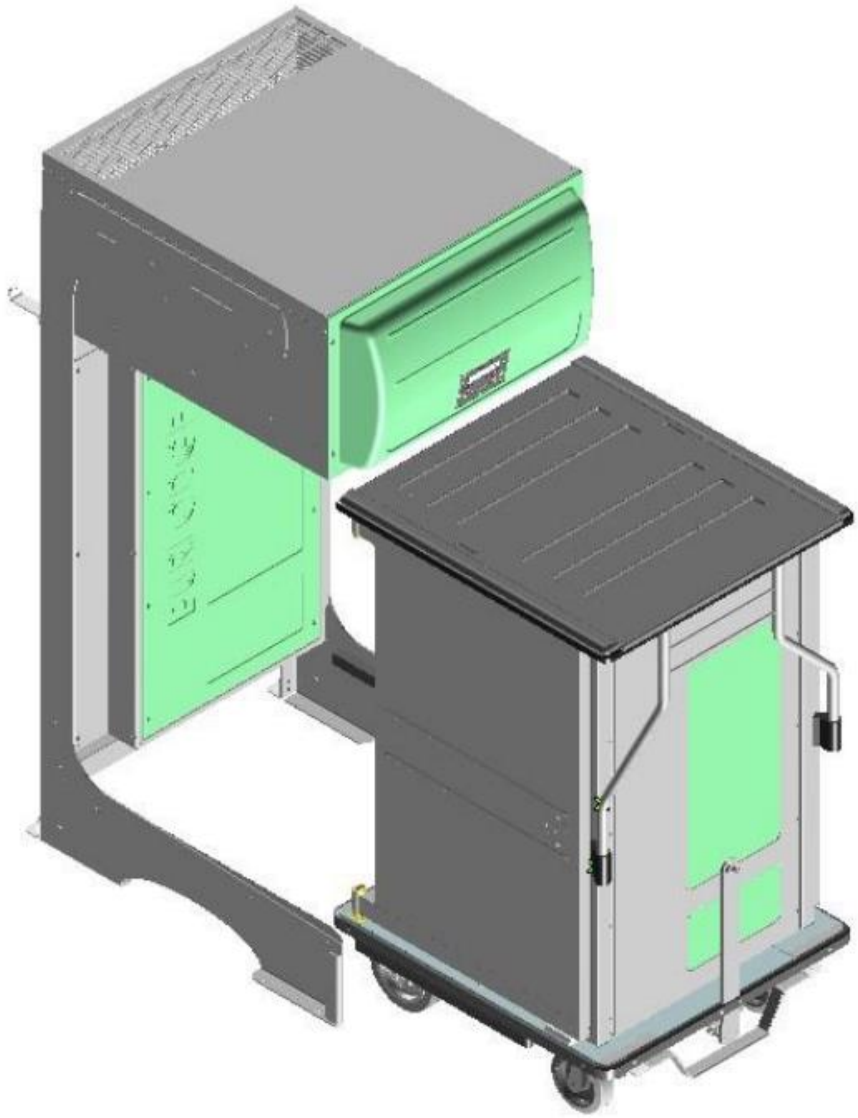
Previous Work:

Current Challenges

Maintaining a constant temperature during transport is challenging due to variables such as delivery delays, changes in external temperature, truck capacity, and route durations. Although current temperature controlled trucks manage to keep meals chilled, the possibility of temperature fluctuations remains, which can compromise food safety. Inconsistent temperatures can result in spoiled food and financial losses, making realtime monitoring essential for largescale operations like those of The Food Factory.

While refrigerated trucks and temperature monitoring systems are not new, many existing solutions are designed to maintain a constant temperature throughout transit. However, these solutions often lack the flexibility to respond to realworld changes in delivery conditions. Existing systems may not fully address dynamic conditions, such as sudden weather changes, mechanical malfunctions, or extended delivery routes, nor do they provide realtime visualization of temperature data. This lack of immediate feedback makes it difficult for companies to take corrective actions in case of temperature fluctuations.

BURLODGE BPODS – Meals Plating :



BPOD System for Hospital Meal Delivery

The BPOD **BPOD (Bulk Portable OnDemand) trolleys**, system is an advanced meal delivery and temperature control solution, widely adopted in healthcare settings to ensure safe and efficient distribution of plated meals to hospital patients. This system is designed to maintain the quality, safety, and optimal temperature of food through precise heating and cooling mechanisms. By leveraging this technology, meals are delivered in accordance with strict dietary and safety requirements, ensuring that patients receive nutritious, temperaturecontrolled meals. The BPOD system plays a critical role in enhancing the overall efficiency of hospital food service operations, reducing the risk of food spoilage and contamination, and ensuring compliance with healthcare standards. In this context, the system represents a significant improvement in hospital meal management, particularly in maintaining temperature consistency throughout the delivery process.

Tray Configuration Each BPOD unit is designed with 12 trays on each side, separated by heating and cooling areas. This separation ensures that hot and cold foods are kept at optimal temperatures until serving time.

Heating and Cooling: The BPOD unit operates by maintaining specific temperatures for different types of food. The heating cycle lasts for a total of 55 minutes, with 50 minutes dedicated to heating and an additional 5 minutes for ventilation, ensuring that food is heated uniformly and safely.

Temperature Control for Different Food Types

Soups	Need higher temperatures to ensure safety and proper consistency.
Main Courses	Require thorough heating to ensure proteins and side dishes are at optimal warmth.
Soft Foods	Must be heated gently to maintain their texture.
Regular Foods	Standard heating procedures apply.
Mince and Moist Foods	Must be kept moist and heated to prevent drying out.
Pureed Foods	Require precise heating to maintain texture and consistency.

BPOD System: Ensuring Safe and Efficient Meal Delivery in Healthcare:

The Burlodge Pod (BPOD) system represents a key innovation in hospital food service, designed to ensure the safe and efficient delivery of meals to patients in healthcare settings. The system is a portable meal delivery and temperature control unit that integrates advanced heating and cooling mechanisms to preserve food quality and safety during transportation and distribution. The BPOD system plays a critical role in maintaining the ideal temperature of food, from the point of meal preparation to delivery, which is essential for preventing foodborne illnesses and maintaining nutritional integrity.

In hospital environments, food safety is of paramount importance. Perishable meals need to be kept within a specific temperature range to prevent bacterial growth, which is one of the leading causes of foodborne illnesses. The BPOD system addresses this challenge by providing precise temperature control, ensuring that meals are held at the correct temperature—whether hot or cold—throughout the meal service process. This allows healthcare facilities to adhere to stringent food safety regulations, protecting patients from potential health risks associated with improperly stored or handled food.

Temperature Monitoring and Precautionary Measures:

To guarantee the BPOD system operates efficiently, it is necessary to implement a set of standard precautions. Regular monitoring and logging of food temperatures are essential to ensure compliance with safety standards. Quality assurance personnel use penshaped thermometers , portable devices specifically designed to measure food temperatures, to verify that meals are within safe temperature ranges after regeneration and before service. Should temperature deviations occur, alarms and alerts prompt immediate corrective actions, minimizing the risk of compromised food quality.

Equally important is the proper handling of food and trays. Staff members must be trained in correct handling procedures to avoid contamination during meal preparation and transportation. The careful handling of trays, utensils, and food items ensures that meals are not exposed to harmful bacteria or unsanitary conditions. To support this, regular maintenance and cleaning of the BPOD units are critical. Scheduled checks guarantee that the equipment is functioning correctly, while routine sanitization after each use helps prevent the buildup of food residues and bacteria.

Comprehensive staff training is vital to the successful implementation of the BPOD system. Employees must be knowledgeable not only about the operational aspects of the system but also about proper food handling techniques, hygiene practices, and maintenance protocols. With thorough training in place, the BPOD system can be operated effectively, maximizing both safety and efficiency.

Implementation in Healthcare Settings

In healthcare settings, the BPOD system facilitates streamlined operations and enhances patient care. It integrates seamlessly with hospital information systems like Manna , which collects data on patient counts and dietary requirements. This data is used to calculate precise meal quantities for each ward, ensuring that all patients receive the correct type and portion of food. Once meals are prepared, they are packed into BPOD trolleys, with each tray carefully labeled to indicate the intended ward and patient.

