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# A Frugal Engineering Approach to Foster Digital Transformation in Emerging Countries: A Digital Inventory Management case study

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## ABSTRACT

Digital Transformation Processes (DTPs) are essential for companies seeking to remain competitive in an increasingly digitalized environment. While DTPs can enhance manufacturing control and operational efficiency, their implementation often poses significant challenges for small and medium-sized enterprises (SMEs) due to the complexity of available technologies and the substantial investments required. This paper presents a novel methodology for digital transformation based on frugal innovation, specifically designed to address the resource and infrastructure limitations commonly faced by SMEs. Unlike traditional maturity models, which demand comprehensive integration and high costs, the proposed approach offers a structured, step-by-step framework that enables organizations to focus on core functionalities, minimize expenditures, and achieve effective performance using accessible, low-cost digital solutions. The methodology is demonstrated through a case study involving an Argentine SME, where it facilitated rapid and measurable improvements in inventory management. Key capabilities of the frugal approach include modular implementation, adaptability to existing workflows, and the ability to deliver tangible results without extensive technical expertise or financial investment. By targeting the most critical processes and leveraging familiar technologies, the proposed frugal method empowers SMEs to overcome barriers to digital transformation and achieve sustainable operational gains. This work addresses a gap in the literature by providing a practical and scalable alternative for resource-constrained organizations, illustrating how frugal innovation can drive successful digital transformation in real-world settings.

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## 1. Introduction

Industry 4.0, also known as the Fourth Industrial Revolution, represents a paradigm shift in the way businesses operate, integrating advanced digital technologies to transform production and management processes [1], [2]. This approach is based on the convergence of several disruptive technological capabilities, such as the internet of things, Artificial Intelligence (AI), advanced robotics, augmented reality, and big data. These technologies enable the creation of cyber-physical systems that merge the physical and digital worlds, facilitating greater automation, efficiency, and customization in production [3], [4]. The adoption of Industry 4.0 not only optimizes operational processes and reduces costs, but also opens up new opportunities for innovation and value creation in a highly competitive and dynamic business environment.

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Digital Transformation Processes (DTP) are the processes through which the transformation of a traditional production system into an Industry 4.0 system is enabled. Digital transformation processes involve the integration of digital technologies in all areas of an organization, fundamentally changing the way companies operate and deliver value to their customers [5], [6]. Digital transformation is not limited to the implementation of new technological tools; it also involves a restructuring of organizational culture to foster innovation, agility, and collaboration. Companies that undertake this transformation can achieve significant improvements in operational efficiency, data-driven decision-making, and responsiveness to market demands. In addition, digitalization enables organizations to create new business models, improve customer experience, and remain globally competitive in an increasingly digitalized business environment [4], [6]. DTPs are complex and challenging for companies because they require the redesign of the organization structure and modification of multiple processes. To resolve this complexity, Maturity Models (MMs) have emerged as a valuable tool to facilitate the DTP and organize efforts and investments to achieve a digitally transformed company [5]. Digital transformation maturity models are tools that enable organizations to assess their level of digitalization and chart a clear path toward continuous improvement. These models categorize a company's progress into several stages, from the initial adoption of digital technologies to the full integration and optimization of these technologies across all aspects of the business.

However, many companies do not have the resources to achieve the high level of digitalization proposed in MMs, especially SMEs in emerging countries. These organizations often do not have the financial capacity to face an intensive technological incorporation process, nor the skills in Human Resources (HR) to reach a level of technological maturity specified by a MM [7]. Recent studies indicate that these barriers prevent the use of maturity models and therefore other types of approaches are needed to address these situations [8]. The authors propose an approach based on Frugal Innovation (FI), which refers to the creation and application of simple, efficient and low-cost solutions designed to maximize value with limited resources [9]. This approach challenges the belief that only advanced and expensive technologies can drive efficiency and sustainability. Instead, it focuses on ingeniously using available resources, reducing waste and promoting reuse and recycling. In practice, FI can involve redesigning equipment to improve functionality with minimal costs, adapting accessible technologies for new purposes, or implementing management methods that optimize the use of human and material resources [10]. For our purpose, value (V) is defined as Functionality (F)/Resources (R). This definition was developed by SAVE International, the professional society for Value Engineers/ professionals. In recent years there have been cases where FI implementation has resulted in significant benefits to the organization with improved capabilities and processes [11], [12].

This work introduces a novel methodology for implementing digital transformation, grounded in the principles of FI. Unlike traditional maturity models, which often require substantial resources and complex integration, our approach leverages FI to develop practical and accessible solutions tailored to organizations facing significant resource constraints. The methodology consists of a series of structured steps designed to guide Digital Transformation Projects (DTPs) in environments where financial and human resources are limited. By focusing on the unique challenges of resource-constrained settings, this approach directly addresses a gap in the current literature, which often overlooks the needs of Small and Medium-Sized Enterprises (SMEs) in emerging economies. To demonstrate the effectiveness of this methodology, we present a detailed case study involving an Argentine SME, showcasing how the FI paradigm can deliver impactful results under real-world conditions.

The paper is organized as follows. Section 2 presents the digital transformation processes and the limitations of the current olos. Section 3 introduces the basic concepts of FI along with the proposed methodology. In Section 4, the case study is developed. Finally, the conclusions are presented in Section 5.

## 2. Digital Transformation processes and barriers

This section outlines the processes involved in digital transformation, highlighting the expected actions and capabilities. It also explores the workings of maturity models and addresses the limitations and barriers that companies may face during the digital transformation journey.

### 2.1 Digital Transformation processes

The motivation for undertaking a digital transformation process lies in the need for companies to remain competitive and relevant in an increasingly dynamic and technological market. Digital transforma-

tion allows for optimizing processes, improving operational efficiency and reducing costs, which translates into increased productivity and profitability. Furthermore, by incorporating advanced technologies and information management systems, companies can make rapid, informed and agile decisions, responding quickly to market demands and customer expectations [2]. Digitalization also facilitates innovation, allowing the development of new products and services that can open up new business opportunities. Digital transformation is not only a strategy to improve current performance, but also a crucial investment to ensure the future and sustainability of the company in a globalized and constantly changing environment [13].

