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Interactive Communication Model for Vaccine Supply Management

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ABSTRACT: Vaccination offers health, economic, and social benefits. Nevertheless, the vaccine supply chain (VSC) continues to face significant challenges, including vaccine quality, demand forecasting, and stakeholder trust, which contribute to its inefficiencies. The COVID -19 outbreak has demonstrated the diverse challenges that supply chain face to significant disruptions. The global availability of human vaccines necessitates sophisticated production techniques, rigorous quality assurance, and dependable distribution networks to guarantee their potency and efficacy upon delivery. The present study also reveals the implications for the management of apply chain, business, government Supply chain management involves the end-to-end coordination and optimization of processes, activities, and resources required to deliver goods or services from the initial production phase to the final consumer. This comprehensive approach encompasses the planning, sourcing, manufacturing, transportation, distribution, and return processes, aiming to streamline efficiency, reduce costs, and enhance customer satisfaction. Effective supply chain management involves collaboration with suppliers, manufacturers, logistics providers, and retailers, leveraging technology and data-driven insights to ensure a seamless flow of goods, minimize disruptions, and adapt to dynamic market demands, ultimately contributing to a resilient and agile business ecosystem.

I.INTRODUCTION

Vaccination for kids is a crucial aspect of public health, providing protection against a range of preventable and potentially serious diseases. Childhood vaccinations typically follow a schedule recommended by health authorities, targeting illnesses such as measles, mumps, rubella, polio, hepatitis, and more.

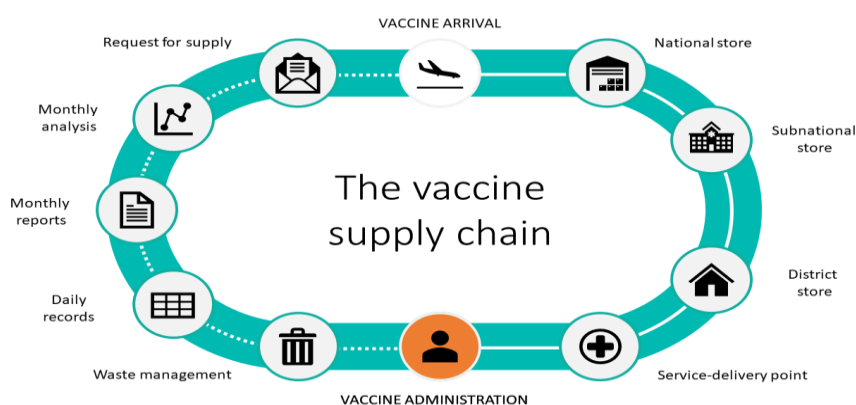
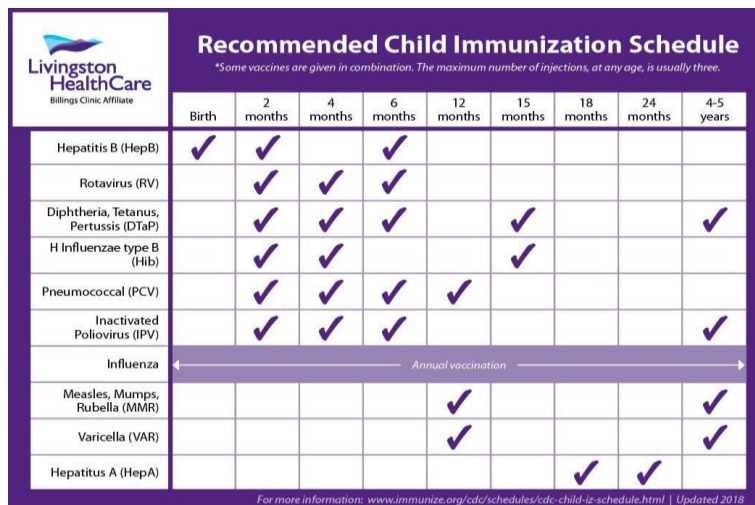


Figure 1: Overall Vaccine Management System

These vaccines not only safeguard individual children but also contribute to community immunity, reducing the overall prevalence of infectious diseases. Immunizing children helps prevent the spread of contagious illnesses, protects those who cannot be vaccinated due to medical reasons, and ensures the well-being of the entire population. Regular vaccinations are a cornerstone of pediatric healthcare, promoting the health and resilience of the younger generation against a spectrum of preventable infections.