The BPOD system supports distribution by allowing ward staff to efficiently deliver meals to patients according to the prescribed dietary instructions. This not only ensures timely meal delivery but also promotes the accuracy of meal service, reducing errors in meal type or portion size. By accommodating a variety of dietary needs, from general to specialized requirements (e.g., Halal, glutenfree, or diabetic meals), the system offers significant flexibility to cater to diverse patient populations.

Benefits of the BPOD System in Healthcare Meal Service

The BPOD system presents multiple advantages for healthcare facilities, contributing to improved operational efficiency, consistent food quality, and enhanced patient satisfaction.

These benefits are particularly notable in high volume settings such as hospitals, where the demand for safe and nutritious meals is constant.

1. **Improved Efficiency :** The BPOD system is designed to handle multiple trays at once, significantly improving the meal preparation and distribution process. Its ability to separate hot and cold food items ensures that meals are delivered at optimal temperatures without requiring multiple deliveries or complicated logistics.

2. **Consistent Quality :** Temperature fluctuations can severely impact the texture, flavor, and nutritional value of food. The BPOD system ensures that temperature sensitive meals are consistently maintained at their proper temperature, thereby preserving the quality and palatability of the food. This results in a better dining experience for patients, which is especially important for those on restricted diets or recovering from illness.

3. **Flexibility in Food Service :** must cater to a wide variety of dietary needs, from general meals to specific medical diets. The BPOD system's design accommodates diverse food types and dietary requirements, making it an ideal solution for healthcare facilities. Whether meals need to be kept cold for certain patients or heated for others, the system can handle the varying needs with ease.

BLAST CHILLING:

Blast Chilling and Refrigeration: Critical Processes in Food Safety and Quality Management

In conjunction with the BPOD system for meal delivery in healthcare settings, the processes of blast chilling and refrigeration play pivotal roles in ensuring the safety, quality, and longevity of food items. These processes are essential in environments where large volumes of meals are prepared, stored, and transported, such as hospitals, care facilities, and largescale catering services. As patient meals require precise control over temperature to prevent foodborne illnesses and maintain nutritional integrity, incorporating advanced food safety measures is critical. Blast chilling, followed by proper refrigeration, is a cornerstone of modern food safety management.

Blast chilling is a rapid cooling method designed to lower the temperature of cooked or hot food quickly, minimizing the time food spends in the temperature danger zone, which ranges between **5°C** and **60°C (41°F to 140°F).** This temperature range is where bacteria multiply most rapidly, posing a significant threat to food safety. By rapidly cooling food from its cooking temperature to below **5°C within 90 minutes**, blast chilling ensures that meals remain safe for consumption and minimizes the risk of bacterial contamination. The use of specialized blast chillers that circulate very cold air (ranging from **5°C to 20°C**) ensures a uniform and efficient reduction in temperature across large batches of food. This process not only safeguards the food from harmful pathogens but also helps in maintaining its texture, flavor, and nutritional value.

In healthcare settings, such as hospitals or care facilities, the importance of food safety cannot be overstated. Vulnerable populations, such as patients and the elderly, are more susceptible to foodborne illnesses, making it imperative that every precaution is taken to minimize the risk of contamination. The BPOD system, integrated with blast chilling technology, provides a comprehensive solution for the safe preparation, storage, and delivery of meals. Once food has been blast chilled, it can be stored safely in the BPOD units, which regulate the temperature during transportation and delivery, ensuring the meals remain safe and of high quality until they are reheated and served.

Process of Blast Chilling

The process of blast chilling begins immediately after food has been cooked. Food is transferred into blast chillers, where high velocity cold air **rapidly cools the food to a temperature below 5°C**. This process is particularly important in preventing the growth of harmful bacteria, which thrive in the danger zone. Additionally, rapid cooling prevents the formation of large ice crystals within the food's cellular structure, which can occur during slow cooling. Large ice crystals can damage the texture and flavor of the food, degrading its overall quality.

By blast chilling food quickly, facilities can extend the shelf life of meals, allowing for efficient batch cooking without compromising on safety or quality. In large operations, this process improves overall kitchen efficiency, allowing food preparation to be carried out in larger batches while minimizing waste. The use of blast chillers also enhances operational planning, as meals can be prepared in advance and stored for later use, reducing the need for lastminute cooking and enabling smoother, more efficient kitchen workflows.

Transition to Refrigeration: Maintaining Food Safety After Blast Chilling

Following the blast chilling process, proper refrigeration is essential to maintain the safety and quality of the food until it is reheated and served. After the food is cooled to below 5°C, it is promptly transferred to refrigeration units, where it must be stored at a consistent temperature between 0°C and 5°C. Ensuring that food remains below 5°C prevents bacterial growth, extending the shelf life and preserving the nutritional value of the meals.

The transition from blast chilling to refrigeration must be done quickly to prevent the food from reentering the danger zone. Overcrowding within the refrigeration units should be avoided, as it can obstruct air circulation and lead to uneven cooling. Storage practices, such as using shallow containers and labeling food with the date of chilling, help ensure proper rotation and facilitate easy access, improving operational efficiency and minimizing the risk of spoilage.

Refrigeration, when combined with blast chilling, significantly extends the shelf life of prepared food, allowing it to be safely stored for several days or even weeks. This is particularly beneficial in healthcare settings, where patient meal schedules need to be carefully managed. Ensuring that food is stored at the correct temperature also maintains the texture, flavor, and nutritional integrity of the meals, especially for delicate items like dairy products, meats, and vegetables.

Monitoring and Maintenance of Refrigeration Units

To ensure the ongoing safety of stored food, refrigeration units must be regularly monitored and maintained. Temperature checks should be conducted at regular intervals, with accurate records kept to ensure compliance with food safety regulations. Modern refrigeration units can be equipped with alarm systems to alert staff to any deviations from safe temperature ranges, ensuring quick corrective actions are taken to safeguard the food.

Preventive maintenance of refrigeration units, including cleaning, checking seals, and servicing cooling mechanisms, helps avoid breakdowns that could compromise food safety. Consistent maintenance and monitoring ensure that the refrigeration units function efficiently, keeping food safe and preventing costly spoilage.

Regulatory Compliance and Food Safety Standards

In the context of regulatory compliance, both blast chilling and refrigeration are critical components in adhering to health and safety regulations. Food safety authorities often mandate that perishable foods be stored at specific temperatures, and proper documentation of temperature control processes is essential for passing health inspections. By implementing rigorous blast chilling and refrigeration practices, food service operations ensure that their processes meet the highest standards of food safety, protecting both the facility and its consumers.

In healthcare settings where large volumes of food are prepared daily, these processes become even more important. The combination of the BPOD system with blast chilling and proper refrigeration ensures that meals are not only delivered on time but also remain safe and nutritious throughout the entire food service process. Through proper temperature control, food handling, and regular maintenance, these systems provide an essential safeguard in maintaining the integrity of the food supply chain.

Overall, the integration of blast chilling and refrigeration with the BPOD system offers a comprehensive approach to food safety in healthcare and largescale catering environments. By rapidly cooling food to safe temperatures and maintaining those conditions during storage and transport, these processes ensure that meals reach their recipients in the best possible condition.

Food Packing and Distribution in Hospital Wards Using the Manna System:

In hospital environments, ensuring that each patient receives the correct meal based on their dietary needs and preferences is crucial for maintaining patient health and wellbeing. The process of food packing and distribution in hospitals is highly organized and requires precise coordination between various departments, including dietary services, food production, and logistics. The Manna system, a comprehensive software solution, plays a central role in facilitating the accurate packing and distribution of meals to hospital wards. By managing patient data, meal orders, and production scheduling, the Manna system ensures that the right quantity and type of meals are delivered to each ward, meeting patients' specific nutritional requirements. This section will detail the systematic approach used to pack and distribute food in hospital settings, with a particular focus on the integration of the Manna system and the BPOD (Bulk Portable OnDemand) trolleys used for transportation.