DTP is a complex process, where production processes and information workflows will need to be modified and redesigned [8]. A DTP is both intense and challenging for companies, since a large part of the organizational structure must also be redesigned and redefined, because the information flow that is managed, accessed and used by each area of the company is also transformed [5]. Given the scope and complexity of addressing a DTP, different tools have emerged to facilitate these processes. Technological MMs are widespread, prominent, and propose a set of procedures and methodologies to structure a DTP, as well as analyze the incorporation of digital technologies and skills in human resources to achieve a fully digitalized level [14]. MMs identify a series of stages where a diagnosis must be carried out to understand the current level and analyze gaps in digital capabilities - this will lead to the creation of a comprehensive, structured and objective roadmap that allows achieving the standards of a fully digital company [15].

To provide a clearer understanding of how MMs address the various stages and capabilities of digital maturity, we present Table 1, which uses the model proposed by Gökalp & Martinez [14] as a guidance tool. The table delineates five levels, with level 1 representing the lowest digital capabilities and level 5 representing the highest. Each level is associated with a set of capabilities that enable the company to consolidate its digital aptitude. As the levels progress, new capabilities are introduced or existing ones are enhanced, thus improving the overall digital maturity of the organization.

**Table 1.** Maturity model for Digital Transformation levels

| | |
|---|---|
| Maturity Level 1 | Organizational Structure Management<br>HR Skills Development<br>Portfolio Management<br>Digital Transformation Strategy Development |
| Maturity Level 2 | Business Process Digitalization<br>IT Strategy Management<br>Enterprise Architecture Development<br>Infrastructure Management<br>Agile Software Development<br>Data Governance and Security Management<br>Project Management<br>Financial Resources and Supplier Management |
| Maturity Level 3 | Business Processes Vertical Integration<br>Enterprise Architecture Development<br>Organizational Change Management<br>Sustainable Learning Management |
| Maturity Level 4 | Business Processes Horizontal integration<br>Data-driven Decision Management<br>Quantitative Performance Management<br>Data Analytics<br>Enterprise Architecture Maintenance |
| Maturity Level 5 | Self-Optimized Decision Management<br>Business Process Integration Towards Life-cycle<br>Quantitative Process Improvement |

### 2.2 Barriers

While MMs provide a roadmap to implement these DTPs, they also point to the need to guide the DTP towards a final state of integration and high efficiency, integrated with the incorporation of technology into a company's processes. These MMs propose that the entire company achieve a "final level" of great digital value (Level 5 of Table 1). Even when this level may not be achieved in the first steps, the objective of an MM is always to get closer to that final level. Investments and HR needs are defined in pursuit of that ultimate goal [8]. Because of the objective of achieving full digitization, some authors, while recognizing the intrinsic value of MMs, indicate that they are not a one-size-fits-all solution. For example, to achieve optimized production levels, MMs propose generating digital tools at all levels so that optimization is completely autonomous.

However, the possibilities of a given SME in an emerging country applying all these MM methodologies is rare, essentially due to constraints in resources (HR and capital) [7], [16], [17]. Further, given the extreme volatility of global scenarios in recent years, with pandemics and wars, and also with drastic changes in legislation, it is not possible to have sufficient predictability for a SME to be able to apply DTPs as proposed by a MM. These barriers are exacerbated in the micro and small enterprise sector (less than 50 employees) [8], [18], [19]. In emerging countries, financing possibilities for SMEs are difficult and scarce, as is finding in-house personnel (or even recruiting new personnel) with the necessary skills.

## 3. Frugal Innovation approach to foster Digital Transformation

FI has had a significant impact on a large number of engineering innovation processes, enabling results where other innovation approaches failed to generate valid solutions. Below is a deeper presentation of the concepts that underpin the FI approach, particularly the principles or criteria that guide an innovation process under the frugal paradigm. Then, the methodology proposed here to implement FI processes in DTP is introduced.

### 3.1 Frugal Innovation

FI is an approach that aims to develop economical, efficient, and accessible solutions, especially designed to meet the needs of emerging markets and communities with limited resources [20]. This paradigm is based on the premise of doing more with less, using available resources in ingenious and creative ways to create functional and sustainable products and services. Unlike traditional methods that often pursue complexity and sophistication, FI emphasizes simplicity, practical utility, and local ingenuity. This approach not only has the potential to drive inclusive and equitable development but also fosters resilience and adaptability, allowing organizations to respond effectively to changing challenges and resource constraints. In essence, FI promotes a development model that is both economically viable and socially responsible [10] in resource constrained environments.

These characteristics have enabled the development of innovation processes in complex areas, both material and human. These approaches have allowed advances and digital developments in various sectors such as the energy industry, financial sector, AI applications, and public services, among other success stories [20]-[22]. These previous cases provide a basis for using a FI approach to address digital transformation problems in SMEs in industrializing countries, as proposed by Khattak et al. [23] and Sukrat & Leeraphong [13].

The FI approach reviews projects, products or a processes taking into account three basic criteria [10]:

- I) A focus only on the core functionalities and project (customer) need,
- II) substantial cost reduction, and
- III) an acceptable performance level.

The criterion of focusing on core functions is a central aspect of FI that will increase Value to the customer or client. The aim is to transform processes or products to meet the core functional needs without adding sophisticated procedures or future functionalities that increase costs without adding value. This point aligns the entire innovation process to a clear and well-defined target.

Regarding the criterion of substantially reducing costs, most FI-based DTPs aim for 'low hanging fruit' that provide high value with minimal capital expenditures. Resource constraints are common for most SMEs when undertaking an innovation process. However, in environments where FI is often applied, these constraints are much tighter than in other contexts. Therefore, costs must be accurately analyzed and considered in every aspect impacted by the innovation process. Clearly stating the core functions helps to align where expenditures are necessary and where they can be minimized.

