Title Page

* The Design and Optimization of a Scalable National Product Information Management System for the NHS
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* 3rd May 2024.

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Abstract

* Concise summary of the thesis objectives, methods, findings, and conclusions.

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Special recognition goes to Afrobeat music for keeping me awake throughout the process of writing this thesis.

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# Chapter 1

# Introduction

## 1.1 Introduction to research

This chapter contains an introduction to the area of focus of this thesis project. It focuses on the main research problem, the motivation for embarking on this research,, research aims and objectives, and the research questions that guide this study. The final section of this chapter presents the overall organizational structure of the thesis.

## 1.2 Overview of the research problem

In modern day healthcare systems, efficient and standardized procurement processes are necessary in ensuring availability of medical supplies, medicines, devices, and equipment essential for the delivery of high-quality care (Steer-Stephenson, 2022). It is important to accurately manage healthcare product data because these products have a direct impact on patient health and safety. It is critical to enable the supply chain to deliver the right products to the right place at the right time (Department of Health & Social Care, 2023).

The primary healthcare provider in the United Kingdom, the National Health Service (NHS), serving millions of patients across the UK, is plagued with challenges in effectively managing the product information sharing process between its suppliers and its vast network of trusts, hospitals, clinics, and healthcare facilities. Due to the absence of a unified and scalable system, product information management within the NHS is characterized by lack of standardization, inconsistency, inefficiency, and fragmentation, with disparate infrastructure and processes essentially leading to difficulties accessing accurate and up-to-date product information (Procurement, Investment & Commercial Division (PICD), 2014). This leads to delays in procurement, disruptions in the supply chain, and poor decision-making, ultimately affecting patient care and outcomes. Hence, it is imperative to address these pressing challenges and improve the management of product information and data sharing within the NHS’ procurement ecosystem.

## 1.3 Background of the research problem

Prior to the set-up of the new NHS Supply Chain in 2019, NHS procurement activities were done through a fully outsourced operating model also called NHS Supply Chain. The new NHS Supply Chain was set up following the Lord Carter report which cited wide variations in products and supplier data across NHS trusts (Carter, 2016). There are several ways for NHS trusts to buy its products as expressed by (Davies, 2024) in Figure 1 below.

Figure 1: How Trusts can buy products

Under the new operating model, NHS trusts may buy medical products through the NHS Supply Chain, or directly from suppliers. Although nearly all trusts buy at least some specialized high-value products through the NHS Supply Chain.

The use of master data across the supply chain is necessary for effective supply chain management, especially in long and complex supply chains such as the NHS’. In addition to accurate analysis of expenditure, hospital catalogue management, and requisition exchange, the use of master product data is critical for patient care management in terms of decision making, and product traceability (Procurement, Investment & Commercial Division (PICD), 2014).

Unfortunately, the use of master product data is very limited within the NHS, from manufacturer to patient. Suppliers of products and medical supplies to the NHS respond to multiple requests for master product data by several NHS providers who use their supplied products as shown in Figure 2 below (Commercial Division, DHSC, 2017). This means that the same medical items are described and coded differently by NHS providers and suppliers (Procurement, Investment & Commercial Division (PICD), 2014).

Historically, product information management within trusts has been plagued with several issues. These issues are outlined in a report by (Department of Health &Social Care, 2018):

1. Out-of-date pricing.
2. Manual data entry at trust level.
3. Product descriptions being designed by trusts and not recognized by suppliers.
4. Instances of incorrect data including product codes.
5. Product data being held in various systems within a given trust, thus creating several versions of the ‘truth’.



Figure 2: Typical product data management process in the NHS.

*Source: Department of Health & Social Care*

This inefficient product data management and exchange across the NHS results in duplication of efforts, increased costs, delays, and compromised data quality (Commercial Division, DHSC, 2017).

Furthermore, in a study done by (Boulding & Hinrichs-Krapels, 2021), some major challenges affecting the procurement decision-making process include:

1. Variations in procurement processes and systems within and across NHS trusts. In fact, certain trusts still have paper-based system of generating orders for medical supplies.
2. Inefficient IT procurement systems: the stakeholders involved in procurement of supplies for the NHS trusts cited that the systems have major shortcomings which affect their decision making. The systems have poor search capabilities, they are bad at providing images of products, and they contain obsolete products which have yet to be taken off the system, causing more challenges for procurement decision-making. According to subjects of the study, the systems can be greatly improved by providing images of products, improving its search functionality, optimization of product lifecycle information etc.

Introduction of a new system is desperately needed in the NHS, and it is necessary to involve the end users of that technology in its development process. Stakeholder involvement is key to the successful development and implementation of any technology within the NHS (Ahmad, et al., 2012).

## 1.4 Problem Statement

The NHS is faced with challenges in managing medical product information within its procurement processes. These challenges include but are not limited to, a glaring inefficient data sharing process between manufacturers/suppliers and NHS trusts, a lack of standardized data formats and identifiers, disparate information scattered across repositories in different departments and healthcare trusts, manual processes for accessing and updating product information. Consequently, healthcare practitioners face difficulties in finding the right products at the right time, causing delays in care and inefficient resource allocation.

The absence of a centralized and scalable system for managing product information poses an obstruction to interoperability and efficient exchange of data with external stakeholders e.g. suppliers, regulatory bodies, patients, and other healthcare organizations. This lack of integration and interoperability brings to fore, the challenges the NHS faces in maintaining accurate and reliable product information throughout its procurement lifecycle.

## 1.5 Motivation for research

This research is primarily motivated by the pressing need to address the challenges the NHS faces in product information management within its procurement process and inventory management system. Efficient management of the procurement process is essential for an effective and functioning healthcare system. For a healthcare system such as the NHS, where resources are stretched thin, optimizing the procurement system is essential for ensuring access to products, medical supplies, and equipment.

The implementation of a scalable national product information management system will enhance procurement efficiency, ensure patient safety, and care quality, meet regulatory requirements, foster collaboration, and drive innovation within the UK’s health system.