Patient Count and Food Orders

The first step in hospital food distribution begins with collecting and managing patient data. This data includes the number of patients in each ward, their dietary restrictions, and any special nutritional needs they may have. Hospital staff regularly update this information in the Manna system to account for any changes such as new admissions, discharges, or patient transfers between wards. For instance, a patient might be newly admitted to a ward and require a specific diet, or a patient might be discharged, reducing the number of meals needed for that ward.

Once the patient count is entered into the system, the Manna software calculates the exact quantity of food required for each ward. This calculation is essential for ensuring that not only the correct number of meals are prepared but also that each meal aligns with individual patient needs, including dietary restrictions such as vegetarian, gluten free, or low sodium meals. The system also considers additional factors such as portion size and meal type (e.g., breakfast, lunch, or dinner) to ensure the nutritional needs of each patient are met. In cases where patients have allergies or medical conditions requiring specialized meals, the Manna system takes these requirements into account, preventing the risk of incorrect meal distribution that could lead to health complications.

Meal Packing: The Role of BPOD Trolleys

Once the Manna system has calculated the required number of meals for each ward, the food is prepared and packed into BPOD (Bulk Portable OnDemand) trolleys, which are designed to facilitate the safe and efficient transportation of meals within the hospital. Each ward typically receives one or two BPOD trolleys, depending on the patient count and the volume of food ordered. These trolleys are temperature controlled, ensuring that hot food remains hot and cold food stays at safe temperatures during transit.

The packing process itself is highly systematic. Factory or kitchen staff follow the instructions provided by the Manna system to portion and pack meals into trays. Each tray is carefully labeled with the patient's name, ward number, and specific dietary information. For example, a patient in Ward 3 may require a diabetic meal, while another in the same ward needs a gluten free option. By labeling each tray according to the Manna system's instructions, the risk of distributing incorrect meals is minimized, ensuring that patients receive exactly what they need.

Once the trays are packed, they are loaded into the BPOD trolleys. The trolleys are divided into compartments to keep different meal types separate, such as vegetarian and nonvegetarian dishes or hot and cold meals. This organization not only makes the distribution process smoother but also prevents cross contamination and maintains the quality of the food. BPOD trolleys, with their temperature control mechanisms, play an essential role in ensuring that meals arrive in the wards in optimal condition, ready to be served fresh to the patients.

Production and Distribution Process

Following the collection of patient data and meal orders, the Manna system transmits the information to the Central Processing Unit (CPU), where production planning takes place. This stage involves coordinating with the kitchen staff to prepare the required number of meals according to the specific dietary needs of patients. The CPU ensures that the necessary ingredients, equipment, and staff are available to fulfill the meal orders in a timely and efficient manner. The Manna system also provides detailed meal preparation guidelines, including the precise quantities of ingredients needed for each dish, helping kitchen staff streamline their work and reduce waste.

Meal preparation in hospital settings is an intricate process that requires adherence to strict food safety standards. Once meals are prepared, they undergo blast chilling, a rapid cooling process that ensures the food is quickly brought to a safe temperature, minimizing the risk of bacterial growth. Blast chilling is critical for maintaining the quality and safety of meals before they are packed into BPOD trolleys for distribution.

The final stage of the process is the distribution of meals to the wards. The BPOD trolleys, filled with labeled meal trays, are transported from the kitchen to the respective wards. This distribution process is carefully timed to ensure that the meals arrive fresh and at the correct temperature, whether hot or cold. Hospital staff are trained to handle these trolleys with care, ensuring that the correct meals are delivered to the appropriate patients according to the labels and dietary instructions provided.

Once the BPOD trolleys reach the wards, ward staff are responsible for distributing the meals to the patients. The labels on each tray ensure that patients receive the correct meal according to their dietary needs and preferences. This level of accuracy is critical in hospital settings, where improper meal delivery could lead to allergic reactions or nutritional deficiencies, particularly among vulnerable patients.

Benefits of the Manna System in Hospital Food Packing and Distribution

The Manna system, combined with BPOD trolleys, offers several key benefits in hospital food packing and distribution. One of the most significant advantages is the precision and accuracy it brings to the meal production process. By calculating the exact number of meals required for each ward and ensuring that each meal aligns with the patient's dietary requirements, the Manna system reduces the risk of human error and ensures that patients receive the right food at the right time.

Another major benefit is the efficiency the system brings to food production and packing. The detailed production schedules provided by the Manna system allow kitchen staff to prepare meals in an organized manner, reducing the time spent on meal preparation and increasing overall productivity. This efficiency is further enhanced by the use of BPOD trolleys, which streamline the transportation and distribution of meals throughout the hospital.

Furthermore, the system supports food safety and quality by ensuring that meals are packed and transported under the correct conditions. The BPOD trolleys maintain the appropriate temperature for each meal, whether hot or cold, and the blast chilling process ensures that meals remain safe to eat while being stored before delivery.

In conclusion, the Manna system and BPOD trolleys provide an integrated solution for the efficient and safe packing and distribution of food in hospitals. By automating the calculation of meal orders, streamlining food packing, and ensuring accurate and timely distribution, these systems play a crucial role in maintaining high standards of patient care and food safety in healthcare settings. Through their application, hospitals can ensure that patients receive nutritious, well prepared meals that meet their specific dietary needs, ultimately enhancing the quality of care provided.

Regeneration Method :

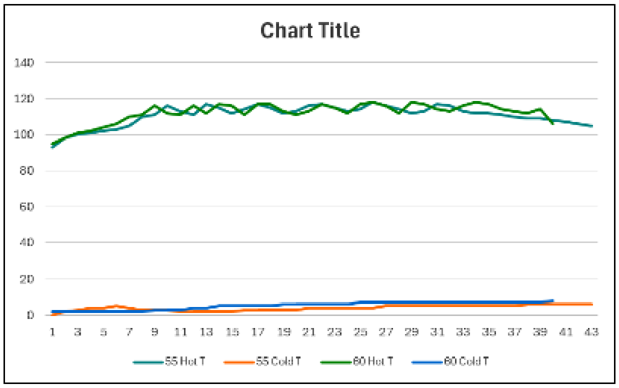
The Burlodge food regeneration system is a specialized solution designed to reheat precooked and chilled meals to their optimal serving temperature while preserving their quality, texture, and nutritional value. This system is widely used in healthcare settings where large volumes of meals are prepared in advance, chilled, and then regenerated just before service. The regeneration process uses precise temperature control to evenly heat both hot and cold food components within a single tray, ensuring that all meals are reheated to safe and appetizing temperatures. Burlodge units are equipped with dual function heating and cooling zones, allowing meals to be reheated without compromising the cold items. This efficient system supports strict hygiene standards, ensuring that food is reheated in compliance with health regulations while maintaining the original quality of the meal.

As part of hospital food service operations, Burlodge regeneration systems enhance both the safety and the dining experience for patients by delivering meals that are both fresh andnutritious.

The BPOD contains 12 trays on each side, separated by heat and cold generating areas. Food will be heated for a total of 45 minutes which include

Temperature	**Duration**
110C	45Minutes – Regeneration
100C	10Minutes – Ventilation

TEMPERATURE VARIES FROM:



45 Minutes Bpod	Hot Temp	Cold Temp
40	93	0
39	98	2
39	100	3
38	101	4
37	103	5
36	105	4
35	110	3
34	111	3
32	116	3
30	113	2
29	111	2
27	117	2
26	115	2
26	112	2
24	114	3
23	117	3
22	115	3
20	112	3
19	116	4
18	117	4
17	115	4
16	113	4
15	114	4
14	118	4
13	116	5
12	114	5
11	112	5
10	113	5
8	117	5
7	116	5
6	113	5
5	112	5
4	112	5
3	111	5
3	110	5
3	109	6
2	109	6
2	108	6
1	107	6
1	106	6
0	105	6

REAL TIME CONTROL MEASURESPENSHAPED THERMOMETER

PenShaped Thermometer

Definition: A penshaped thermometer is a portable device used to measure the temperature of food.
Usage: Quality assurance personnel use this thermometer to check the temperatures after food regeneration and upon receiving goods, ensuring that all food items meet safety standards before they are stored or served.

