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A Lean-Based Spreadsheet Information System for Improving Inventory Control in a Small Primary School

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Abstract

Ban Nong Bong School is a small primary school with limited personnel, which has resulted in non-standardized inventory management practices. Reliance on manual record-keeping and paper-based documents has caused undocumented withdrawals, duplicated requests, and equipment loss. This study aims to develop a prototype information system for recording and managing equipment withdrawals by applying systems engineering principles together with Lean management concepts, tailored to the context of a small educational institution. This research follows an applied research approach. The prototype information system was developed using spreadsheet-based software, such as Microsoft Excel or Google Sheets, with the data structure designed in a single worksheet. The system integrates withdrawal recording, item receiving, and remaining inventory calculation into one workflow. Lean techniques were applied to reduce unnecessary steps, including eliminating paper-based withdrawal forms and consolidating multiple recording processes into a single worksheet. The system was tested with 10 teachers and staff members of Ban Nong Bong School over a two-month trial period, using data from actual system usage and user satisfaction questionnaires. The results show that after implementing the prototype system, no duplicated withdrawals and no equipment loss were observed during the trial period, compared with the pre-implementation phase in which two duplicated withdrawals and three missing items were identified. Overall user satisfaction was high, with an average score of 4.6 out of 5. These findings indicate that a simple spreadsheet-based information system combined with Lean-based process simplification can effectively improve inventory control in small primary schools without requiring complex or costly technologies.

Keywords
systems engineering, inventory management, lean management, spreadsheet-based system, small primary school

1. Introduction
Small primary schools operating in resource-constrained environments often face significant challenges in managing inventory effectively. Due to limited personnel and the absence of dedicated inventory staff, inventory control processes are frequently handled manually by teachers or administrative personnel as secondary responsibilities. These manual and paper-based procedures often result in undocumented withdrawals, duplicated requests, lack of

traceability and occasional loss of equipment. Over time, such issues reduce operational efficiency and limit the ability of school administrators to make data-driven procurement decisions.

Although digital inventory systems are widely adopted in large organizations, many available solutions are costly, complex, and require technical expertise that small educational institutions may not possess. As a result, small schools often continue to rely on informal processes, even when inefficiencies are evident. Existing studies on inventory management and Lean-based process improvement have primarily focused on industrial or large-scale organizational contexts, with limited emphasis on small public educational institutions that operate under strict resource constraints. From a systems engineering perspective, inventory management problems should not be addressed solely through isolated technological solutions, but rather through a structured integration of stakeholder requirements, process redesign, and information system support. Systems engineering emphasizes requirement analysis, stakeholder identification, system integration, verification, and validation to ensure that solutions align with organizational needs and operational constraints. However, the application of a formal systems engineering framework to inventory process redesign in small primary schools remains underexplored.

Therefore, this study applies a systems engineering approach to redesign inventory management processes in Ban Nong Bong Primary School, Thailand. The research integrates stakeholder-driven requirement analysis with Lean-based process simplification and the development of a low-cost spreadsheet-based prototype information system. The objective is to improve traceability, reduce duplication and equipment loss, and enhance overall inventory control performance within a small primary school context.

2. Systems Engineering Framework

2.1 Stakeholder Identification and System Context

The first step in the systems engineering approach was to identify key stakeholders and define the system boundary. In the context of Ban Nong Bong Primary School, the primary stakeholders include teachers, administrative staff, and the school director. Teachers are responsible for requesting and using instructional materials and sports equipment. Administrative staff oversee recording and documentation, while the school director is responsible for procurement approval and resource allocation.

The inventory system boundary was defined to include withdrawal requests, receipt recording, inventory balance updating, and reporting functions. External factors such as budget approval from higher authorities and supplier lead times were considered environmental constraints rather than components of the internal system. By clearly defining stakeholders and system boundaries, the study ensured that the redesigned process addressed actual user needs within realistic operational limitations.

2.2 Requirement Analysis

A structured requirement analysis was conducted to identify functional and non-functional system requirements. Requirements were derived from interviews with users, observation of existing processes, and review of historical inventory issues.

The primary functional requirements include:

- Real-time visibility of inventory status
- Recording of withdrawal and receipt transactions
- Automatic calculation of remaining inventory
- Traceability of user transactions
- Reduction of duplicated withdrawal requests

Non-functional requirements include:

- Low-cost implementation
- Ease of use for non-technical staff
- Minimal training requirement
- Compatibility with existing digital tools

The requirement analysis emphasized that the solution must be simple, accessible, and sustainable within the constraints of a small primary school.