## 1.6 Aims and Objectives of research.

### 1.6.1 Research Aims

The primary aim of this research is:

1. To design and optimize a scalable national product information management system for the NHS.

### 1.6.2 Research Objectives

In order to achieve the project’s aim, the following objectives were set:

1. To analyse the existing product information management practices within the National Health Service (NHS) procurement ecosystem, identifying key challenges and assessing the needs and requirements of stakeholders.
2. To design the conceptual, logical, and physical database frameworks for a scalable national product information management (PIM) system tailored to the needs and requirements of the NHS.
3. To develop a prototype of the proposed PIM system, leveraging advanced relational database management technologies and methodologies to ensure scalability, optimization, and usability in a real-world NHS setting.
4. To evaluate the effectiveness and impact of the PIM system in improving procurement processes, supply chain management, and patient care outcomes within the NHS through testing and user feedback.
5. To provide recommendations and guidelines for the implementation and adoption of the national product information management system within the NHS.

## 1.7 Research Questions

This research will be guided by the following questions:

1. What are the key challenges faced by the NHS in managing product information within its procurement processes?
   * + ANS- data fragmentation, disparate systems, inconsistent data
2. How can the implementation of a national product information management system improve procurement efficiency within the NHS?
   * + ANS- improved uniformity informs correct decision making and hence improve patient care outcomes. also, reduction of manual interphases and workload leads to more accuracy and efficiency.
3. What are the essential features and functionalities required in a scalable product information management system tailored to the needs of the NHS?

## 1.8 Significance of the study.

The significance of a study on the design and optimization of a scalable national product information management (PIM) system for the NHS cannot be overemphasized. By streamlining procurement and hospital catalogue management systems through the implementation of a national PIM system, the NHS can increase its efficiency, minimize administrative burdens, and improve the overall procurement process. A centralized and up-to-date product information management system will provide healthcare practitioners with reliable information about medical devices and products thereby minimizing the risk of errors, and further ensuring patient safety.

Furthermore, a scalable national product information system has the potential to ensure optimization of the supply chain by enhancing interoperability and collaboration between healthcare providers, suppliers, and other stakeholders critical to ensuring the delivery of service within the NHS. A seamless data exchange and real-time access to accurate product information will foster transparency and accountability across the procurement ecosystem.

Additionally, embracing the implementation of innovative technologies and digital solutions such as a product information management system can help the NHS leverage opportunities in advanced analytics, artificial intelligence, and automation to optimize the procurement process, identify cost saving opportunities, and position itself at the forefront of healthcare innovation.

Overall, this study has the potential to revolutionize the healthcare procurement and information management process, improve patient outcomes, and advance healthcare delivery not just within the NHS but globally.

## 1.9 Structure of the Thesis

This section explains the organizational structure of this thesis. This thesis is organized into 7 chapters, each one serving a specific purpose to providing an overall understanding of the work. Chapter 1 introduces the study. It serves as a foundational framework for the study, by providing context, outlining the background, the research problem, aims & objectives, significance of study and structure.

Chapter 2 presents a comprehensive review of relevant literature to healthcare procurement, and product information management. It discusses key concepts, methodologies, and findings in this field, highlighting existing gaps in the literature which this research seeks to address.

Chapter 3 precents a thorough assessment of the needs and requirements for the design of a product information management system for the NHS. It employs the mixed-methods approach to collecting data from primary and secondary sources on the information needs of the relevant stakeholders within the NHS procurement ecosystem.

Chapter 4 discusses the design and modelling of a conceptual framework for the proposed product information management system, including the discussion of relevant entities, database the normalization process, optimization strategies employed, and design of the user interface.

Chapter 5 focuses on the implementation and development of the system. It discusses the implementation of the database system, the user interface, and the integration with external systems. It also discusses the process of testing and quality assessment.

Chapter 6 discusses the evaluation of the developed product information management system. Specifically, it discusses the evaluation criteria employed, and the evaluation of the system in comparison with set objectives.

In conclusion, chapter 7 discusses the result of the research, draws conclusion based on the results, and presents recommendations for future research.

# Chapter 2

# Literature Review

## 2.1 Introduction to literature review

In today’s dynamic healthcare landscape, efficient information management systems and procurement practices are essential for ensuring access to medical products, optimizing resource allocation, and improving care outcomes. Though there is limited literature in recent times on the design and implementation of a product information management system especially for a healthcare organization such as the NHS, this literature review aims to explore existing literature on the design, optimization and application of scalable product information management systems, catalogue management and data sharing practices within the NHS, including challenges faced in this area. This chapter aims to inform the research objectives of this study by providing a thorough understanding of the current state of knowledge by synthesizing key concepts, methodologies, and findings from relevant sources.

## 2.2 Product Information Management

### 2.2.1 What is Product information?

Product Information is any information about a product which a client or customer uses to make an informed decision about purchasing a product. (Palmer, 2024)

### 2.2.2 Product Information management

The concept of Product Information Management (PIM) began relatively circa 2003 (Abraham, 2014). Product information management is sometimes referred to as Product Data Management (Vedapudi, 2000).

So, what is Product Information Management (PIM)? To put it simply, PIM is the management of Product information. To further expatiate on this definition, PIM may be defined as the processes and technologies set up to manage product information in one shared place – “a single source of truth”, to further distribute that information into different systems without having to manually re-enter it. (Abraham, 2014).

<http://ndl.ethernet.edu.et/bitstream/123456789/55870/1/44%202014.pdf> ABRAHAM 2014

There are 3 sequential phases for the centralization of product information management (Battistello, 2020):

Figure 3:Framework for centralization of Product Information

In the As-Is Analysis in the next section, the progress of the NHS towards the centralization of product information management will be analyzed against these phases.

## 2.3 Centralization of Product Information Management in the NHS (An As-Is Analysis)

The As-Is Analysis phase of the PIM system scoping framework aims to provide an understanding and assessment of the processes and systems currently in place in the organization looking to implement a PIM system (Battistello, 2020). As the author (Battistello, 2020) proposed, the NHS has begun the sequential phases for the centralization of product information management.