The BPOD system ensures that food is maintained at safe temperatures, significantly reducing the risk of bacterial growth and foodborne illnesses.

A pen shaped thermometer is a compact, portable device designed for precise temperature measurement in various settings, such as food safety, laboratory use, and industrial environments. Its design mimics a pen, making it convenient for carrying and easy to use, featuring a slim, cylindrical body with an integrated digital display or a dial indicator at one end.

Features and Applications

The pen shaped thermometer typically uses a stainless steel probe for fast and accurate temperature detection. Depending on the model, it may have different measurement ranges, with some thermometers being suitable for low temperature readings in refrigeration or freezing environments, while others can measure high temperatures, such as in ovens or industrial processes. Its use is widespread across sectors, including in the food factory to ensure that cooked and stored food maintains appropriate temperature ranges to avoid bacterial growth.

Technology and Functionality

Pen shaped thermometers may employ either thermocouples, thermistors, or RTD (Resistance Temperature Detectors), depending on the desired accuracy and temperature range. The sensor is usually embedded in the probe, and the results are displayed on a digital screen located at the upper section of the device. Advanced models offer features such as backlit displays, auto shutoff, data logging, and Bluetooth connectivity to transfer readings to other devices for recordkeeping and analysis.

Temperature Tabulation Comparison

For this thesis, a comparison of temperature tabulation will involve:

1. Accuracy Across Different Models: Comparisons between thermocouple based pen thermometers and thermistor based ones, with considerations of factors such as sensitivity, response time, and error margins.

2. Range Compatibility: Comparing models that have a broad measurement range for industrial and culinary applications against those designed for more specific tasks like medical or laboratory use.

3. Usability in Varied Conditions: Analysis of each thermometer's performance in extreme conditions (e.g., freezing vs. boiling temperatures) to ensure usability across different environments. Models with a higher accuracy at extreme temperatures might be more suited for specialized industrial use than those with limited ranges.

This comparison can be tabulated based on factors such as:

- Temperature range
- Accuracy

- Response time
- Durability in different environments
- Ease of use

Penshaped thermometers offer a practical solution for precision temperature measurement across a variety of fields. In this thesis, the tabulated data would compare different models based on their functionality and performance to determine the best model suited for specific applications.

CALIBRATION:

Calibrating a penshaped thermometer is essential to ensure accurate temperature readings, especially when it's used in critical applications like food safety, laboratories, or industrial environments. Calibration involves adjusting the thermometer to match a known temperature standard, which helps account for any deviations that may have developed over time due to wear or environmental factors.

Materials Needed

- A penshaped thermometer
- Ice water (for lowtemperature calibration)
- Boiling water (for hightemperature calibration)
- A container to hold water
- Tongs or heatresistant gloves (for handling hot water)

StepbyStep Calibration Process:

1. IcePoint Method (LowTemperature Calibration)

This method involves calibrating the thermometer using ice water, which should ideally be at 32°F (0°C), the freezing point of water.

1. **Prepare an Ice Water Bath:**
    - Fill a container with ice and add just enough cold water to cover the ice.
    - Stir the mixture to ensure the temperature stabilizes at 32°F (0°C). Let the mixture sit for a minute to reach equilibrium.
2. **Insert the Probe:**
    - Insert the probe of the pen thermometer into the ice water bath. Make sure the sensing tip of the probe is submerged at least 2 inches into the water and not touching the sides or bottom of the container.
    - Stir the probe gently for consistent contact with the cold water.

3. **Wait for the Reading:**
   - Wait until the thermometer's temperature reading stabilizes, which may take a few seconds.
4. **Adjust the Calibration:**
   - If the reading is not exactly 32°F (0°C), many digital pen thermometers have a calibration adjustment feature (check the user manual for specific instructions). Typically, this involves pressing a button or turning a screw to adjust the reading until it matches 32°F (0°C).
5. **Verify and Repeat:**
   - Once adjusted, remove the thermometer and repeat the process to ensure the reading remains accurate. If the reading continues to be inaccurate, there may be a more significant issue with the thermometer that requires further inspection or replacement.

2. BoilingPoint Method (HighTemperature Calibration)

For hightemperature calibration, boiling water is used as the reference. The boiling point of water is 212°F (100°C) at sea level, though this can vary slightly depending on altitude and atmospheric pressure.

1. **Prepare a Boiling Water Bath:**
   - Boil a pot of water and ensure it reaches a rolling boil (with bubbles rapidly forming).
2. **Insert the Probe:**
   - Carefully place the probe into the boiling water. Ensure that the probe is submerged deeply enough but not touching the sides or bottom of the pot.
3. **Wait for the Reading:**
   - Wait for the thermometer reading to stabilize, which could take a few seconds. Use tongs or heatresistant gloves if necessary to avoid burns.
4. **Adjust the Calibration:**
   - If the thermometer does not read 212°F (100°C) and has a calibration feature, adjust the temperature using the calibration button or screw until it reads 212°F (100°C).
   - **Altitude Adjustment:** If you are at a higher elevation, the boiling point of water will be lower than 212°F. You can calculate the expected boiling point based on your altitude or check online to find the correct value.

5. **Verify and Repeat:**
    - Once adjusted, repeat the process to verify the accuracy. If the thermometer still reads inaccurately, further inspection or replacement may be needed.

3. TwoPoint Calibration:

For more precise calibration, especially in scientific or industrial settings, you may perform both the icepoint and boilingpoint methods. This twopoint calibration ensures accuracy over a broader range of temperatures. If your penshaped thermometer allows, adjust for both 32°F (0°C) and 212°F (100°C) as part of the same process.

Additional Tips for Calibration:

- **Check Manufacturer's Instructions:** Always consult the thermometer’s user manual, as different models may have specific calibration procedures or tools.
- **Recalibration Schedule:** Regularly recalibrate the thermometer, especially after it has been dropped or exposed to extreme conditions. Some industries recommend calibration at specific intervals (e.g., weekly, monthly, or quarterly).
- **Digital vs. Dial Thermometers:** For digital penshaped thermometers, calibration often involves pressing buttons, while dial or analog versions may require turning a screw to adjust the dial.

Why Calibration is Important:

- **Accuracy in TemperatureSensitive Applications:** In food safety, an incorrect temperature reading can lead to improper food storage, increasing the risk of bacterial growth. In laboratories or industrial processes, even small deviations in temperature can affect outcomes significantly.
- **Consistency:** Ensuring that multiple thermometers used in the same environment are calibrated ensures consistent results across different devices.
- **Compliance:** Many industries, especially in food safety (like HACCP standards), require regular calibration of thermometers to comply with regulations.

By following these steps, a penshaped thermometer can be reliably calibrated to ensure accurate and precise temperature readings across a variety of applications.

Once in a year probe must be calibrated within the organization or externally.

A standard **penshaped thermometer** is typically designed to measure **temperature only** and does not have the capability to measure humidity. These devices are focused on providing quick and accurate temperature readings in various settings, such as food safety, industrial applications, and laboratory experiments. However, there are specialized instruments called **thermohygrometers** that combine both temperature and humidity measurement capabilities in a single device, and some of these are also designed in a compact, penlike shape.

ThermoHygrometers

A device that can measure both **temperature** and **humidity**, should use a **penshaped thermohygrometer**. These devices feature two sensors:

- A **temperature sensor** (such as a thermocouple or thermistor) to measure ambient or surface temperature.
- A **humidity sensor** (usually a capacitive or resistive sensor) to measure the relative humidity in the air.

PenShaped ThermoHygrometer Functions:

- **Temperature Measurement**: Similar to a penshaped thermometer, it has a probe or sensor that detects the temperature, typically displayed on a digital screen.
- **Humidity Measurement**: The device also includes a humidity sensor that measures **relative humidity**—the amount of water vapor in the air relative to the maximum amount the air can hold at that temperature. The humidity reading is usually expressed as a percentage (%RH).