The final criterion, maintaining an acceptable performance level, is a distinctive feature of FI. Pursuing an optimal performance or service level can be seen as a natural extension of the first two criteria. When all project aspects are aligned with a clear and concrete objective and costs are minimized, the expected performance or service level is naturally regulated by the other two criteria. This approach ensures achieving the optimal level, avoiding both excesses and deficiencies. For a deeper dive, FI, the reader is invited to read [24]-[27].

## 3.2 Frugal Methodology Proposal for Digital Transformation Processes

FI principles provide an appropriate theoretical framework to address DTP problems with resource scarcity. However, the implementation of that theory is a decisive factor in the success of the approach. In this context, it is proposed to use Value Methodology [28] as a methodological framework. This approach allows the incorporation of design tools and strategies to guide the innovation process towards achieving the expected results, focusing resources and efforts on aspects that contribute to the stated objective. In terms of FI, this can be explained as VM providing the tools and strategies to achieve a process that fulfills core functionalities with optimized performance at the lowest possible cost.

Thus, it is proposed to redefine "value" in terms appropriate for the work proposed here. To do this, we must consider that the problem to be addressed is the improvement of an inventory management system. Therefore, the aspects that add "value" are the functionalities or capabilities of that system. In this sense, following the value logic presented in the VM Guide, we adapt the definition of value to the following formula.

$$Value = \frac{Functionality}{Resources},$$

Here it is clear that to increase the value of the innovation process outcome, functionalities must be increased while maintaining the resources allocated to the system, or maintaining functionalities while reducing resources, or a combination of both. The proposed methodology for developing DTPs following a FI approach consists of the following 6 steps:

(1) Establish the problem
(2) Establish project focus based on customer (or core) need.
(3) Identify sections of DTP to implement based on customer need
(4) Develop “islands of DTP”
(5) Implement
(6) Measure Outcomes

### 3.2.1 Establish the problem

The first step is to clearly define the specific problem to be addressed. A key aspect of this definition is ensuring that it aligns with the company’s mission. In other words, the problem should be framed in a way that integrates with the company’s overall strategy, thereby ensuring the creation of value. At Table 2 the full description of the technical sheet is presented. This sheet guides the execution of the first step of the methodology pointing out the clear purpose of the step, the core activities to achieve it, the expected outputs and the governance and timeline.

### 3.2.2 Establish project focus based on customer (or core) need

Once the problem has been defined, it is essential to identify a potential solution or the desired impact that a solution should have on the problem outlined in the previous step. This solution or impact must be closely aligned with the problem definition to ensure that efforts are optimized. All resources should be efficiently directed toward addressing the identified issue. This step is crucial as it encourages solutions that minimize resource usage, avoiding over-engineered or oversized outcomes. As well as the first step, Table 3 compiles the purpose of the step, the core activities to achieve it, the expected outputs and the governance and timeline indications.

### 3.2.3 Identify sections of DTP to implement based on customer need

With the problem and expected outcome clearly defined, the next step is to analyze the various parts and areas involved in the issue that can contribute to achieving the desired result. This analysis must be conducted with the assistance of professionals specialized in digital transformation, as they can identify the sections that will have the greatest impact on achieving results while minimizing resource usage. At this stage, it is essential to define the approaches and strategies for developing the DTP, always aiming to achieve the expected outcome. Basically, here the intention is follow value equation concept. Table 4, presents the purpose of the fourth step, the core activities to achieve it, the expected outputs and the governance and timeline indications.

**Table 2.** Technical sheet for the first step of the Frugal Methodology proposed, Establish the problem

| **Frugal Methodology for Digital Transformation Processes** | |
|---|---|
| STEP 1 : Establish the problem | |
| *Purpose:* Create a concise, measurable problem statement aligned with company strategy and business impact | |
| *Core activities* | • Conduct rapid stakeholder mapping and 30–60 minute interviews with production, warehouse, sales, purchasing and finance.<br>• Perform a time-boxed data audit: sample transactions, reconciliation cycles and recent physical counts to quantify error rates and update latency.<br>• Map the current information flow (SIPOC or simple flowchart) showing where errors and delays arise.<br>• Catalogue constraints: budget ceiling, staff hours available, connectivity, devices, legacy systems, regulatory needs.<br>• Define minimum acceptable performance (error tolerance, update frequency, response times). |
| *Outputs* | • Problem statement and impact summary (losses, customer effect, operational waste).<br>• Baseline metrics: inventory accuracy, update latency, time spent on counts, stockout frequency.<br>• Current-state process map and constraint inventory.<br>• Top 3 root causes prioritized by impact and feasibility. |
| *Governance and timeline* | • Owner: operations manager or plant manager.<br>• Timebox: 1–2 weeks (fast-track variant: 3–5 workdays).<br>• Decision gate: approve problem statement and baseline metrics to continue. |

**Table 3.** Technical sheet for the second step of the Frugal Methodology proposed: Establish project focus based on customer (or core) need

| **Frugal Methodology for Digital Transformation Processes** | |
|---|---|
| STEP 2 : Establish project focus based on customer (or core) need. | |
| *Purpose*: Define a narrow, value-driven scope that targets customer/stakeholder pain and avoids overengineering | |
| *Core activities* | • Translate stakeholder needs into 2–3 measurable objectives (e.g., reduce stockouts by X%, cut count time by Y%).<br>• Create a “must-have” vs “nice-to-have” feature list using the Functionality/Resources lens.<br>• Define success criteria and acceptance tests for each objective (how will you know the island solved the problem?).<br>• Estimate rough resource envelope (budget, staff hours, required devices). |
| *Outputs* | • Project charter: objectives, scope boundaries, success metrics, resource envelope.<br>• Prioritized feature backlog with clear acceptance criteria.<br>• Risk register focused on feasibility and adoption risks. |
| *Governance and timeline* | • Stakeholder sign-off required before design.<br>• Timebox: 3–7 days. |

### 3.2.4 Develop "islands of DTP"

Naturally, the FI-based approach aims to address the problem directly, while also considering the broader context and ecosystem in which the developed solution will need to interact. This ensures that the solution not only meets the functional requirements for the problem at hand but also allows for future integration with other solutions developed within the framework of the DTP. In other words, the solution must meet minimum interoperability standards. In Table 5, the technical sheet presents the purpose of the fourth step, the core activities to achieve it, the expected outputs and the governance and timeline indications.