1. **Phase 1**: **Simplification and implementation of product description standards**

Upon recognizing the need for, and benefits of improving its systems to improve data quality and data-sharing processes, the NHS launched the *NHS eProcurement Strategy,* to guide the adoption of GS1 standards as the supply chain coding standard by the NHS and its supplier base (Department of Health, 2013). GS1 standards are global coding standards used for the unique identification of products and locations, to enable data synchronisation and end-to-end traceability from manufacturer to patient.

The NHS recognized the adoption of GS1 coding standards by NHS providers and suppliers as the building block for improving data quality and enable interoperability between NHS provider and supplier systems (Procurement, Investment & Commercial Division (PICD), 2014).

The NHS mandated both NHS providers and suppliers to adopt GS1 standards, including a requirement to place master product data in a GS1-certified data pool, through conditions of contract such as:

1. the NHS Terms and Conditions for the Supply of Goods and the Provision of Services
2. the 2014/2015 NHS Standard Contract between healthcare commissioners and NHS providers

This adoption plan was mandated to encompass all goods supplied to the NHS providers, except for medicines which already had an established management system in place.

1. **Phase 2**: **Preparation of the organization for transformation process**

The preparation phase involves the organization preparing for the transformation process by establishing an understanding of the benefits of the project. The NHS embarked on a *Demonstration of Technology (DoT)* project to show how the adoption of GS1 can solve the problems of the NHS (Commercial Division, DHSC, 2017). The main purpose of the DoT was to understand the impact of adopting GS1 standards on the interoperability between NHS trusts systems and supplier systems, data quality assurance, process, and scalability from the DoT to an NHS-wide implementation.

1. **Phase 3**: **Implementation of PIM system**

A diagram of information on a green background

Description automatically generated

in NHS section; talk about the progress of NHS in these stages and identify the gap.

* 1. simplification- GS1 data pools
* 2. preparation – maybe that testing site thing
* 3. implementation: MY WORK
* <https://www.gs1uk.org/sites/default/files/MDE_Demonstration_of_Technology_Case_Study.pdf> master data exchange demonstration of technology - PREPARATION
  + - * <https://scan4safety.nhs.uk/wp-content/uploads/2022/11/Scan4Safety_Product__How_To_Guide-1.pdf>
        + scan4safety/ catalogue mgt/product information
      * <https://scan4safety.nhs.uk/how-to-get-started/first-steps-for-suppliers/>
      * supplier how to get started
    - Challenges in NHS Procurement
      * <https://assets.publishing.service.gov.uk/media/5a7c267840f0b61a825d6c48/procurement_development_programme_for_NHS.pdf> 2013
        + There is very little consistency across NHS Procurement. NHS organisations currently deploy a wide range of procurement processes, methodologies, techniques, tools and templates to identify, procure and manage many similar requirements across identical spend categories. Not surprisingly, suppliers to the NHS encounter a broad range of differing documents and approaches when bidding for (often) similar requirements
        + The production, publication and sharing of procurement best practice and related case studies across the NHS is negligible. It is almost impossible to identify publications of relevant best practice
        + NHS Procurement development programme/ similar to e-procurement strategy :The programme will contain four integrated initiatives: 1. Delivering immediate efficiency and productivity gains 2. Improve data, information and transparency including the adoption of GS1 coding standards (contains valuable information on GS1 etc.)
      * <https://www.gs1uk.org/sites/default/files/GS1_UK_Healthcare_Terms_2024.pdf>

## 2.4 Product Information Management (PIM) System

A Product Information Management (PIM) System is an information system used to centrally store, enrich, manage, and distribute product information across several different units of an organization, thus alleviating the need to manually re-enter the data in a different system. (Battistello, et al., 2021). Product Information management systems are necessary for the unification and synchronization of disparate product information.

[The digitalization journey of PIM](https://backend.orbit.dtu.dk/ws/files/254676406/Thesis_Loris_Battistello.pdf) (Battistello, 2020)

### 2.4.1 Benefits of a PIMS

A Product Information Management (PIM) System offers several benefits across various industries. The following are some of the benefits of a PIM system as identified by the authors (Abraham, 2014; Battistello, 2020):

1. Centralized Data Management: a PIM system provides a centralized repository for storing, organizing, and managing product information. This ensures data consistency and accuracy by eliminating errors, duplicates, and/or redundancy.
2. Data Quality Improvement: a PIM system ensures the maintenance of a high data quality, by enforcing standardized data formats and data validation rules. Good quality data ensures reliability and compliance with regulatory requirements.
3. Enhanced Operational Efficiency: a PIM system helps to streamline product information management processes by removing manual workloads, minimizing errors, and improving data accuracy.
4. Increased Productivity: implementing role-based access controls and workflow management capabilities in PIM systems lead to improved productivity and faster decision-making.
5. Legal & Regulatory Compliance: a PIM system helps to ensure compliance with regulations on data privacy protections, standardization, and other data security measures.
6. Scalability: PIM systems offer the ability for organizations to expand product catalogs and support large volumes of product data.

### 2.4.2 Product Information Management (PIM) vs similar Information Systems

A Product Information Management (PIM) system is comparable to several other information systems that manage product data (Battistello, 2020). These systems include Product Data Management (PDM), Product Lifecycle Management (PLM) and Master Data Management (MDM).

Product Lifecycle Management (PLM) and Product Data Management (PDM) systems are internal-facing systems which focus on the manufacturing and developmental lifecycle of a product from ideation till after the product is no longer being sold (for example, product not yet on the market, product discontinued etc.). (Abraham, 2014)

Master Data Management is the comprehensive management and maintenance of master data within an organization. A Master Data Management (MDM) system focuses on providing solutions to problems of data fragmentation, incoherent processes, and disparate systems (Nurminen, 2022).