Applications of a PenShaped ThermoHygrometer:

- **Indoor Environmental Monitoring**: Useful in homes, offices, and greenhouses to monitor comfort levels or the health of plants.
- **HVAC Systems**: Helps in maintaining optimal temperature and humidity levels for efficient heating, ventilation, and air conditioning systems.
- **Industrial and Laboratory Settings**: Monitoring both temperature and humidity is essential in many controlled environments, including manufacturing processes and storage facilities.
- **Food Storage and Safety**: Ensuring that both the temperature and humidity levels are within the required range, especially in refrigeration units.

While a regular **penshaped thermometer** only measures temperature, a **penshaped thermohygrometer** can measure both temperature and humidity. If you require humidity measurement, you would need to invest in a device that explicitly supports both functions, which is common in many modern compact devices designed for environmental monitoring.

In the context of food safety and quality control, the temperature check using a penshaped thermometer by a quality assurance person involves several critical steps:

1. After Regeneration of Food:

Definition: Regeneration refers to the process of reheating precooked food to make it ready for serving.

Procedure: Once the food has been reheated, the quality assurance person uses the penshaped thermometer to measure the internal temperature of various food items. This ensures that the food has reached the appropriate temperature to be safe for consumption and to meet regulatory standards.

Purpose: This step is crucial for verifying that the reheating process was effective and that the food is served at a safe temperature, preventing any risk of foodborne illnesses.

2. Receiving Goods:

Procedure: Upon receiving deliveries of perishable goods, the quality assurance person checks the temperature of these items using the penshaped thermometer.

Purpose: This ensures that the goods have been transported and stored under appropriate conditions, maintaining the cold chain and preventing spoilage or contamination.

Importance: Verifying the temperature of incoming goods is essential for maintaining food safety standards from the point of receipt through to preparation and serving.

By consistently using the penshaped thermometer during these critical points, the quality assurance person plays a vital role in maintaining food safety and quality throughout the food handling and preparation process.

TEMPERATURE BEING FOLLOWED:

TYPE DESCRIPTION	ACTUAL TEMPERATURE RANGE	ACCEPTABLE RANGE
BLAST CHILLER	15C	18C TO 21C
CHILLER	0C TO 5C	5C TO 8C
AFTER REGENERATION	72C TO 75C	70C TO 80C

ANYLOGIC FUNCTIONS :

AnyLogic is a versatile, multi-method simulation software that allows for modeling complex systems across various industries, including logistics, transportation, manufacturing, and healthcare. It supports three simulation methodologies: **Discrete Event Simulation (DES)**, **System Dynamics (SD)**, and **Agent-Based Modeling (ABM)**, which can be used individually or combined in one model. AnyLogic's flexibility allows users to simulate real-world systems with different levels of granularity and to visualize the processes in a dynamic and intuitive way. This software is widely adopted in industries where complex interactions between variables are critical to understanding, optimizing, and managing processes.
AnyLogic offers extensive features such as 3D modeling, GIS integration for real-world mapping, and real-time data analysis. These functionalities make it suitable for simulating scenarios in logistics, manufacturing, and supply chain management, among others.

Why Use AnyLogic for this Project?

In the context of this food transportation model, AnyLogic is an ideal choice due to its flexibility and ability to simulate complex, real-world processes. The transportation of temperature-sensitive goods requires precise monitoring of various factors, including time, temperature, resource allocation, and route optimization. AnyLogic allows for the seamless integration of all these variables into one dynamic simulation model, providing a comprehensive understanding of how the logistics system operates.

1. Multi-Method Simulation Capabilities

AnyLogic's ability to combine **Discrete Event Simulation**, **Agent-Based Modeling**, and **System Dynamics** allows me to accurately model not only the transportation flow but also the interactions between entities, such as trucks, temperature-monitoring systems, and route planners. This is particularly useful for simulating complex logistics systems, where the behavior of multiple interacting components must be analyzed over time.
In this model:

- **Discrete Event Simulation (DES)** is used to simulate the discrete processes of loading, transportation, unloading, and monitoring events like temperature checks.
- **Agent-Based Modeling (ABM)** helps to model each truck as an independent agent that interacts with the environment and other system components, making decisions based on predefined rules (e.g., if temperature exceeds 20°C, alert is triggered).
- **System Dynamics (SD)** is utilized to model the overall flow of goods, resources, and information across the entire logistics chain, providing a macro-level view of how temperature fluctuations and transportation delays affect the system.

2. GIS Integration and Real-Time Mapping

For a logistics-based simulation, the use of **Geographical Information Systems (GIS)** is critical to ensure the accuracy of route planning and transportation tracking. AnyLogic provides the capability to integrate GIS data into the simulation, which allows for real-world mapping of routes and distances between the factory and various destinations (e.g., hospitals or distribution centers). This enhances the accuracy of the model and ensures that transportation time and environmental factors are realistically represented.

3. Real-Time Data Monitoring

A key requirement of the project is maintaining temperature control throughout the transportation process. AnyLogic allows for the creation of dynamic variables that can be monitored and updated in real time during the simulation. For example, the **temperatureFunction** used in the model checks and logs the truck's internal temperature at each point in the simulation, ensuring that the goods are kept within a safe temperature range.

Additionally, AnyLogic supports real-time feedback and visualizations, which make it easier to track potential issues like temperature fluctuations. The visual elements in AnyLogic, such as the red and green indicators, allow for quick identification of whether the temperature exceeds the set limits, triggering alerts to prevent spoilage or damage to the food.

4. Agent-Based Decision-Making and Resource Allocation

In logistics, resource allocation and route optimization are essential for ensuring that deliveries are made on time without compromising product quality. AnyLogic allows me to create **agent-based models**, where each truck, driver, and resource acts as an independent entity making decisions based on real-time data (e.g., changing routes if a temperature issue is detected). This provides a more realistic representation of how a logistics network operates in the real world, offering deeper insights into how to manage resources effectively.

Advantages of Using AnyLogic

1. Scalability and Flexibility

AnyLogic's multi-method approach means that the model can be easily scaled or adjusted to fit different scenarios, such as transporting goods to more destinations, handling additional variables like weather conditions, or incorporating new technologies like automated trucks. This flexibility ensures that the model can evolve alongside the logistics operation it simulates.

2. Visualization and User-Friendly Interface

One of the most significant advantages of AnyLogic is its ability to visually represent complex processes in a way that is easy to understand. The **drag-and-drop interface**, along with the 2D and 3D visualization capabilities, allows for the clear depiction of the truck movements, temperature monitoring, and resource allocation processes.

This visual representation makes it easier for stakeholders, such as logistics managers and engineers, to interact with and understand the model without requiring extensive technical knowledge. The real-time visualization of truck movements and temperature data provides immediate feedback on the system's performance.

3. Integration with External Data

AnyLogic can integrate with external databases, real-time sensors, and API data, which makes it ideal for creating models that need to reflect real-world data. For example, actual temperature sensor data could be fed into the model to test how the system responds to real fluctuations, offering deeper insights into the robustness of the transportation system.

4. Scenario Testing and Risk Management

AnyLogic allows users to create and test different scenarios within the model. For example, the impact of a truck malfunction or a temperature control failure can be simulated to analyze how the system reacts under stress. This helps in identifying bottlenecks or potential issues before they occur in the real world, allowing for better risk management and contingency planning.

5. Enhanced Decision-Making

Because of its ability to simulate and visualize multiple complex processes at once, AnyLogic enhances decision-making in logistics. Users can test various strategies (e.g., different delivery routes, different numbers of trucks) and see how these changes affect the overall system. This leads to more informed, data-driven decisions that optimize resources and ensure that deliveries meet safety and timing requirements.

Benefits of Using AnyLogic for this Project

1. Ensuring Temperature Control

The transportation of temperature-sensitive goods is highly dependent on maintaining specific temperature ranges. AnyLogic provides dynamic monitoring and alert systems to ensure that the goods do not spoil during transportation. The ability to simulate and control environmental conditions helps ensure product quality.

2. Optimizing Logistics and Routes

AnyLogic's **GIS integration** allows for route optimization, helping to minimize transportation time and fuel consumption. This leads to more efficient delivery systems and reduced costs for logistics companies.