### 3.2.5 Implement

Execute the chosen solution to address the problem defined in step 1, ensuring that it adheres to the specifications established in step 2. For having a clearer perspective, Table 6 introduce a technical sheet to execute the implementation of the innovative solution designed and developed in the previ-

**Table 4.** Technical sheet for the third step of the Frugal Methodology proposed: Identify sections of DTP to implement based on customer need

| **Frugal Methodology for Digital Transformation Processes** | |
|---|---|
| STEP 3 : Identify sections of DTP to implement based on customer need | |
| *Purpose*: Select the minimal set of processes, roles and data elements that must be digitized to deliver the defined objectives | |
| *Core activities* | • Decompose the information lifecycle into micro-processes (receipt, storage, consumption, production issue, shipment, returns, reconciliation).<br>• Assess which micro-processes create the largest value gap using baseline metrics and the Functionality/Resources ratio.<br>• Define the minimal data model and event triggers needed to achieve objectives (item ID, location, qty, timestamp, user, doc ref).<br>• Identify integration touchpoints with existing systems and manual workflows. |
| *Outputs* | • Scope map listing included micro-processes and excluded processes.<br>• Minimal data model and event/transaction definitions.<br>• Integration plan (export formats, sync frequency, manual handoffs). |
| *Governance and timeline* | • Include at least one frontline super-user in decisions to ensure practicality.<br>• Timebox: 3–10 days depending on complexity. |

**Table 5.** Technical sheet for the fourth step of the Frugal Methodology proposed: Develop "Islands of DTP"

| **Frugal Methodology for Digital Transformation Processes** | |
|---|---|
| STEP 4 : Develop "Islands of DTP" | |
| *Purpose*: Design modular, interoperable digital islands that implement the selected microprocesses with minimal technology and cost. | |
| *Core activities* | • Choose frugal technology stack (cloud spreadsheets + forms, low-code platform, lightweight DB) based on constraints.<br>• Define clear APIs, CSV export rules or scheduled sync procedures to ensure future interoperability.<br>• Design simple UIs and job aids for each role (data capture forms for shop-floor, dashboards for planners).<br>• Create basic validation and reconciliation rules to reduce input errors.<br>• Plan a staged deployment (pilot unit, scale criteria, rollback plan). |
| *Outputs* | • Solution blueprint: architecture diagram, data flows, UI mockups, validation rules.<br>• Integration specification: formats, schedule, responsible parties.<br>• Pilot plan with acceptance criteria and rollback triggers. |
| *Governance and timeline* | • Technical lead (internal or short-term contractor) to own build tasks.<br>• Timebox: design 1–2 weeks. |

ous 4 steps. Table 6 incorporates the purpose of the step, the core activities, expected outputs , governance and timeline, but also risk mitigation strategies, since in the implementation the risk of failure become real.

### 3.2.6 Measure Outcomes.

As with any design and improvement process, it is essential to verify whether the desired impact has been achieved and to evaluate how the solution performs under real-world conditions. For assistance in measuring outcomes, Table 7 provides practical technical advice. The core activities of this step are related to the metrics and targets defined for the problem, some suggestions for monitoring the evolution of the implementation are given, too. Finally, at the bottom of Table 7 the technical sheet delivers useful information for long-term governance.

To develop new islands and to scale the DTP to other functions or areas while preserving the frugal strategy and aligning with achieved improvements, it is important to sustain a same methodology approach. For this scaling, it would be advisable to prioritize features and future islands using the Functionality/Resources metric, and to keep solutions modular, well

**Table 6.** Technical sheet for the fifth step of the Frugal Methodology proposed: Implementation

| **Frugal Methodology for Digital Transformation Processes** | |
|---|---|
| STEP 5 : Implementation | |
| *Purpose*: Build, pilot and operationalize the island with emphasis on rapid learning, adoption and low-cost execution. | |
| *Core activities* | • Configure tools and build templates (spreadsheets, forms, dashboards).<br>• Implement validation and simple automation (scripts, scheduled jobs) to enforce rules.<br>• Train 1–2 super-users and run a short pilot on a single product family, zone or shift.<br>• Conduct daily standups during pilot to capture issues and quick-fix UI or process problems.<br>• Expand rollout in waves after pilot achieves acceptance criteria.<br>• Change management and training (Deliver 1–2 page job aids and 15–30 minute micro-training sessions; model correct behavior and highlight early wins; capture user feedback and iterate weekly during rollout) |
| *Outputs* | • Operational island (configured tools and documented workflows).<br>• QuickStart guides and escalation contact list.<br>• Training attendance records and pilot log. |
| *Governance and timeline* | • Project owner: operations manager.<br>• Build lead: technologist or contractor (2–4 weeks).<br>• Super-users: 1–3 frontline staff.<br>• Timebox: Pilot length: 2–4 weeks; phased rollout: 1–3 additional weeks per wave. |
| *Risks and mitigations* | • Data entry errors: enforce validations, minimize free-text.<br>• Low adoption: involve users in build, incentivize correct use, show metrics.<br>• Connectivity/device failure: allow offline capture and scheduled sync |

**Table 7.** Technical sheet for the sixth step of the Frugal Methodology proposed: Measure outcomes

| **Frugal Methodology for Digital Transformation Processes** | |
|---|---|
| STEP 6: Measure Outcomes | |
| *Purpose*: Demonstrate value, validate assumptions, and decide whether to scale, iterate or redesign. | |
| *Core activities related to: key metrics targets* | • Inventory accuracy (physical vs recorded) (target e.g., % improvement)<br>• Update latency (target e.g., transactions reflected within N hours)<br>• Time saved on counts (target e.g., -X% person-hours).<br>• Stockout incidents (target e.g., -Y incidents/month).<br>• Adoption rate (percentage of transactions entered through the island).<br>• Operational ROI proxy (labor hours saved, avoided lost sales, reduced carrying costs). |
| *Timeline and evolution* | • Daily reconciliation report during pilot; weekly KPI dashboard in month 1; monthly consolidated report after stabilization.<br>• Use reconciliation templates, simple dashboards and a lessons-learned log.<br>• Run short user satisfaction surveys and capture qualitative issues.<br>• Predefine go/no-go thresholds (e.g., if accuracy ≥ target and adoption ≥ 70%, then, foster and scale).<br>• If metrics improve but adoption lags, then, invest in training and UI fixes.<br>• If metrics do not improve, then, revisit problem definition and microprocess selection. |
| *Long-term Governance* | • Archive documentation and data export standards to avoid technical debt.<br>• Define triggers for re-evaluation (data volume, transaction rates, error trends) that signal when migration toward broader DTP efforts or maturitymodel steps is justified.<br>• Schedule periodic PDCA cycles to incrementally improve island performance. |