Master data is the definitive single source of truth for all information which an organization holds about its core entities such as its products, employees, suppliers, accounts etc. (Nurminen, 2022). Master data serves as the foundational data which may be shared and reused by different information systems and business process applications in an organization as a source for accurate reporting, and for reduction of errors and redundancy (Edel & Sutedja, 2023; Pansara, 2021). This is further supported by (Nurminen, 2022) who posited that Master data must be accurate, relevant (data attribute selection), timely (synchronization), complete, and accessible.

Master Data Management (MDM) may be said to be the first step in a Product Information Management (PIM) process (Abraham, 2014). Product Information Management (PIM) is a subset of Master Data Management that deals with product-related information for sales and marketing purposes (Battistello, 2020). In essence, a Master Data Management process must first be implemented to be able to implement a outward-facing Product Information Management system.

<https://www.utupub.fi/bitstream/handle/10024/153916/Nurminen_Arttu_opinnayte.pdf?sequence=1> NURMINEN, 2022

Both PIM and MDM systems, to some extent, aim to solve the same product data management challenges. However, where a Product Information Management system focuses on the outward view of Product information for sales & marketing activity, a PMDM focuses on the management of product data and leveraging it to improve business process and decisions that are dependent on product data (Sheldon & Goetz, 2014)

Research Gap 1: Lack of distinguishment between Product Information Management Needs and Product Master Data Management Needs within the NHS.

Product Master Data Management challenges (Pansara, 2021) :

* master model agility: (to ensure model agility, organization should establish a profound data model, define organizational rules, define data validation controls, and outline responsibilities and security measures).
* data governance: what is data gov? bad data gov leads to inconsistencies in the master data management system. (eProcurement strategy and guideline for GS1 for PEPPOL)
* data standards: data integrity and gov depend on data standards (Pansara, 2021) process for data standardization should happen in advance. (GS1 data pools)
* data integration: integrating other data application systems with MDM reveals cumbersomeness. some departments (read suppliers) are more substandard than others hence might transfer data differently. a fundamental approach will be to define data integration policies and ensure the management of the integration process with external and internal applications (GDSN)

REMOVE EVENTUALLY

## 2.5 Information Management System Development Life Cycle

The lifecycle of an information or database system includes all the steps necessary for the design and implementation of the system. According to (Langer, 2008) , system developments projects must include the following steps, regardless of which design methodology is used:

1. Identifying the need for a business process improvement/support system e.g. a Product Information management system
2. Defining the goals for that system
3. Gathering the business requirements
4. Converting the business requirements to system requirements
5. Designing the system
6. Building, testing, and deploying the system.

INSERT SOFTWARE DEVELOPMENT LIFECYCLE DIAGRAM

These outlined steps will serve as a guide for the execution of this research project in achieving its outlined research objectives.

## 2.6 Tools and Technologies used in design of Information Management Systems

### 2.6.1 Database Management Systems

A database management system is a software which manages and controls access to a collection of logically related data called a database, designed to meet the information needs of an organization. (Connolly & Begg, 2015). A database is said to resemble a well-organized electronic filing cabinet whose content is managed by a powerful software known as the database management system (Coronel & Morris, 2016)

* Advantages and Disadvantages of Database Management Systems

The advantages and disadvantages of a database management system are listed in the tables below:

Table 2: Advantages of a DBMS

|  |
| --- |
| ADVANTAGES |
| * 1. Improved data sharing |
| * 1. Improved data security |
| * 1. Minimized data inconsistency. |
| * 1. Improved data integration |
| * 1. Improved data access |
| * 1. Improved decision making |
| * 1. Increased productivity |

Table 3: Disadvantages of a DBMS

|  |
| --- |
| DISADVANTAGES |
| 1. Complexity of DBMS software |
| 1. Size |
| 1. Cost of DBMSs |
| 1. Additional hardware costs |
| 1. Cost of conversion |
| 1. Performance |
| 1. Greater impact of a failure |

### 2.6.2 Types of DBMS

### 2.6.3 How a DBMS works/structure of DBMS

### 2.6.4 Database Language (DDL, DML): SQL

### 2.6.5 DBMS environment

### 2.6.6 Types of DBMS

### 2.6.7 Software selection

* + The choice between SQL and NoSQL depends on the needs of the organization and the type of data being managed. Organizations with a need for structured and consistent data will find SQL databases more preferrable while organizations with large amounts of unstructured data will prefer NoSQL (Dhasmana, et al., 2023)
  + The product information needs of the NHS are structured, relational data, most of which are stored on spreadsheets across NHS Trusts and hospitals. Hence, a relational database system (SQL) would be best utilized.
* <http://www.cherrycreekeducation.com/bbk/b/Cengage_Learning_Database_Systems_12th_Edition_1305627482.pdf> DATABASE SYSTEMS Design, Implementation, and Management

## 2.7 Scalability in Relational Database Systems

* Scalability is the ability of a system to handle growing amounts of work or changing demands (Wikipedia, 2023). In essence, it is the ability of a system to grow to accommodate larger volumes of data and users.
* SQL db (scale vertically), NoSQL (Scale horizontally) (Dhasmana, et al., 2023)
* prerequisites for scalability
* Data storage should be sufficiently large to store and process all the incoming data.
* Data writing, searching, and retrieval for a single patient’s data have to be very fast and independent of the number of patients in the system.
* Data will be written once and read several times. In fact, most of the data that is stored will never be modified or deleted; hence we can exploit this property of this data.
* how to implement scalable DBMS?
  + - Replication: ensures scalability and stability by making sure application continues to be accessible in the case of server failure. you can replicate data across many servers (Šušter & Ranisavljević, 2023)

## 2.8 Optimization strategies for relational database systems

Explain what optimization is in the context of databases and information systems.