3. Improved Resource Utilization

With the **agent-based modeling** approach, AnyLogic enables efficient allocation of resources like trucks and drivers. The simulation helps identify potential bottlenecks in resource allocation and enables the design of strategies for optimal use of available assets.

4. Reducing Risks

Through scenario testing and real-time feedback, AnyLogic helps predict and mitigate risks before they impact the actual operation. It allows testing of various “what-if” scenarios to ensure that contingency plans are in place for any logistical challenge.

AnyLogic is a powerful and flexible simulation tool, uniquely suited for modeling complex logistics systems like the transportation of temperature-sensitive goods. Its multi-method simulation capabilities, real-time data integration, and advanced visualization features make it the perfect solution for this project. By using AnyLogic, we can ensure the safe delivery of products, optimize resources, and enhance overall system performance, all while mitigating risks and improving decision-making processes.

JAMES AGENT :

1. Introduction to the James Manufacturing Side

Begin the section by providing context on why the simulation of the James manufacturing side is necessary. This includes discussing the importance of food safety, temperature controlled logistics, and how the simulation helps optimize the process.

Example:

The transportation of temperature sensitive food products is a critical part of maintaining quality and safety throughout the supply chain. This section of the AnyLogic model, referred to as the "James Manufacturing Side," simulates the end to end process of food transportation from a factory to multiple destinations, ensuring that the products are delivered under strictly controlled conditions. Temperature monitoring plays a central role in preventing spoilage and ensuring regulatory compliance, making the simulation a valuable tool for understanding and improving logistics operations.

2. Detailed Overview of the Process Flow

2.1. Enter Block – Initiating the Manufacturing Process
This section explains in detail the function of the enter block. Expand on how this represents the real world process of products entering the system. Discuss the importance of starting the transportation journey with proper registration and data logging for each item, and how this ensures accuracy throughout the simulation.

2.2. Resource Task Start – Resource Allocation and Task Management
Here, dive deeper into how the resource Task Start block ensures the availability of essential resources (e.g., personnel, trucks). Discuss the complexities involved in resource management, including scheduling and ensuring the right resources are in place at the right time. You can also elaborate on how resource constraints affect the overall logistics performance.

Example:

In real world logistics, ensuring the availability of key resources such as transport vehicles and personnel is paramount to smooth operations. The resource Task Start block in the James manufacturing side simulates this allocation process by ensuring that all necessary components, including trucks and handling personnel, are available before goods are loaded for transport. This step is crucial for avoiding delays, optimizing the scheduling process, and ensuring that goods reach their destination on time.

3. Seizing and Uploading – Preparing for Transportation

3.1. Seize Block – Allocating Transport Vehicles

Go into more detail about how the seize block is used to "seize" the truck or resource that will be responsible for transporting the products. Discuss the operational challenges faced in real world logistics (e.g., vehicle availability, scheduling) and how this block simulates such scenarios.

3.2. Upload Block – Loading the Goods

Expand on how the upload block simulates the process of loading the goods into the truck. You can discuss different types of goods (e.g., perishable vs. nonperishable) and how the model is flexible enough to account for different requirements.

4. Moving the Goods to Destinations

This section will cover how the move To Hospitals block simulates the transportation of goods. Go into detail about route optimization and how the simulation ensures that the most efficient path is taken. You can also introduce some variables and discuss how real time traffic data or other logistics variables can affect the route in a real world scenario.

Example:

Transportation logistics often face challenges such as traffic congestion, road conditions, and distance to destination. The move To Hospitals block simulates the optimal route selection process, ensuring that the goods reach their destination in a timely manner. Factors such as transportation distance, vehicle speed, and environmental conditions are accounted for in the model, ensuring realistic outputs.

5. Unloading and Completing the Task

5.1. Download Block – Offloading the Products

Here, explain how the download block simulates the offloading process. Talk about the real world implications of this, such as ensuring that products are handled correctly during unloading to avoid spoilage or damage.

5.2. Release Block – Completing the Delivery

Go into detail about the release block, explaining how it finalizes the task and prepares the system for the next operation. Discuss how the release function is key to completing the logistics cycle and maintaining operational flow.

5.3. MoveToFactory and Sink – Returning Vehicles and Ending the Task

Describe how trucks return to the factory and how the simulation resets for the next batch of goods. Talk about how this closing loop ensures continuity in real world operations.

6. Temperature Monitoring and Control

6.1. Importance of Temperature Control in Food Transportation

In this section, discuss the importance of maintaining specific temperature levels throughout the transportation process. Explain the real world risks associated with temperature fluctuations and how the simulation mitigates these risks.

Example:

Maintaining a stable temperature during food transportation is crucial for preserving product quality and ensuring consumer safety. Fluctuations in temperature can lead to food spoilage, bacterial growth, and violations of food safety regulations. In the James manufacturing simulation, temperature monitoring is performed continuously, ensuring that goods are kept within safe temperature ranges.

6.2. Temperature Monitoring System and Indicators

Here, explain in more detail how the model monitors the temperature using the temperature Function and how alerts are triggered if the temperature goes above or below specific thresholds. Discuss the red and green indicator system, and how this visual representation of temperature conditions allows for real time monitoring and corrective actions.

Example:

The model incorporates a temperature monitoring system that continuously checks the internal environment of the transportation vehicle. If the temperature exceeds 20°C, a red indicator appears, alerting the operator to potential risks. If the temperature remains within the acceptable range, a green circle is displayed, providing assurance that the goods are being transported safely. This immediate feedback allows operators to take corrective actions, such as adjusting cooling systems or rerouting the truck to a nearby storage facility.

7. Dynamic Movement of Visual Elements

Discuss the visual representation of the trucks and how the circles (red and green) follow the truck's movements across the map. You can also elaborate on how these visual elements provide a user friendly interface for operators to monitor real time conditions.

8. Results and Analysis

This section will analyze the results of the simulation, such as delivery times, temperature fluctuations, and resource utilization. You can provide insights into how the model helps improve overall efficiency in logistics operations and what potential real world benefits can be derived from using this system.

Summarize the key aspects of the James manufacturing side simulation, emphasizing how it improves logistics operations, ensures food safety, and helps with route and resource optimization. Highlight its potential applications in real world logistics and the broader implications for transportation management systems.

This structure should provide a solid 10page thesis section with enough content to cover the simulation in detail. Each section can be expanded further with theoretical background, related research, and additional diagrams/screenshots from your AnyLogic model.

This section of the AnyLogic simulation code is responsible for retrieving and processing the current time within the simulation, ensuring that it remains within a specific cycle (1 to 24 hours), retrieving the corresponding temperature for that time, and finally outputting this data to both the console and a plot if one is set up. This functionality is vital for monitoring the temperature over time during the transportation process of temperature-sensitive goods.

CODE EXPLANATION :

Main – Temperature Update Event :

```
// Get the current simulation time in hours
double currentTimeInHours = time();  // Get the simulation time in hours

// Cycle time to always stay between 1 and 24 hours
double cyclicTimeInHours = (currentTimeInHours - 1) % 24 + 1;  // Ensure time stays
between 1 and 24

// Get the temperature for the cyclic time
currentTemperature = temperatureFunction(cyclicTimeInHours);  // No need for 'main.'

// Output time and temperature to the console
traceln("Time: " + cyclicTimeInHours + " | Temperature: " + currentTemperature + "
°C");

// Add data to plot (if you have a graph setup)
temperatureDataSet.add(currentTimeInHours, currentTemperature);
```

1. Retrieving the Current Simulation Time

double currentTimeInHours = time();

- The first step of the program involves retrieving the current simulation time in hours using AnyLogic's built-in time() function.
- **Explanation**: The time() function returns the current simulation time in hours, which is continuously updated as the simulation runs. This value is crucial for tracking the current point in the simulation, particularly when it comes to monitoring temperature changes over time during the transportation process.

For example, if the simulation has been running for 5.5 hours, the time() function will return 5.5, providing an accurate representation of how much time has passed.