documented, and easily exportable to avoid future integration costs. Another important factor would be to favor low-friction change through short training sessions, clear job aids, and visible dashboards that demonstrate immediate benefits, this will contribute to achieve synergies with previous islands. A last remark would be to maintain small, time-limited build teams while engaging external technical sup-

port when internal capacity is insufficient, this would avoid a disorganization in the extension and scaling of DTP to other areas.

The following section presents a case study where these steps were successfully applied to achieve a DTP.

## 4. Case study: Digital Inventory management

This section first presents the case study and the characteristics of the problem to be addressed, along with the limitations of the environment. The authors then detail how the methodology above is implemented for DTP development following a FI approach.

### 4.1 Case Study Presentation

The case study focuses on an Argentine SME, working in the printing industry as a supplier for various industrial and logistical applications. This company has almost 30 employees, including all production, administrative, and managerial staff. The motivation to develop a DTP arose from the need to improve the quality and accessibility of inventory information. Inventory information was erratic, with significant discrepancies between what was recorded in the system and the actual physical stock. These differences led to critical stockouts and did not allow synchronized and organized tasks between various areas of the company. The inventories seen by the sales department (both finished products and raw materials for estimating future sales) were utilized to guide the actions of the customer facing portion of the organization including establishing sales targets, delivery times, etc. However, with inaccurate information at the end of each month, both customer and the sales personnel were frustrated. Inventory balances needed to be manually corrected with lost customers. Similarly, production planners did not have accurate information on availability, so planning was constantly modified, preventing optimal planning and smooth operation of the process. Additionally, the purchasing department does not have a clear overview and was unable to define strategies and agreements with suppliers.

Among the main reasons for this information management shortfall is the fact that much of this information was handled analogically, from the physical inventory check in the warehouse to the production management (consumption of raw materials and entry of finished products). Paper spreadsheets were abundant and disconnected. These were then entered into the system manually, which was updated once a week, although sometimes it took up to 2 weeks to update. Another aspect that exacerbated this issue is that each department, lacking precise and updated information, created its own records and updated the projected inventory according to its estimates. These modifications based on each department's actions and decisions were not integrated into the central database. Consequently, multiple versions of the same information existed, each with a different modification history, making the task of closing balances and reconciling these versions complex, difficult, and prone to errors.

This situation forced the company to seek solutions to improving inventory information management. To this end, they developed a digital strategy to address the quality and accessibility of information. The strategy considered the company's resource limitations, as it does not have an IT department to develop its solution or the financial resources to purchase a comprehensive market solution or pursue obtaining a high level of digital maturity as proposed by the maturity models in the literature. Hence, the solution needed to be tailored to the available resources and be as easy to use as possible. In this context, it was proposed to create a tool based on the FI paradigm and achieve a DTP in inventory management, contributing to more orderly company management.

### 4.2 Implementation of the Frugal Innovation approach

To address the problem described in the previous section, the implementation of the six steps mentioned in Section 3 is carried out. To better conceptualize the problem described in the previous section, Figure 1 is presented. Figure 1 schematically shows how the inventory system worked before the DTP. Each stakeholder interacted with stock managed in isolation. Each interaction was invisible to the other stakeholders, giving rise to significant deviations from computed levels of stocks. The ‘solution’ to this challenge was to undertake frequent physical counts, establish high levels of safety stocks, and utilize non-standardized communication (phone or WhatsApp) to reconcile and track parts and products.

Then, the 6 steps presented in section 3.2 were applied following the following approach.

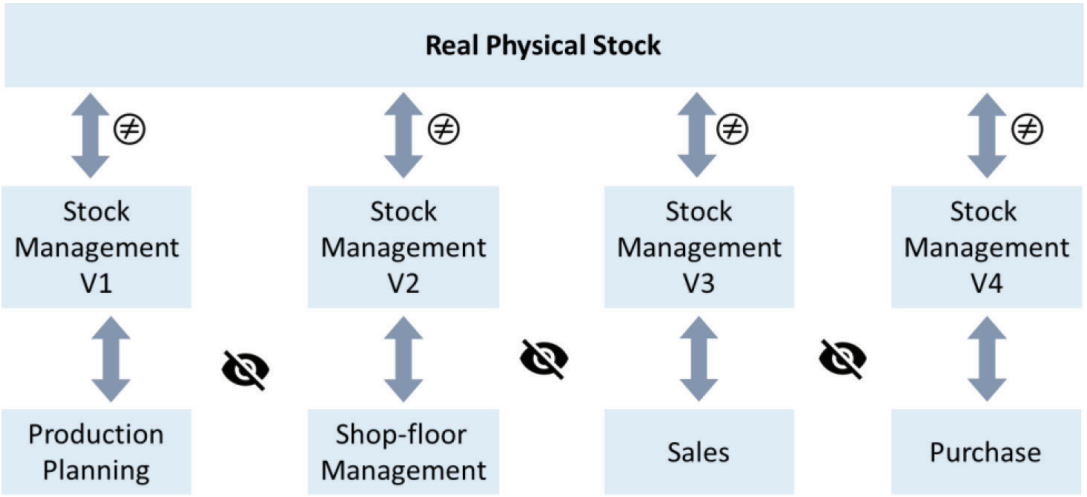


**Figure 1.** Stock Management system of the company previously to Digital Transformation process

### 4.2.1 Establish problem

Here the company reviewed its entire product flow from purchase of raw materials to receipt of payment from the final customer. For this, the core activities defined in Table 2 were followed, and the problem statement and impact summary were achieved.