* + Physical programming (partitioning, indexing, data compression and data clustering) page 144 (Šušter & Ranisavljević, 2023)
    - * data types e.g use TINYINT instead of INT or BIGINT
      * storage engines
      * index design
    - field optimization-based method (Gyórödi, et al., 2021)
    - [Indexing strategies for performance optimization of rel db](https://d1wqtxts1xzle7.cloudfront.net/70501062/IRJET_V8I5695-libre.pdf?1632898460=&response-content-disposition=inline%3B+filename%3DIRJET_Indexing_Strategies_for_Performanc.pdf&Expires=1711464845&Signature=hDjSUKe2spXkGbV12Dppp9ipa7RkgtsWZnoCzrHj7m7zwgD8h0sFumeEUFgqH1F4nRNDhfQ52NAfSvFv6qKDJvCci8SkVOnIqKmuKs3svy8BRYljkycVX~4y0AA8b-WdTwRFiOLmmbAGxh30lLNpHzQ41U3Ju1uhKFsHbsrbciuF33EgRzHGQIGBIW8gp6yn8MXoaoMI8kwhIC3o3~3YEHdcXapq2LUpBSYn5udQa2R~yamfdA8v3~KzfnSXKoUoo1l3GD0LmCughdXvAcUUdcT4YOjbz9rvoMKZomnEnZUSw7OixEq2XSmDSgE~E8bsSrTaMd~l0O-OiyXvycgBBQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA) (Praveena & Chikkamannur, 2021)
    - Indexing results in a higher performance and energy efficiency. (Mahajan, et al., 2019)
  + Data Tuning (also known as performance optimization) to locate and get rid of bottle necks. page 146 (Šušter & Ranisavljević, 2023)
    - Query optimization is a critical part of data tuning, for ensuring that SQL queries perform better.
      * improving joins, indexing frequently queried columns (suster and ranislav). (Maesaroh, et al., 2022)
      * avoid using select \*, callout the column names (Mahajan, et al., 2019)
      * use EXISTS instead of IN
    - server configuration, size of buffer pool be changed to optimize memory utilization and boost query performance. max\_connections parameter increase to manage high number of concurrent users (suster and ranislav)
    - normalization: reduction of data redundancy and duplication can enhance query performance and lower storage costs. (find reference on normalization)
    - Caching and replication: caching saves frequently accessed data in memory for easy retrieval.

## 2.9 Case studies and best practices – application of PIM in healthcare, and in other industries

1. Evaluating Database Management Systems: A Framework And Application To The Veteran's Administration Hospital <https://dspace.mit.edu/bitstream/handle/1721.1/61034/06564848-MIT.pdf;sequence=2>
2. Database Management System for Student Admissions <https://soar.suny.edu/bitstream/handle/20.500.12648/10380/Savelios%20Aslanidis%20-%20Thesis%20Project_DBMS%20for%20Student%20Admissions.pdf?sequence=1&isAllowed=y>
3. DESIGN AND IMPLEMENTATION OF SPECIAL EDUCATION APPS INFORMATION MANAGEMENT SYSTEM

<https://etd.ohiolink.edu/acprod/odb_etd/ws/send_file/send?accession=kent1492704386514278&disposition=inline>

1. An information management system for a large-scale biological collaboration

<https://trace.tennessee.edu/cgi/viewcontent.cgi?article=6723&context=utk_gradthes>

1. Web-based forensic information management system

<https://researchrepository.wvu.edu/cgi/viewcontent.cgi?article=3386&context=etd>

1. Development of a Database-Driven Management System for Retail Food Packaging Eye Tracking Studies

<https://tigerprints.clemson.edu/all_dissertations/2171/>

1. design and dev elopement of web based biomed dbms for health services multispecialty

<https://web.archive.org/web/20210428045611id_/https://jusst.org/wp-content/uploads/2020/12/Design-and-Development.pdf>

1. Evaluation Of Performance of NoSQL Database Management System: -MongoDB And Relational Database Management System: - PostgreSQL for Efficient Management Of Healthcare Data

<http://sifisheriessciences.com/journal/index.php/journal/article/view/2331>

1. DESIGN AND IMPLEMENTATION OF A WEB-BASED HEALTH CARE RECORDS MANAGEMENT SYSTEM

<http://ir.mtu.edu.ng/xmlui/bitstream/handle/123456789/178/OIBO%20JOY%20OPEYEMI%20-%20FULL%20PROJECT.pdf?sequence=1&isAllowed=y>

1. Database System for Medical Record Keeping and Retrieval

<http://jae-tech.com/index.php/jaet/article/view/101/86>

1. Implementation of product data management system

<https://oulurepo.oulu.fi/bitstream/handle/10024/15456/nbnfioulu-202009162929.pdf?sequence=1&isAllowed=y>

1. EVALUATION OF DATABASE MANAGEMENT SYSTEMS – PostgreSQL better than MySQL & SQlite in terms of speed and info retrieval

<https://hh.diva-portal.org/smash/get/diva2:367006/FULLTEXT01.pdf>

1. Design and Implementation of a Web Shop System

<https://www.theseus.fi/bitstream/handle/10024/22377/Shen_Yeyin.pdf?sequence=1&isAllowed=y>

# Analysis and Design of Information Systems

By Arthur M. Langer

<https://books.google.co.uk/books?hl=en&lr=&id=fHZBQZkp-TYC&oi=fnd&pg=PR2&dq=design+of+information+management+system&ots=zszXu4RAdr&sig=lOBhWdu0FQwBFPce-mknLWjkivw&redir_esc=y#v=onepage&q=design%20of%20information%20management%20system&f=false>

## 2.10 Summary of key findings and gaps in the literature.

INSERT TABLE OF RELEVANT PAPERS AND THEIR CONTRIBUTION. IDENTIFY GAP in literature

empirical review

* domain
* database management system/database infrastructure
* optimization techniques
* user interface

|  |  |  |  |
| --- | --- | --- | --- |
| Author(s) | Methodology | Finding(s) | Gap |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

There is a dearth of literature on the design of product information management systems especially in the UK healthcare space, hence the need for this project to fill that gap.