2.3 Process Modeling and Integration

After defining requirements, the existing inventory process was modeled to identify inefficiencies. The original workflow involved multiple manual steps, including paper-based withdrawal forms, separate recording of receipt transactions, and manual calculation of remaining inventory. These fragmented processes increased the risk of recording errors and duplicated entries.

Using systems engineering principles, the redesigned process aimed to integrate multiple functions into a single, coherent workflow. Lean-based techniques were applied to eliminate non-value-added steps, while maintaining alignment with stakeholder requirements. The redesigned process consolidated withdrawal recording, receipt documentation, and inventory balance calculation into a unified structure within a single worksheet environment.
This integration ensured functional coherence between data input, processing, and output reporting, forming the foundation for prototype system development described in the next section.

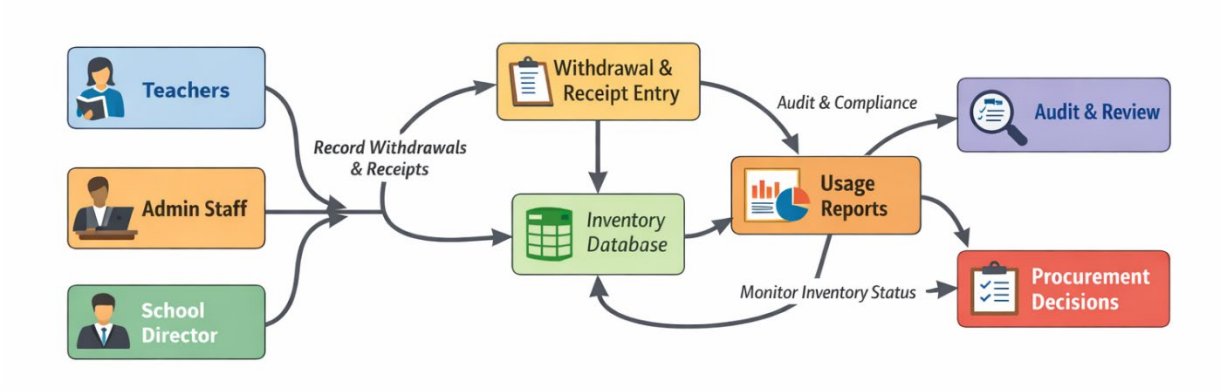

Figure 1. System Context Diagram of the Inventory Management Workflow

Figure 1 illustrates the system context and integration of key components within the redesigned inventory workflow.

3. Lean-Based Process Redesign

Although the overall framework of this study follows systems engineering principles, Lean management techniques were applied as operational tools to improve process efficiency. The purpose of Lean integration was to eliminate non-value-added activities while maintaining alignment with stakeholder requirements identified in the previous section.

3.1 Identification of Process Waste

The original inventory workflow at Ban Nong Bong Primary School involved several inefficiencies:

- Paper-based withdrawal forms
- Separate recording of item receipt and withdrawal
- Manual calculation of remaining inventory
- Redundant data entry in multiple documents

These issues correspond to common categories of waste in Lean thinking, including unnecessary motion, over-processing, duplication, and waiting. The lack of integration between withdrawal recording and inventory balance updating increased the likelihood of human error and data inconsistency.

3.2 Process Simplification Using ECRS

The redesign process applied the ECRS principle (Eliminate, Combine, Rearrange, Simplify):

- **Eliminate:** Paper-based withdrawal forms were removed.
- **Combine:** Withdrawal recording, receipt documentation, and inventory balance calculation were merged into a single workflow.
- **Rearrange:** Data input fields were structured to follow the natural sequence of user actions.
- **Simplify:** Manual inventory balance calculation was replaced with automatic spreadsheet formulas.

Through this structured simplification, the number of operational steps was reduced and redundant documentation was removed, while preserving traceability and accountability.

The Lean-based redesign did not replace the systems engineering framework; rather, it operationalized the requirement analysis into a practical and streamlined workflow.

4. Prototype Development

4.1 System Architecture

Based on the defined requirements and redesigned workflow, a prototype information system was developed using spreadsheet-based software, such as Microsoft Excel or Google Sheets. The decision to use spreadsheet tools was driven by the non-functional requirements of low cost, accessibility, and ease of use.
The system architecture consists of:

- A single integrated worksheet for transaction recording
- Structured data fields for withdrawal and receipt entries
- Embedded formulas for automatic inventory balance calculation
- Filter and reporting functions for traceability

The integration of these components ensures that each transaction automatically updates the inventory status without requiring separate manual calculations.