For the problem statement, it was settled that the company's inventory management system suffers from significant discrepancies between recorded stock levels and actual physical inventory. Information is fragmented across departments, updated infrequently, and maintained through disconnected manual records. This lack of accurate, real-time inventory data leads to frequent stockouts, excess inventory, and inefficient coordination between production, sales, and purchasing functions.

Meanwhile, the impact of this problem was perceived in several areas and activities. These impacts where identified as follows:

- Operational Inefficiency: Time spent on manual inventory counts and reconciliation is excessive, diverting staff from value-added activities.
- Lost Sales and Customer Dissatisfaction: Inaccurate inventory data results in missed sales opportunities, delayed deliveries, and customer frustration.
- Increased Costs: Overstocks and emergency purchases inflate operational costs and tie up working capital.
- Poor Cross-Department Coordination: Disconnected records and communication breakdowns hinder effective planning and decision-making across the company.
- Resource Constraints: Limited budget and lack of IT expertise prevent adoption of comprehensive digital solutions, exacerbating the problem.

### 4.2.2 Establish project focus based on customer (or core) need

The company needed to minimize capital expenditure and human skills on the shopfloor. Yet, it is needed to implement a DTP project with a short turnaround time that yielded high benefits. This step is vital to achieve properly the aim of the project, as well as to the adoption of FI perspective. The objectives and the targets for each objectives were defined as follows:

- Improve inventory accuracy by consolidating and digitizing stock records.
    - Inventory accuracy improvement (target: ≥ 90%).
- Reduce time spent on manual inventory counts and reconciliation by at least 50%.
    - Reduction in manual counting time (target: ≥ 50%).
- Minimize stockouts and excess inventory through real-time data visibility.
    - Decrease in stockout incidents (target: ≤ 2 per month).
- Enable cross-departmental coordination with a unified inventory system.
    - User adoption rate (target: ≥ 70% of transactions entered digitally).

The scope of this project is specifically focused on improving inventory management processes,

including the receiving, storing, issuing, and reconciling of stock. The initiative aims to digitize only the essential data fields (such as item ID, location, quantity, timestamp, and user) to ensure accurate and efficient tracking. Where feasible, the new digital solution will be integrated with existing manual workflows and legacy systems to facilitate adoption and minimize disruption. At this stage, the project will not consider full Enterprise Resource Planning integration, keeping the transformation targeted and manageable within current resource constraints. The project will operate with a minimal budget, making use of existing devices and free or low-cost cloud-based tools to keep expenses low. For the pilot phase, a small team of one to three super-users will be responsible for day-to-day operations, supported by the operations manager to ensure smooth implementation. The technological foundation will consist of cloud spreadsheets, online forms, and basic dashboards, providing an accessible and efficient platform for inventory management. Governance of the project will be overseen by the operations manager, who will act as the project owner. Technical leadership will be provided by internal staff or, if necessary, a short-term contractor. Before moving forward with design and rollout, stakeholder sign-off will be required to confirm alignment and commitment across all involved parties.

### 4.2.3 Identify sections of DTP to implement based on customer need

After analyzing the company's operational challenges and resource constraints, it was determined that inventory management is the most critical area for digital transformation. This section directly impacts production planning, shop-floor operations, sales forecasting, and purchasing decisions. Inefficiencies and inaccuracies in inventory control were found to be the root cause of frequent stockouts, excess inventory, and poor coordination across departments. Thus, considering Table 4 guidance, the following activities were chosen to achieve the objectives of the previous step and to conduct the implementation phase.

- Process Decomposition: The inventory lifecycle was broken down into microprocesses, including receipt of goods, putaway, consumption, production issue, shipment, returns, and reconciliation. Each micro-process was evaluated for its contribution to the overall value gap.
- Value Gap Analysis: Baseline metrics revealed that the largest discrepancies and operational losses occurred during stock reconciliation and real-time inventory updates. These processes were prioritized for digitalization due to their high impact on company performance.
- Minimal Data Model Definition: Essential data elements were identified: item ID, location, quantity, timestamp, user, and document reference. These fields were selected to ensure accurate tracking and reporting without overcomplicating the system.
- Integration Points: The new digital solution was designed to interface with existing manual workflows and legacy systems, allowing for gradual adoption and minimizing disruption.

In order to keep a frugal perspective on the whole implementation is important to state clearly the scope of implementation. In this sense, the DTP will focus exclusively on digitizing inventory management processes, starting with the most error-prone and resource-intensive activities. Other business functions will remain unchanged during the initial phase, but the solution will be designed for future integration and scalability.

The main rationale that underpins these activities is that by targeting inventory management as the first "island" of digital transformation, the company can achieve rapid, measurable improvements in operational efficiency and data accuracy, while keeping costs and complexity to a minimum.

### 4.2.4 Develop "islands of DTP"

Given the company's fragmented and inaccurate inventory management system (which leads to frequent stockouts, excess inventory, operational inefficiency, and customer dissatisfaction) the digital transformation approach must be both targeted and resourceconscious. The solution is to develop modular "islands" of digital transformation that focus specifically on the most critical inventory processes, instead of going for MM Level 5 as the objective. The Islands development consists of the next activities:

- Targeted Technology Selection: To address the lack of real-time, unified inventory data, select simple, low-cost digital tools such as cloud-based spreadsheets and online forms. These technologies are accessible, require minimal investment, and can be quickly adopted by staff.
- Modular Process Digitization: Build independent digital modules ("islands") for the most error-prone and resource-intensive inventory

activities, such as stock receipt, consumption tracking, and reconciliation. Each island is designed to solve a specific problem identified in the impact summary, such as reducing manual counting time and improving data accuracy.