	Birth	2 months	4 months	6 months	12 months	15 months	18 months	24 months	4-5 years
Hepatitis B (HepB)	✓	✓		✓					
Rotavirus (RV)		✓	✓	✓					
Diphtheria, Tetanus, Pertussis (DTaP)		✓	✓	✓		✓			✓
H Influenzae type B (Hib)		✓	✓			✓			
Pneumococcal (PCV)		✓	✓	✓	✓				
Inactivated Poliovirus (IPV)		✓	✓	✓					✓
Influenza	← Annual vaccination →								
Measles, Mumps, Rubella (MMR)					✓				✓
Varicella (VAR)					✓				✓
Hepatitis A (HepA)							✓	✓	

For more information: www.immunize.org/cd/schedules/cdc-child-iz-schedule.html | Updated 2018

Figure 2: Vaccination Schedule For Children

II.LITERATURE REVIEW

Present and future perspectives of Blockchain in supply chain management(2023)[1]: An increasing number of papers are exploring the application of Blockchain to supply chain management, broadening the scope for scholars and practitioners seeking to understand the current advancements in this emerging field. Therefore, we present the current state of the art of Blockchain in supply chain management and highlight the key gaps that need to be addressed to further advance knowledge in this area. We utilize a systematic literature review approach in a review of reviews, examining 103 review papers published in peer-reviewed scientific journals listed in the Scopus and Web of Science databases. Our findings broaden the discourse through a holistic approach that incorporates Blockchain technology into supply chain management from various angles, covering the interaction between physical and virtual flows beyond the traditional one-step-back and one-step-forward view. Additionally, we examine the disruptive potential of Blockchain technology as a means to integrate diverse supply chain stakeholders and facilitate information sharing, thereby supporting process monitoring and decision-making across different industries and sectors. The contributions provided by this paper are divided into three main categories. Initially, a comprehensive and current overview of the state of the art is provided, highlighting Blockchain as a suitable technology for production and logistics applications. Then, gathering the analysis of reviews helps researchers identify contents to be examined and to avoid developing overlapping reviews. Furthermore, the array of directions identified in the sample serves as a significant foundation for guiding future research endeavors, while the outlined research topics offer valuable pathways for subsequent literature reviews to be conducted.

A new vaccine supply chain network under COVID-19 conditions considering system dynamic: Artificial intelligence algorithms(2022)[2]: With the advent of the COVID-19 vaccine, decision-makers have been predominantly concerned with distribution management, optimal placement of vaccination centers, and inventory control of all vaccine types. Given the high demand for the COVID-19 vaccine, strategic planning for equitable distribution is imperative. Universities, as some of the most densely populated areas in cities, are critical targets for vaccination to mitigate virus spread. Consequently, this study introduces a novel stochastic multi-objective, multi-period, and multi-commodity simulation-optimization model designed to address the production, distribution, location, allocation, and inventory control of the COVID-19 vaccine. The proposed supply chain network encompasses four echelons: manufacturers, hospitals, vaccination centers, and volunteer student vaccinators. Vaccine manufacturers distribute vaccines to both hospitals and vaccination centers. Students with underlying health conditions, such as heart disease, corticosteroid use, or blood clot history, are vaccinated in hospitals due to the need for greater medical care access, while other students are vaccinated at the centers. A system dynamics model of COVID-19 prevalence in universities was developed, estimating vaccine demand via simulation and incorporating this demand as a stochastic parameter in the mathematical model. The model aims to minimize supply chain costs, maximize student vaccination desirability, and ensure equitable vaccine distribution. To solve this model, the Variable Neighborhood Search (VNS) and Whale Optimization Algorithm (WOA) are employed. Key novelties of the simulation model include considering the impact of virtual education and quarantine measures on vaccine demand estimation. In the mathematical model, significant contributions include factoring in social distancing during vaccination and the possibility of vaccination

during both working and non-working hours. The solution methodology introduces a new heuristic approach, the Modified WOA with VNS (MVWOA), which demonstrates superior performance in terms of performance metrics and CPU time compared to other algorithms. A case study from the COVID-19 pandemic period in Tehran, Iran, is used to validate the proposed algorithm. The results show that as demand increases, costs rise sharply while student vaccination desirability decreases at a gradual rate.

Vaccine supply chain management: An intelligent system utilizing Blockchain, IoT and machine learning (2022)[3]: Vaccination offers health, economic, and social benefits. However, three major issues—vaccine quality, demand forecasting, and stakeholder trust—continue to plague the vaccine supply chain (VSC), leading to inefficiencies. The COVID-19 pandemic has amplified these weaknesses but also presents opportunities to leverage digital technologies for better management. For the first time, this study introduces an intelligent VSC management system designed to provide decision support during the pandemic. This system integrates blockchain, the Internet of Things (IoT), and machine learning to effectively address the VSC's challenges. Blockchain ensures transparency and trust among stakeholders. The IoT offers real-time monitoring of vaccine status, safeguarding vaccine quality. Machine learning predicts vaccine demand and performs sentiment analysis on vaccine reviews, helping companies enhance vaccine quality. This study also discusses the broader implications for managing supply chains, businesses, and government operations.