4.2 Functional Integration

The prototype integrates three key functions within one worksheet:

1. Recording of withdrawal transactions
2. Recording of receipt transactions
3. Automatic updating of remaining inventory

This integration reduces duplication and minimizes the risk of inconsistent records. The system also enables simple reporting and historical tracking of user transactions, supporting managerial oversight.

4.3 Usability Considerations

Given that system users are teachers and administrative staff who do not have specialized technical training, usability was prioritized. The interface was designed to:

- Minimize required input fields
- Use clear labeling
- Avoid complex formulas visible to users
- Allow straightforward filtering and sorting

This user-centered design aligns with systems engineering principles that emphasize socio-technical integration and practical applicability.

5. Verification and Validation

5.1 Trial Setup

The prototype system was implemented and tested at Ban Nong Bong Primary School over a two-month trial period. The system was used by 10 teachers and staff members who were directly involved in inventory-related activities.
During the trial period, all withdrawal and receipt transactions were recorded using the spreadsheet-based system. Data were collected from actual system usage and user feedback surveys to evaluate both functional performance and user acceptance.
The evaluation framework distinguishes between system verification and system validation in accordance with systems engineering principles.

5.2 System Verification

System verification focuses on confirming that the system performs according to defined functional requirements.
The following verification criteria were evaluated:

- Accuracy of automatic inventory balance calculation
- Completeness of transaction recording
- Traceability of withdrawal records
- Elimination of duplicated withdrawal entries

During the trial period, no duplicated withdrawal transactions were recorded, compared to two duplicated cases identified before system implementation. In addition, no equipment loss was observed during the two-month trial, whereas three missing items were recorded in the pre-implementation period.

Automatic inventory balance calculations were verified by cross-checking recorded transactions with physical inventory counts. No discrepancies were identified during the trial period.
These results indicate that the prototype system met its primary functional requirements.

5.3 System Validation

System validation evaluates whether the developed solution satisfies stakeholder needs and improves overall performance.
User satisfaction was assessed using a structured questionnaire. The results show that the overall satisfaction score was 4.6 out of 5, indicating a high level of user acceptance.
Users reported improvements in:

- Ease of tracking inventory status
- Reduction of duplicated requests
- Transparency of transaction history
- Simplicity of the recording process

The absence of duplicated withdrawals and equipment loss during the trial period further supports that the redesigned system aligns with stakeholder expectations and operational needs.

5.4 Summary of Quantitative Results

Table 1. Comparison of Inventory Performance Before and After System Implementation

Indicator	Before Implementation	During Trial Period
Duplicated withdrawals	2 cases	0 cases
Missing items	3 items	0 items
User satisfaction	–	4.6 / 5

6. Discussion

The results demonstrate that the application of a systems engineering framework, combined with Lean-based process simplification (Table 1), can effectively improve inventory management performance in a small primary school. Rather than introducing a complex or high-cost digital system, this study emphasizes structured requirement analysis, process integration, and stakeholder-centered design.

One key finding is that system simplicity plays a crucial role in successful adoption. The prototype did not rely on advanced software or specialized programming. Instead, it leveraged widely accessible spreadsheet tools aligned with user familiarity. This approach reduced resistance to change and minimized the learning curve among teachers and administrative staff.

From a systems engineering perspective, the improvement was not solely technological but socio-technical. The integration of stakeholder requirements, process redesign, and usability considerations ensured that the solution aligned with real operational needs. The elimination of duplicated withdrawals and the absence of equipment loss during the trial period reflect the effectiveness of structured system integration.

The study also highlights the importance of contextual design in resource-constrained environments. Solutions suitable for large organizations may not be appropriate for small public institutions with limited technical capacity. A lightweight, spreadsheet-based system can provide sufficient traceability and accountability when designed under a systematic framework.

However, several limitations should be acknowledged. First, the trial period was limited to two months, which may not fully capture long-term system performance. Second, the study was conducted in a single school, which may limit generalizability. Future research may extend the framework to multiple schools or incorporate longer evaluation periods to assess sustainability and scalability.

7. Conclusion

This study presents a systems engineering approach to redesigning inventory management processes in a resource-constrained primary school. By integrating stakeholder-driven requirement analysis, Lean-based process simplification, and the development of a spreadsheet-based prototype information system, the study demonstrates measurable improvements in inventory control performance.

The verification results confirm the elimination of duplicated withdrawals and missing items during the trial period, while validation results indicate high user satisfaction. These findings suggest that structured systems engineering principles can be effectively applied to small public educational institutions without requiring complex or expensive technologies.

The proposed framework contributes to both practical implementation and academic discussion by illustrating how systems engineering can support process redesign in small organizations. The approach may serve as a replicable model for similar schools seeking low-cost and sustainable inventory management solutions.

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Biographies

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