- Interoperability and Future Integration: Ensure each island can exchange data with others using basic formats (CSV exports, simple APIs) and scheduled synchronization. This modularity allows for future scaling and integration as the company's digital capabilities grow.
- User-Centric Design: Develop straightforward interfaces and job aids tailored to each department's needs. For example, provide easy-to-use forms for shop-floor staff and realtime dashboards for planners, directly addressing the coordination and communication issues highlighted in the impact summary.
- Validation and Error Reduction: Implement basic validation rules to minimize data entry errors, ensuring that the digital records are reliable and actionable.
- Pilot and Iterative Deployment: Start with a pilot in a single department or product line, using clear acceptance criteria based on the desired impact (e.g., reduction in stockouts, improved inventory accuracy). Gather feedback, make adjustments, and expand the rollout in phases.

The expected outputs of the Islands development step are: (i) Modular digital solutions for key inventory processes; (ii) Integration specifications for data exchange and future scaling; and (iii) Pilot deployment plan with measurable success criteria. In developing these islands, the DTP is focused on those sections that would maximize the impact on the defined objectives. Then, by developing focused "islands" of digital transformation, the company can quickly address its most pressing inventory management challenges, achieve measurable improvements in efficiency and accuracy, and lay the foundation for broader digital integration, all within its resource constraints.

### 4.2.5 Implement

With the modular digital "islands" designed to address the company's fragmented and inaccurate inventory management, the implementation phase focuses on building, piloting, and operationalizing these solutions for rapid impact and adoption. Mainly, the implementation consists on the following tasks:

1. Tool Configuration: Set up the selected digital tools (e.g., cloud spreadsheets, online forms, dashboards) according to the blueprint developed in the previous phase. Ensure that essential data fields and validation rules are in place to support accurate, real-time inventory tracking.
2. Pilot Launch: Begin with a pilot deployment in a single department, product family, or shift. Train 1–2 super-users to operate the new system and provide concise job aids and micro-training sessions to facilitate quick adoption.
3. Feedback and Iteration: Conduct daily stand-ups during the pilot to capture user feedback, identify issues, and implement quick fixes to the user interface or process. Monitor key metrics such as inventory accuracy, update latency, and user adoption.
4. Phased Rollout: Once the pilot meets predefined acceptance criteria (e.g., improved accuracy, reduced manual counting time, high user adoption), expand the rollout in waves to additional departments or product lines. Continue to provide support and training to ensure smooth transition.
5. Change Management: Engage users throughout the process, highlight early wins, and incentivize correct use of the new system. Address resistance by demonstrating tangible improvements in efficiency and communication.

The implementation will result in a fully operational digital "island" for inventory management, complete with documented workflows and Quick-Start guides to facilitate user adoption. Training records and pilot logs will be maintained to support ongoing learning and troubleshooting, while an escalation contact list will be provided to address any technical or process-related issues that arise.

To mitigate risks, several strategies will be employed. Data entry errors will be minimized by reducing free-text input and enforcing strict validation rules. To encourage user adoption, staff will be actively involved in the build process, offered incentives, and shown performance metrics that demonstrate the system's benefits. Connectivity issues will be addressed by enabling offline data capture and scheduled synchronization, ensuring the reliability of the digital solution. By implementing these digital "islands" in a staged, user-focused manner, the company can rapidly tackle its most pressing inventory management challenges, reduce operational inefficiencies, and enhance customer satisfaction—all while staying within its resource constraints

### 4.2.6 Measure outcomes

Following the implementation of the digital "islands" for inventory management, the company conducted a thorough evaluation to determine the effectiveness of the solution and its impact on operations. The main outputs of the project can be listed in the following:

- Significant Time Savings: The company achieved an estimated 80% reduction in time spent on physical inventory control. Manual counting and reconciliation tasks, which previously consumed substantial staff hours, were streamlined through automated digital processes.
- Reduction in Stockouts: The frequency of stockouts was markedly reduced. Real-time inventory data enabled better planning and timely replenishment, minimizing lost sales and improving customer satisfaction.
- Improved Data Accuracy: Inventory records became more reliable and up-to-date. The consolidation of information into a single cloud-based system eliminated discrepancies between departments and ensured that all stakeholders had access to the same data.
- Enhanced Coordination and Communication: Friction between personnel was virtually eliminated. The new system provided a unified platform for inventory management, allowing production, sales, and purchasing teams to coordinate more effectively.
- Cost Avoidance: The company avoided expensive investments in physical hardware and comprehensive commercial solutions by leveraging existing digital capabilities and frugal technologies.

For the long-term management of this implemented solution, as well as to consider further extensions of digital transformations processes, it is advisable to continue monitoring KPI (such as inventory accuracy, update latency, and user adoption rates were monitored through dashboards and regular reports). Also, compile user feedback on usability and process improvements, which was used to refine the digital solution, this will accelerate new DTPs. Finally, with the success of the initial implementation, the company established criteria for scaling the solution to other departments and processes, ensuring continued alignment with resource constraints and business needs.

## 4.3 Concluding remarks from the case study

The new implemented system after DTP was one where all information was routed through a single cloud-based server, the interfaces with each stakeholder – further, the system was customized to customer needs, implementing spreadsheets, forms or reports. After a few initial hiccups, stock counts were automatically synchronized and reconciled. This real-time communication enabled a significant reduction in inventory and also improved accuracy, and importantly, avoided expensive investments in physical hardware.

The new Stock Management system is shown in Figure 2. In this figure, it can be observed that the digital inventory information is consolidated and unified into a single version. This version is then shared with the stakeholder areas, who can interact with it, and these interactions are visible to the rest of the stakeholders. The advantage of this solution is that it did not require investment in external systems.