Exploring the challenges of the COVID-19 vaccine supply chain using social media analytics: A global perspective(2023)[4]: The Coronavirus (COVID-19) pandemic has highlighted the importance of effective vaccine supply chain management (SCM). As the world rushed to curb the virus's spread, efficiently distributing vaccines became essential to ending the pandemic. However, the challenges of global COVID-19 vaccine distribution were compounded by the pandemic itself, causing delays, shortages, and disruptions under disaster conditions. This study uses social media analytics to examine the impact of COVID-19 vaccine supply chain challenges from a global perspective. Data were collected from Twitter and the Global Database of Events, Language, and Tone (GDELT) between January 2020 and November 2022. The analysis employed Natural Language Processing (NLP) techniques, including topic modeling and sentiment analysis. The results indicated that vaccine supply chain challenges significantly affected healthcare systems' responses to the pandemic, with notable regional disparities, particularly in developing countries. These findings emphasize the need for better coordination and collaboration in vaccine supply chain management to ensure equitable access. Additionally, this research demonstrates the practical value of social media analytics in enhancing decision-making capabilities for policymakers and industry leaders. The study presents a global perspective on the impact of vaccine supply chain challenges using big data analytics, analyzing 33,194 tweets and 36,761 events from GDELT.

Mapping research in logistics and supply chain management during COVID-19 pandemic(2021)[5] The paper conducts a literature review on the impact of the COVID-19 outbreak on supply chains, analyzing peer-reviewed papers from 2020. Using a systematic approach, the authors establish criteria and build a framework addressing major disruptions in supply chain management (SCM). Considerations include individual organizational features, overall supply chain characteristics, performance metrics for sustainability, and attributes related to external disruptions. The resulting framework suggests areas for further investigation, such as collaboration, technology adoption, and knowledge creation. The paper emphasizes the importance of strategies to shape and promote awareness among supply chain stakeholders in the face of ongoing challenges, contributing valuable insights to SCM. This work conducted a Systematic Literature Review (SLR) on research papers published during the COVID-19 outbreak, specifically focusing on disruption management in supply chains. The methodology employed followed a systematic process, clearly defining search and selection criteria for research papers. The reviewed papers were categorized into three subject areas, reflecting the significant interest from academics, practitioners, and policymakers due to the severe impact of the pandemic on supply chains. While the SLR protocol ensures transparency and reproducibility, there are limitations, such as the exclusive search in Scopus, potentially missing relevant literature outside this database. Additionally, the review only includes papers published in 2020, acknowledging the ongoing nature of research in 2021. The decision to focus on 2020 allows for a fair comparison of existing literature, with future analyses anticipated to explore the evolving strategies in supply chain and logistics management as populations undergo mass vaccination.

Smart supply chain management in Industry 4.0: the review, research agenda and strategies in North America(2022)[6] : The paper underscores the pivotal role of emerging Information and Communication Technologies (ICT) associated with Industry 4.0 in bolstering supply chain performance. This adoption of smart technologies has given rise to what is termed as smart supply chains. Understanding the profound impact of Industry 4.0 and related ICT on smart supply chains is deemed crucial for both practical and academic communities. What distinguishes this paper is

its integrated approach, combining an introduction to the prevailing national strategies in North America, an analysis of the research status on ICT-assisted supply chains from major North American national research councils, and a systematic literature review on the subject. The paper introduces a hierarchical framework for smart supply chains with multi-level intelligence, providing a comprehensive understanding of their evolution. Furthermore, the challenges faced by supply chains in the era of Industry 4.0 are examined, and the paper outlines future research directions in this dynamically evolving field.

III.METHODOLOGY OF SYSTEM

Implementation is the process of defining how the system should be built, ensuring that it is operational and meets quality standards. It is a systematic and structured approach for effectively integrating a software-based service or component into the requirements of end users. It uses the structure created during architectural design and the result of system analysis to construct system elements that meets the stakeholder requirements and system requirements developed in the early life cycle phases.