2. Ensuring Time Cycles Between 1 and 24 Hours

double cyclicTimeInHours = (currentTimeInHours - 1) % 24 + 1;

- This line of code ensures that the current time is always within a range of 1 to 24 hours by applying a **modulus operation**.
- **Explanation**: The transportation process modeled in the simulation is cyclical, meaning that time needs to be confined within a 24-hour cycle. To achieve this, the code first subtracts 1 from the current time (to align the start of the day to 1 hour rather than 0 hours), applies the modulus operator (% 24), and finally adds 1 to ensure that the resulting time always stays between 1 and 24.

In real-world logistics, the temperature of goods can vary depending on the time of day, and we want the model to reflect a continuous cycle over a 24-hour period. For example, if the simulation time reaches 25 hours, this code ensures that the time "resets" back to 1 hour, mimicking the cyclical nature of day-to-night transitions.

3. Getting the Temperature for the Current Time

currentTemperature = temperatureFunction(cyclicTimeInHours);

- This line retrieves the temperature for the corresponding cyclicTimeInHours by calling the temperatureFunction.
- **Explanation**: The temperatureFunction is a predefined function that returns the temperature based on the time of day. This function likely simulates temperature fluctuations throughout the day, where temperatures may vary depending on factors such as the time of day, weather conditions, or cooling system behavior in the truck.

For instance, early morning hours might have lower temperatures compared to afternoon hours. This line ensures that the temperature is accurately calculated based on the current cyclic time and allows the model to simulate real-time temperature changes as the transportation progresses.

4. Outputting Time and Temperature to the Console

traceln("Time: " + cyclicTimeInHours + " | Temperature: " + currentTemperature + " °C");

- This line outputs the current time and temperature to the console in a readable format.
- **Explanation**: By using traceln(), the simulation prints a log of the time and temperature at regular intervals. This is essential for monitoring the transportation process in real-time. In a real-world scenario, this feature would allow operators to track the temperature conditions inside the truck at any given point during the delivery, ensuring that the goods are being transported within the safe temperature range.

The output look like this:

Time: 08:00 | Temperature: 5°C

Time: 12:00 | Temperature: 15°C

5. Adding Data to a Temperature Plot

temperatureDataSet.add(currentTimeInHours, currentTemperature);

- This line adds the current time and temperature data to a temperature plot for visualization.
- **Explanation**: If a graph or data plot is set up in the simulation, this line adds the temperature data for each point in time to the plot. This allows for the creation of a visual representation of temperature changes throughout the transportation process, providing a more comprehensive view of how well the cooling system performs over time.

By plotting the data, operators or analysts can see trends, such as temperature spikes or drops, and take corrective actions if necessary. This is critical in ensuring that the products being transported remain within safe temperature thresholds.

Lorry Event Function :

```java
// Get the current simulation time in hours
double currentTimeInHours = time();  // Get the simulation time in hours

// Round the time down to the nearest whole hour and ensure it stays between 0 and 23
int roundedTimeInHours = (int) (Math.floor(currentTimeInHours) % 24);

// Format the time for display, so it appears like "04:00", "08:00", etc.
String formattedTime = String.format("%02d:00", roundedTimeInHours);

// Access the Main agent (assuming get_Main() works or use getOwner())
Main main = (Main) get_Main();  // Or use: Main main = (Main) getOwner();

// Get the temperature for the current rounded time from the Main agent's temperature
function
currentTemperature = main.temperatureFunction(roundedTimeInHours);

// Output the formatted time and temperature to the console
traceln("Time: " + formattedTime + " | Temperature: " + currentTemperature + " °C");

// Update the message label with the formatted time and temperature
messageLabel.setText("Time: " + formattedTime + " | Temperature: " +
currentTemperature + " °C");

// Check temperature for circle display
if (currentTemperature > 20) {
   circleRed.setVisible(true);    // Show the red circle
   circleGreen.setVisible(false); // Hide the green circle
   messageLabel.setText("Warning: Temperature above 20°C!");
} else {
   circleRed.setVisible(false);   // Hide the red circle
```

```
    circleGreen.setVisible(true);  // Show the green circle
    messageLabel.setText("");      // Clear any warning message
}

// Move the temperature labels along with the truck
double truckX = getX();  // Get the X-coordinate of the truck
double truckY = getY();  // Get the Y-coordinate of the truck

// Update the position of the circles to follow the truck
circleRed.setX(truckX);
circleRed.setY(truckY);

circleGreen.setX(truckX);
circleGreen.setY(truckY);
```

This section of the code is crucial for tracking and visualizing the transportation of temperature-sensitive goods in the simulation model. It simulates the current time in hours, retrieves the corresponding temperature, formats it for display, and visualizes the temperature status using indicators such as red and green circles. This logic ensures real-time temperature monitoring throughout the transportation process, which is essential for ensuring product safety.

1. Getting the Current Simulation Time in Hours

double currentTimeInHours = time();

- This line retrieves the current simulation time in hours using the time() function.
- Explanation: The simulation runs on a continuous timeline, and the time() function returns the exact point in time in hours. This is essential for tracking when the temperature readings are taken. For example, if the simulation has been running for 4.5 hours, this line of code will return the value 4.5. In the context of temperature-sensitive goods, it is crucial to monitor environmental conditions at specific intervals to prevent spoilage or safety issues.

2. Rounding the Time to the Nearest Whole Hour

int roundedTimeInHours = (int) (Math.floor(currentTimeInHours) % 24);

- The next step is to round the current time down to the nearest whole hour, ensuring that the value stays within a 24-hour cycle (0 to 23 hours).
- Explanation: Many real-world systems operate on an hourly cycle, where readings are taken at specific times (e.g., 08:00 or 16:00). This line of code uses the Math.floor() function to round down the time and apply a modulus operation (% 24) to ensure the time stays within a 24-hour period. This simulates real-world systems, like temperature regulation, where actions are typically performed on an hourly basis.

3. Formatting the Time for Display

String formattedTime = String.format("%02d:00", roundedTimeInHours);

- After calculating the rounded time, this line formats the time for display in a standard "HH:00" format.
- Explanation: The String.format() method ensures that the time is displayed in two-digit format with a trailing ":00" to represent the start of the hour. For example, if roundedTimeInHours is 4, the formattedTime will be "04:00". This makes the time more readable and suitable for user interfaces or logs. In transportation, especially when dealing with perishable goods, it is important to provide clear, precise time records for when temperature readings are taken.

4. Accessing the Main Agent

Main main = (Main) get_Main();

- This line accesses the Main agent of the simulation, which contains key variables and functions such as temperature controls.
- Explanation: In AnyLogic simulations, different agents (like trucks, locations, or sensors) interact within the environment. The get_Main() function is used to access the primary agent (called "Main") where essential functions, such as temperature regulation, are located. The code ensures that the simulation retrieves the correct data from the Main agent, which is crucial for performing operations like fetching the current temperature.

5. Getting the Temperature Based on Time

currentTemperature = main.temperatureFunction(roundedTimeInHours);

- This line retrieves the current temperature for the specific hour from a temperature function defined in the Main agent.
- Explanation: The temperatureFunction() in the Main agent returns the temperature based on the rounded time. Temperature changes over time in a real-world scenario, where mornings might be cooler than afternoons. This function simulates that behavior by returning a temperature value that corresponds to the specific hour of the day. For example, the temperature at 04:00 might be lower than the temperature at 12:00. This is critical in simulating the transportation of temperature-sensitive goods, where constant monitoring is required to ensure safe delivery.

6. Outputting the Time and Temperature to the Console

traceln("Time: " + formattedTime + " | Temperature: " + currentTemperature + " °C");

- This line outputs the current time and temperature to the console for logging purposes.
- Explanation: By using the traceln() function, the simulation prints the current time and temperature to the console, making it easy to monitor changes as the simulation progresses. This provides real-time feedback for operators or analysts, ensuring that they can track temperature fluctuations. For instance, if the temperature rises above a certain threshold (e.g., 20°C), immediate action can be taken to prevent product spoilage.