* that textbook chapter 11
* Battistello page 60

Chapter 3

Needs Assessment and Requirements Analysis

### 3.1 Introduction to Needs Assessment

This chapter covers the needs assessment and requirements analysis section of this project. This is a foundational step in the system development lifecycle of a national Product Information Management (PIM) system for the NHS.

This phase is necessary in order to capture all the business needs in relation to the proposed PIM system (Langer, 2008).

### 3.2 Summary of National Product Information Management (PIM) System Goals

The problem which the PIM system aims to solve is the inefficient data sharing process and inconsistent product information management between suppliers of those products and NHS trusts. This system aims to improve accessibility and quality of medical product data distributed across the UK healthcare system.

*Users of the system must be able to use the system to view product data, search for product information, apply appropriate filters, and export product information from the system.*

This national PIM system will act as a shared reference point for exchanging information about medical products for NHS stakeholders. It will make data sharing more efficient, and the use of accurate, consistent data is going to improve the decision-making process, thus improving patient care outcomes.

### 3.3 Identification of Stakeholders

Stakeholder identification is the first step in the Requirements analysis phase. Identifying the key stakeholders whose interests must be considered in the design and implementation of this national PIM system is crucial.

To have a clear overview, a classification of the stakeholders may be done; for example, stakeholders can be divided in core stakeholders and secondary stakeholders. In a multinational company, the stakeholders can be classified by divisions, departments, and markets. Once the classes of the stakeholders are identified, the representatives for each class need to be defined.

### 3.4 Assessment of the current state (As-Is Analysis).

1. Organizational business introduction: understand how product information was managed across the organization and identify the main digital and physical touchpoints of product information.
2. Identification of stakeholders’ requirements
3. Data localization and ownership: current IT architecture in product infor process. how product data is stored and managed and who owns them
4. Product model identification: identification/collection of existing product classifications and product models in different divisions of the company

* GDSN, suppliers and NHS datapools

Evaluation of existing processes, technologies, and systems within NHS

* + - Currently, the approach for sharing information about medical products in the health system is inefficient and leads to poor quality data. NHS Trusts often collect this information individually at a local level and MedTech manufacturers have to respond to multiple requests for the same information. It is dispersed throughout the system. This information is often shared manually (e.g. emailing Excel files) which means it can easily become wrong, out-of-date, or inconsistent with other sources. This means that there is no standardised way of referring to a product or the category it belongs in as different users in the health system often refer to the same products in different ways. Overall, it is a burden for the health system to provide, manage, and use medical product information. The inaccurate and incomplete data collected poses a risk to patient safety and effective procurement and administrative processes There is a risk that manufacturers will not correct or verify the quality of their data which would restrict the usefulness of the proposed solution as trusts would have limited reason to trust and use the data.

### 3.3 Stakeholders’ Needs Assessment

This section provides a comprehensive overview of major stakeholders and their interests in relation to this PIM system.

1. Stakeholder: Suppliers/Manufacturers

* Information Need(s): Suppliers and manufacturers of medical devices and products in the UK need to share information about their product with the NHS for the trusts to have accurate, consistent information about them. The product information provided by suppliers is used as the basis of the Product master data management system within the NHS. This data forms the basis of the PIM system.

1. Stakeholder: Data Systems Leads

* Information Need(s): Data systems leads in NHS trusts needs to have accurate product information so that this information may be used in other systems within the trust e.g. financial records, electronic health records etc.

1. Stakeholder: Procurement Leads

* Information Need(s): Procurement Leads in NHS trusts need to have adequate, accurate information about medical products or devices in order to fully understand the characteristics of different products and be able to make the right decision on which products to buy, and/or alternatives.

1. Stakeholder: Patient Safety Leads

* Information Need(s): Patient Safety leads in NHS trusts are responsible for ensuring products and devices being used in patients’ care are safe. They need to have accurate and up-to-date information about products to facilitate product traceability in case of recalls, and to meet other national safety initiatives like the Scan4Safety.

1. Stakeholder: Data Analysts

* Information Need(s): Data analysts in core sectors of the UK Health System like the NHS England, the Medicines and Healthcare products Regulatory Agency (MHRA), and the Department of Health & Social Care (DHSC), need to have information about products being used in patient care for easy export and joining with product information with other datasets, to analyse the market and understand patient safety trends.

1. Stakeholder: Patients

* Information Need(s): Patients need to have information about products or devices being used on them in order to ensure their confidence in the safety of the products.
  + - Evaluation of the compatibility and interoperability of current systems with the proposed national PIM system
    - Identification of inefficiencies, gaps, and opportunities for improvement
* <https://scan4safety.nhs.uk/wp-content/uploads/2022/11/gs1_uk_inventory_management_systems_guidance-1.pdf> inventory management system implementation guidance scan4safety

TALK ABOUT THE DISCOVERY PHASE

### 3.5 To-Be Analysis

talk about the 3 Phases simplification > Preparation > Implementation

Classification standards

Classification standards suppor

* ﻿﻿procurement intelligence, by enabling similar items to be grouped together for spend analysis and demand aggregation;
* ﻿﻿the traceability requirements of regulatory agencies.

NHS Class is the primary classification standard currently used by procurement teams in the NHS, whilst pharmacy teams use the dm+d standard for the classification of medicines. The application of NHS Class is inconsistent across the NHS and it is not resourced or maintained to the level of an international standard.

* + - Work will be undertaken at the national level to determine the most appropriate procurement classification standards for use by the NHS. The outcome of this work may be to maintain the status quo or to recommend an alternative approach. A likely outcome will be different classification standards for different categories. (eProcurement strategy)
    - Data/Attribute selection: proper master data management entails an organization identifying and understanding data that is most meaningful to the business. Quality over quantity. (Nurminen, 2022)
    - Master data vs transactional data: master does not change as often as transactrional which changes continuously. (Nurminen, 2022) (talk about not using price data since its dynamic i.e. transactional)

### 3.6 Legal and Regulatory Requirements

* + - Overview of legal and regulatory requirements relevant to PIM in healthcare
    - Analysis of compliance obligations, standards, and regulations governing data privacy, security, and interoperability.
    - Influence of legal and regulatory considerations on the design and implementation of the NHS PIM system.