The Vaccine Management System was developed using a combination of modern web technologies to ensure robustness, security, and user-friendliness. PHP was chosen as the primary server-side scripting language for its ease of integration with web servers and databases. PHP also facilitated efficient handling of server requests and user sessions, critical for secure login and user management functionalities. MySQL was used for the database, providing a reliable and scalable solution for storing and managing data related to hospitals, vaccines, bookings, and users.

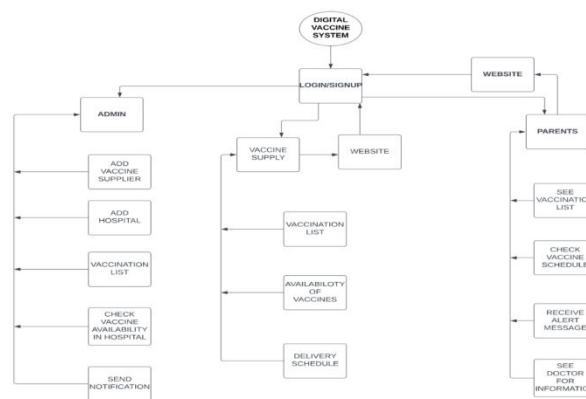


Figure 3: Digital Vaccine System Architecture

Algorithm

The Vaccine Management System incorporates several key algorithms and methods to ensure secure and efficient functionality. User authentication is achieved through a secure login and registration process, utilizing hashing algorithms like crypt to protect passwords and validating user inputs to prevent SQL injection and other attacks. The vaccine booking system employs search and filtering algorithms using SQL queries to allow users to find available vaccines based on criteria such as hospital and vaccine name, with results paginated for better performance. Email notifications are handled by integrating PHPMailer, which sends confirmation and update emails to parents after registration and vaccination status updates. For generating vaccination certificates, the TCPDF library is utilized to create PDFs that include essential details such as the child's name, vaccine name, hospital, and vaccination date. These PDFs are stored in the database and linked to the respective booking records. Session management is crucial for user authentication, with session variables securely storing user information to pass data like phone numbers between pages without exposing them in URLs. Stock management algorithms ensure accurate inventory tracking by updating vaccine stock based on vaccination status changes, using SQL queries to reflect these updates. Secure data transmission is maintained through URL encoding and decoding, allowing sensitive data to be passed between pages safely. These combined efforts result in a robust and user-friendly platform for managing vaccinations.

Backend

In the backend of the Vaccine Management System, we have implemented a robust and secure architecture to handle all functionalities seamlessly. The system is built using PHP for serverside scripting, ensuring dynamic content generation and efficient database interactions. We have utilized MySQL as the database management system to store and manage all the data related to users, vaccines, bookings, and vaccination status. The database schema is designed to maintain relational integrity and optimize query performance. User authentication and session management are handled through PHP sessions, ensuring that only authenticated users can access certain features. Passwords are securely hashed using algorithms like bcrypt to enhance security. The system includes functionality for hospitals to request permission to join the platform, add vaccine stocks, set prices, and manage orders from parents. Hospitals can also update the vaccination status, which triggers real-time updates and notifications to parents via email, handled by the PHPMailer library. For parents, the system allows for registration and vaccine booking from various hospitals. Optional email notifications keep them informed about their booking status and vaccination details. After successful vaccination, the system generates a vaccination certificate in PDF format using the TCPDF library, which includes all relevant details and is sent to the parent via email. Throughout the backend development, security measures such as input validation, SQL injection prevention, and session management have been prioritized to ensure the system's integrity and reliability.

Email Implementation

In the Vaccine Management System, we implemented email functionality using the PHP Mailer library, chosen for its robust and versatile features. PHP Mailer allows us to send emails securely through the SMTP protocol. Key attributes used in our implementation include setting the SMTP host to a reliable email server, enabling SMTP authentication, and providing the necessary username and password for secure access. We also ensured the use of encryption by configuring TLS for secure data transmission and specified the appropriate port for communication. This setup allows us to send emails, including HTML content and attachments, to provide users with important updates such as vaccine status and vaccination certificates.

PDF Implementation

In the Vaccine Management System, we implemented PDF generation using the TCPDF library to create vaccination certificates. TCPDF provides a comprehensive set of features for generating and formatting PDF documents. Key attributes and methods used in our implementation include setting the document properties, such as font styles and sizes, adding images (such as the hospital logo), and formatting text to display vaccination details. We utilized TCPDF's methods to create cells and position elements precisely within the document. The generated PDF can then be stored in the database or sent as an email attachment, ensuring that users receive a professionally formatted vaccination certificate upon successful vaccination.