7. Updating the Message Label with Time and Temperature

```
messageLabel.setText("Time: " + formattedTime + " | Temperature: " + currentTemperature + " °C");
```

- This line updates a message label on the user interface with the current time and temperature.
- Explanation: The message label displays important information for the user, allowing them to see the time and temperature visually. This is particularly useful for simulations with user interfaces, where operators or stakeholders need to monitor conditions in real time without checking the console. By updating the label, the simulation provides a clear indication of current conditions, enabling better decision-making.

8. Checking the Temperature for Visual Indicators

```
if (currentTemperature > 20) {
   circleRed.setVisible(true);
   circleGreen.setVisible(false);
   messageLabel.setText("Warning: Temperature above 20°C!");
} else {
   circleRed.setVisible(false);
   circleGreen.setVisible(true);
   messageLabel.setText("");
}
```

- This block of code checks whether the current temperature exceeds 20°C and displays a visual warning using red and green circles.
- Explanation: In this simulation, maintaining the temperature below 20°C is critical for product safety. The code checks if the temperature is greater than 20°C and displays a red warning circle if it is, while hiding the green circle. Conversely, if the temperature is within the safe range, the green circle is shown, and the warning message is cleared. This visual alert system is vital for real-time monitoring, as it allows operators to quickly identify problems and take corrective actions.

9. Moving the Temperature Labels with the Truck

```
double truckX = getX();
double truckY = getY();
```

- These lines get the current X and Y coordinates of the truck.
- Explanation: In the simulation, the truck moves along a path to deliver goods, and it’s important to update the temperature indicators (red and green circles) as the truck moves. The getX() and getY() functions retrieve the truck's current position, allowing the temperature labels to follow the truck visually on the simulation screen.

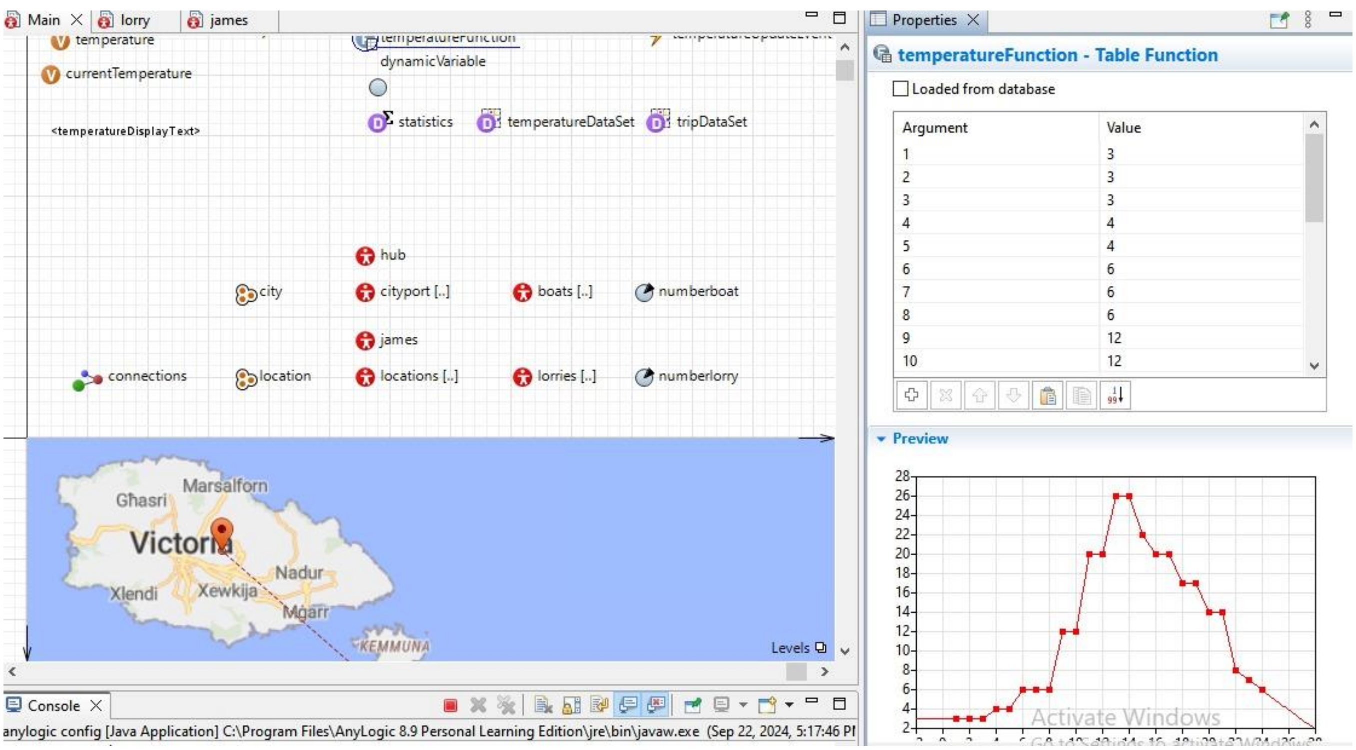
10. Updating the Position of the Circles

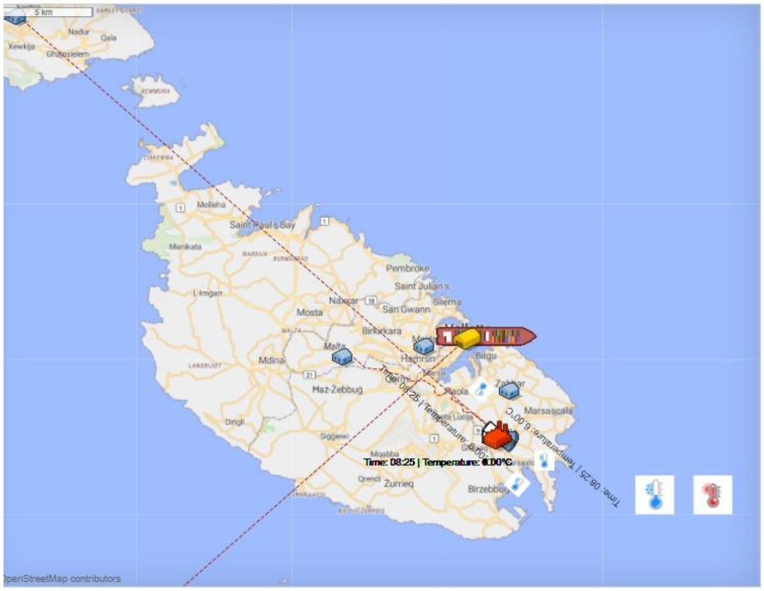
```
circleRed.setX(truckX);
circleRed.setY(truckY);

circleGreen.setX(truckX);
circleGreen.setY(truckY);
```

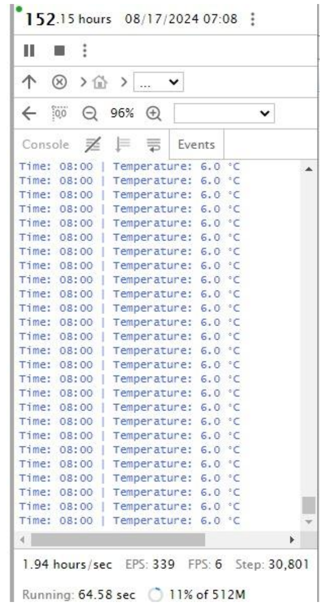
- These lines update the positions of the red and green circles to follow the truck.

- Explanation: By dynamically updating the X and Y coordinates of the circles, the simulation ensures that the visual indicators (red for warning, green for safe conditions) always follow the truck as it moves. This helps operators easily identify which vehicle is experiencing temperature issues in a multi-truck simulation. The visual alignment enhances the user experience by providing a clear, real-time representation of temperature conditions throughout the transportation process.

This program section is an integral part of the simulation, responsible for ensuring that temperature-sensitive goods are safely transported under controlled conditions. By continuously monitoring the temperature, displaying real-time feedback, and alerting operators when conditions become unsafe, the code helps maintain the integrity of the products being transported. The combination of time-based temperature monitoring, visual feedback, and dynamic movement of visual indicators makes the simulation a powerful tool for analyzing and optimizing logistics operations.







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