### Summary of NA findings

Chapter 4: Design and Modelling

### Introduction to system design chapter 8-10

* 1. <http://www.cherrycreekeducation.com/bbk/b/Pearson_Database_Systems_A_Practical_Approach_to_Design_Implementation_and_Management_6th_Global_Edition_1292061189.pdf>
  + Overview of purpose and scope of system design phase
  + Explanation of importance of a well-designed system in meeting stakeholders’ needs and requirements.

### 4.2 Database Architecture. chapter 12

* + Description of proposed database architecture for the NHS national PIM system
  + Explanation of the database structure, including tables, fields, and relationships
  + Discussion of choice of relational Database technology and suitability for managing product information in healthcare

### 4.3 Data Modelling

* + Overview of data modelling process for the PIM system
  + Entity-Relationship model
  + Identification and definition of key entities, attributes, and relationships
  1. Normalization chapter 14-15

### 4.4 Scalability

* 1. analysis of scalability requirements
  2. discussion of scalability challenges and solutions in database design
  3. description of strategies for ensuring scalability of the database architecture

### 4.5 Introduction to Optimization Strategies

Discussion of optimization techniques employed to enhance system performance and scalability. (query optimization, Indexing, Minimizing redundant data retrieval, etc.)

### 4.6 User Interface

* 1. overview of user interface design for the NHS national PIM system
  2. description of the UI components, layout, and navigation.
  3. discussion on usability principles and best practices in interface design to enhance user experience.

### 4.7 Integration with GS1 certified data pools

* 1. Explanation of how the PIM system will integrate with GS1 certified datapools.
  2. description of data exchange protocols, standards and interfaces used for interoperability.
  3. Description of the benefits of integrating GS1 standards for product identification and synchronization

One of the purposes of deploying GS1 data standards is to improve data accuracy and consistency across multiple systems. The use of GS1 standards will also act as an enabler for Automatic Identification and Data Capture (AIDC) technology, which is used to correctly identify a product at the point of use.

### 4.8 Summary of System Design

* 1. summary of key design decisions and considerations
  2. identification of design principles and strategies aimed at meeting stakeholder needs and achieving system objectives
  3. transitioning to implementation phase, highlighting how the system design will guide the development of the system

Chapter 5: Prototyping

### 5.1 Introduction to Implementation

* + Overview of implementation phase and significance in bringing proposed PIM system to life
  + Explanation of the objectives and scope of the implementation process

### 5.2 System Development

* + Description of the development lifecycle followed for implementing the PIM system

### 5.3 Database Implementation

* + steps involved in implementing database infrastructure
  + description of the process i.e. database creation, configuration, and optimization
  + Discussion of challenges encountered during implementation

### 5.4 Integration with External Systems

* + Overview of the integration process for connecting PIM system with external systems and data sources
  + Description of standards and protocols used to facilitate interoperability
  + Discussion of integration requirements and considerations for data exchange with GS1 certified datapools and other external systems

### 5.5 User Interface development

* + Descrption of the UI development process for the PIM system
  + Overview of the design principles, UX considerations and usability testing conducted during interface development
  + Discussion on how iterative design process informed the development of the user interface
  + <https://docs.streamlit.io/knowledge-base/tutorials/databases/postgresql>
  + <https://www.datacamp.com/tutorial/streamlit>
  + <https://www.youtube.com/watch?v=ns-Pd-1F4uU>

### 5.6 Testing and QA

* + explanation of the testing methodologies to validate functionality and performance of PIM system
  + description of testing phases
  + discussion of results, bug fixes, and QA measures implemented to ensure efficiency and reliability of system

### 5.7 Summary of Implementation

* + key milestones and successes
  + Challenges encountered and solutions adopted during implementation.
  + recommendations for future system implementations

Chapter 6: Evaluation and Results

### 6.1 Introduction to Evaluation

* + overview of the evaluation phase and importance in assessing the effectiveness and performance of the developed PIM system
  + Explanation of the objectives and scope of the evaluation process

### 6.2 Evaluation Metrics and Criteria

* + description of metrics and criteria used to evaluate the PIM system
  + KPI and criteria for assessing system effectiveness, usability and impact

### 6.3 Evaluation methodology

* + Overview of evaluation methods i.e. surveys or interviews employed to collect feedback from stakeholders

### 6.4 Evaluation of System Scalability

* + analysis of the scalability of the PIM system to handle increasing volumes of data and user traffic
  + description of tests for assessing system performance
  + discussion of scalability challenges and recommendations for enhancing system scalability

### 6.5 Presentation of Results

* + presentation of data collected during evaluation process
  + SWOT analysis of the PIM system

### 6.6 Comparison with objectives and requirements

* + comparison of evaluation results with objectives and requirements defined for the PIM system
  + Assessment of the extent of the system meeting stakeholder needs, fulfill project goals and addresses identified challenges

### 6.7 Summary of findings

* + Summary of key findings, insights and conclusions from evaluation phase
  + Summary of recommendations for enhancing system performance, usability and scalability

Chapter 7: Discussion and Conclusion

### 7.1 Interpretation of the findings in relation to the research objectives.

### 7.2 Discussion of implications, limitations, and future directions.

Use of relational limits the db to only relational, structured data. future research should look into the implementation of NoSQl databases

### 7.3 Summary of key findings and contributions of the thesis.

### 7.4 Recommendations for practice, policy, or further research.

# Bibliography

Abraham, J., 2014. *Product Information Management: Theory and Practice.* Cham: Springer International Publishing.

Ahmad, R., Kyratsis, Y. & Holmes, A., 2012. When the user is not the chooser: learning from stakeholder involvement in technology adoption decisions in infection control. *The journal of Hospital Infection,* 81(3), pp. 163-168.