Module 1 - ADMIN

This module provides a provision for the admin or the person who is involved in creating a robust platform to manage inventory, distribution, and tracking. Key features should include user authentication, real-time inventory updates, order processing, and reporting functionalities to ensure efficient vaccine distribution to pediatric facilities.

Module 2: Parent

The Parent module is designed to facilitate parents in booking vaccinations for their children. First, parents need to register on the website to book vaccines. Once registered, they can browse and book vaccines from different hospitals. Parents have the option to provide an email address to receive updates about their bookings. After a successful vaccination, parents will receive a certificate from the website containing all relevant vaccination details, ensuring they have official documentation of the vaccination.

Module 3: Hospital

The Hospital module is designed to provide hospitals with the tools necessary to efficiently manage their vaccination services. First, hospitals must request and obtain permission from the admin to access the website. Once granted, hospitals can add vaccine stocks, set prices, and manage vaccine information. They have access to a list of parents who have ordered vaccinations and can update the vaccination status to indicate whether a child has been vaccinated or not. This ensures a streamlined process for managing vaccination services and keeping accurate records.

IV. OUTCOME OF PROJECT WORK

The Vaccine Management System project successfully achieved its goal of providing a comprehensive platform for managing vaccine distribution and administration. The system enables seamless interaction between parents, hospitals,

and administrators through a user-friendly interface and robust backend functionality. Key features such as user authentication, vaccine booking, hospital management, and detailed reporting have been effectively implemented. The system's secure and efficient architecture ensures data integrity and privacy, while real-time updates and notifications keep all stakeholders informed. The implementation of responsive design principles ensures accessibility across various devices, enhancing the overall user experience.

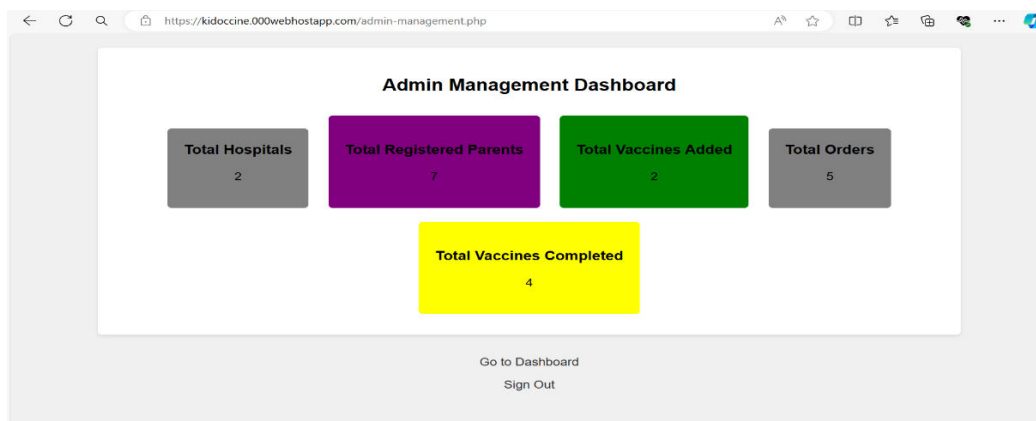


Figure 4: Overall Analysis and Statistics of Vaccine System

The PDF implementation, using the TCPDF library, proved to be highly effective in generating vaccination certificates. This feature allows parents to receive a professionally formatted PDF certificate containing essential vaccination details such as parent and child names, vaccine information, and vaccination date. The generated PDFs are clear, accurate, and easy to download, providing parents with tangible proof of vaccination that can be used for various purposes.



Figure 5: PDF Implementation

This implementation not only adds a valuable service for users but also enhances the credibility and reliability of the Vaccine Management System.

V.CONCLUSION AND FUTURE WORK

In conclusion, the Vaccine Management System was successfully implemented, providing a robust platform for managing the vaccination process for pediatric facilities. The system includes user roles for parents, hospitals, and administrators, each with specific functionalities such as booking vaccines, managing inventory, and handling requests. Technologies like HTML, CSS, PHP, JavaScript, and MySQL were utilized to create an efficient, user-friendly interface and a reliable backend system. Key features such as email notifications via PHPMailer and PDF certificate generation were integrated to enhance user experience and operational efficiency.

For future work, the system can be enhanced by incorporating additional features such as real-time analytics for better tracking of vaccine distribution and usage. Integration with national health databases can provide more comprehensive data management and reporting capabilities. Additionally, mobile app development can be explored to provide greater accessibility and convenience for users. These enhancements will further strengthen the system's ability to manage and streamline the vaccination process effectively.

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