Šušter, I. & Ranisavljević, T., 2023. Optimization of MySQL Database. *Journal of Process Management and New Technologies,* 11(1-2), pp. 141-151.

Battistello, L., 2020. *The digitalization journey of product information management,* Lyngby: Management Science.

Battistello, L., Haug, A., Suzic, N. & Hvam, L., 2021. Implementation of product information management systems: Identifying the challenges of the scoping phase. *Computers in Industry,* 133(103533).

Boulding, H. & Hinrichs-Krapels, S., 2021. Factors influencing procurement behaviour and decision-making: an exploratory qualitative study in a UK healthcare provider. *BMC Health Services Research,* 21(1087).

Carter, P., 2016. *Operational productivity and performance in English NHS acute hospitals: Unwarranted variations.* [Online]   
Available at: https://assets.publishing.service.gov.uk/media/5a80bdfae5274a2e87dbb8f5/Operational\_productivity\_A.pdf  
[Accessed 23 March 2024].

Commercial Division, DHSC, 2017. *GS1 and PEPPOL Adoption Case Study: Master Data Exchange Demonstration of Technology.* [Online]   
Available at: https://www.gs1uk.org/sites/default/files/MDE\_Demonstration\_of\_Technology\_Case\_Study.pdf  
[Accessed 2 April 2024].

Connolly, T. & Begg, C., 2015. *Database Systems: A Practical Approach to Design, Implementation, and Management.* 6th Edition ed. Harlow(Essex): Pearson education Limited.

Coronel, C. & Morris, S., 2016. *Database Systems: Design, Implementation, and Management.* 12th Edition ed. Boston(Massachussetts): Cengage Learning.

Crown Commercial Service, 2024. *Procurement details: DHSC: Medical Technology - Product Information Management Data Platform - Alpha phase.* [Online]   
Available at: https://redirect.contractawardservice.crowncommercial.gov.uk/digital-outcomes/opportunitiesDetails?projectId=38863&lot=1  
[Accessed 2 April 2024].

Davies, G., 2024. *NHS Supply Chain and efficiencies in procurement: NHS England, NHS Supply Chain,* London: National Audit Office.

Department of Health & Social Care, 2023. *Medical Technology Strategy.* [Online]   
Available at: https://assets.publishing.service.gov.uk/media/63dbe1f68fa8f57fbfff3db3/medical-technology-strategy.pdf  
[Accessed March 2024].

Department of Health &Social Care, 2018. *A Trust's guide to Product and catalogue management.* [Online]   
Available at: https://scan4safety.nhs.uk/wp-content/uploads/2022/11/Scan4Safety\_Product\_\_How\_To\_Guide-1.pdf  
[Accessed 2 April 2024].

Dhasmana, G., Gujjar, P. J., Prasad, G. M. & Kumar, P. H., 2023. *SQL and NOSQL Databases in the Application of Business Analytics.* Bangalore, 2023 International Conference on Computer Science and Emerging Technologies (CSET), pp. 1-5.

Edel, W. & Sutedja, I., 2023. Master Data Management Analysis For Today's Company: A Literature Review System. *Journal of Theoretical and Applied Information Technology,* 30 April.101(8).

Essig, M. & Arnold, U., 2001. Electronic Procurement in Supply Chain Management: An Information Economics-Based Analysis of Electronic Markets. *The Journal of Supply Chain Management,* September, 37(4), pp. 43-49.

Gyórödi, C. A. et al., 2021. Performance Impact of Optimization Methods on MySQL Document-Based and Relational Databases. *Applied Sciences,* 11(15).

Langer, A. M., 2008. *Analysis and Design of Information Systems.* 3rd Edition ed. London: Springer Science & Business Media.

Maesaroh, S. et al., 2022. Query Optimization in MySQL Database Using Index. *International Journal of Cyber and IT Service Management (IJCITSM),* 2(2), pp. 104-110.

Mahajan, D., Blakeney, C. & Zong, Z., 2019. Improving the energy efficiency of relational and NoSQL databases via query optimizations. *Sustainable Computing: Informatics and Systems,* June, Volume 22, pp. 120-133.

Nurminen, A., 2022. *Master data management in industry,* Turku: University of Turku.

Palmer, B., 2024. *What is Product Information?.* [Online]   
Available at: https://www.plytix.com/blog/what-is-product-information  
[Accessed March 2024].

Pansara, R., 2021. Master Data Management Challenges. *International Journal of Computer Science and Mobile Computing,* October, 10(10), pp. 47-49.

Praveena, M. V. & Chikkamannur, A. A., 2021. Indexing Strategies for Performance Optimization of Relational Databases. *International Research Journal of engineering and Technology (IRJET),* 08(05).

Procurement, Investment & Commercial Division (PICD), 2014. *NHS eProcurement Strategy.* [Online]   
Available at: https://assets.publishing.service.gov.uk/media/5a7ebfa3e5274a2e8ab47f34/NHS\_eProcurement\_Strategy.pdf  
[Accessed March 2024].

Sheldon, P. & Goetz, M., 2014. *The Forrester WaveTM: Product Information Management (PIM), Q2 2014,* Cambridge, MA: Forrester Research, Inc..

Steer-Stephenson, C., 2022. *Procurement strategies in the healthcare industry.* [Online]   
Available at: https://procurementmag.com/procurement-strategy/procurement-strategies-in-the-healthcare-industry  
[Accessed 8 March 2024].

Vedapudi, M., 2000. *Requirements for a Product Information Management (PIM) Infrastructure to support partner programs,* Massachusetts: Massachusetts Institute of Technology (MIT).

Wikipedia, 2023. *Database scalability.* [Online]   
Available at: https://en.wikipedia.org/wiki/Database\_scalability  
[Accessed 2 April 2024].

Wyatt, J. C., 1995. Hospital information management: the need for clinical leadership. *The BMJ,* 15 July.311(175).

Appendices:

* Supplementary materials such as raw data, survey, or technical documentation.