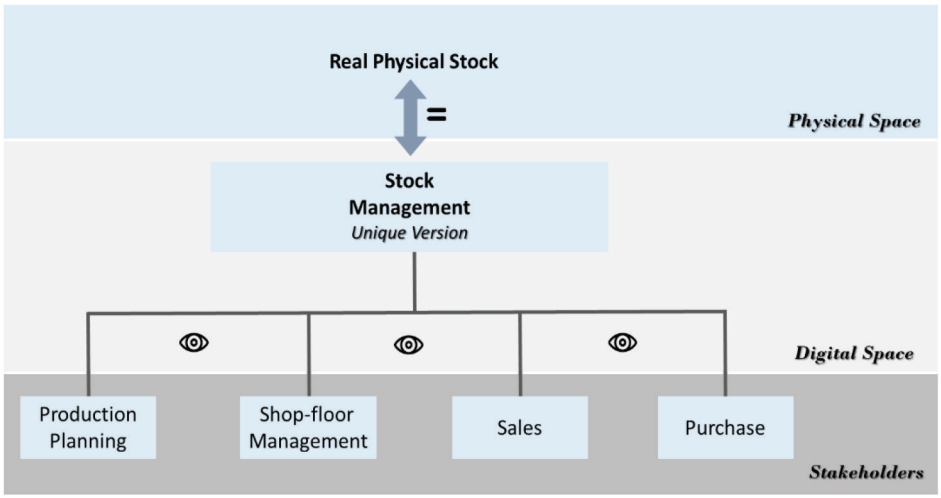


**Figure 2.** Stock Management system of the company after to Digital Transformation process

Instead, by using the same architecture and digital capabilities, it was possible to create a workflow that addressed the majority of the previously mentioned difficulties. The measured outcomes demonstrated that the frugal digital transformation approach delivered rapid, tangible improvements in inventory management. The company now benefits from greater operational efficiency, reduced costs, and impoved customer service, all achieved within its limited resource environment.

## 4.4 Discussions: comparative analysis to Maturity Models

Considering the success of the implementation of the FI approach to DTP, some general insights can be proposed. This approach tries to approach a clear gap on the literature as well as in the practice, where MM cannot overcome the limited factors that challenge SME's managers [7] [8]. In the same vein, the proposed approach provides a feasible means to get over those limitations and to achieve reasonable performance rates [29], [30], and contribute in the digital transformation of this type of enterprises [20].

The Frugal FI islands approach focuses on solving a clearly defined core problem with minimal investment and rapid deployment. It delivers tangible improvements quickly by prioritizing essential functionality and using familiar tools that reduce training needs. The approach lowers the financial and human resource barriers to digital transformation for SMEs, enabling immediate operational benefits and building organizational confidence in digital practices [23]. On the other hand, the maturity-model driven approach aims for comprehensive capability building and enterprise-wide integration [14]. It requires substantial time, capital, and specialized personnel to reach high levels of digital maturity. This path creates stronger long-term foundations for advanced analytics, lifecycle automation, and self-optimizing processes, but the upfront commitments increase exposure to implementation delays and higher failure risk [31].

The FI islands approach offers several distinct advantages. First, it delivers rapid results, with targeted deployments producing measurable gains in just weeks rather than months. Its affordability is another key strength, as minimal hardware and software expenditures make digital improvements accessible even to firms with tight budgets. Adoption is practical and straightforward, thanks to low training requirements and the continuity with existing workflows, which helps reduce user resistance. Additionally, the modular nature of these islands exposes simple integration points, supporting future scaling as the organization's needs evolve.

In contrast, full maturity-model transformations bring their own set of strengths. They enable comprehensive enterprise integration, with unified data models and consistent processes across all functions. This approach supports advanced capabilities, including high-level analytics, predictive functions, and cross-process optimization [32]. Furthermore, maturity-model initiatives typically incorporate robust governance and compliance features, such as security, reporting, and standardization, which are essential for regulated businesses. In Table 8, this comparison between FI Islands and Maturity model methods are highlighted.

In terms of practical guidance, i.e. for practitioners, it is advisable to begin with FI islands in order to achieve rapid wins and establish a reliable foundation of digital data. Each island should have clearly defined boundaries and interfaces to prevent the creation of isolated silos and to facilitate future integration. Value should be tracked using the Functionality over Resources metric, helping to prioritize which islands to deploy first [28]. Additionally, these islands can serve as a platform for building internal skills and confidence before committing to a comprehensive maturity-model transformation.

However, there are risks to consider. Frugal islands may accumulate technical debt if solutions are not properly documented or lack standardized interfaces for future integration. This risk can be mitigated by enforcing straightforward documentation standards and designing exportable data formats from the outset. On the other hand, the full maturity-model approach carries the risk of long implementation timelines and costly rework. To address this, it is recommended to stage maturity-model adoption

**Table 8.** Comparison between proposed method (FI Islands) and Maturity-models

| Approach | Cost | Time to implement | Required HR skills | Scalability | Risk of failure |
|---|---|---|---|---|---|
| FI islands (this paper) | Low | Short | Low-tomoderate | Medium (modular) | Low-tomoderate |
| Maturitymodel driven (full MM) | High | Long | High | High | High |

into phased milestones and to validate assumptions through small frugal pilots before embarking on large-scale rollouts.

There are also valuable research opportunities in this area. Empirical studies that compare the total cost of ownership and performance outcomes for firms that scale from frugal islands to maturity-model programs, versus those that adopt full maturity models from the start, would help clarify the trade-offs over a three to five year horizon. Furthermore, defining objective transition triggers (such as data volume, transaction rates, or capability thresholds) would assist managers in determining the optimal timing to move from isolated islands to a comprehensive digital transformation.

It is important to acknowledge that limitations remain. Frugal islands risk accumulating technical debt if ad hoc solutions are not properly documented or standardized for later integration. A medium-term (three to five year) comparative cost– benefit analysis is needed to determine when migrating from islands to platform-led solutions becomes economically advantageous. Future research should focus on developing hybrid roadmaps and objective transition triggers, such as data volume, transaction rates, or staff skill thresholds, to guide SMEs in expanding from isolated islands to broader digital transformation investments.

## 5. Conclusions

The possibility of improving business performance through digital transformation (DT) has generated growing interest in DT processes. The available tools for the development of DTP are not always suitable for all companies, particularly when there are limitations in resource availability, such as in the case of SMEs. These limitations require new and innovative tools to tackle a DTP. This work contributes in this regard by providing tools that facilitate DTPs in scenarios with limited economic and human resources. The proposed tools are based on the FI paradigm and effectively address these limitations.

A case study was developed in which the proposed methodology was applied and its effectiveness was proven. The case study involved the design and development of a new digital inventory management system that improved the accuracy of inventory information as well as the accessibility of that information. The proposed methodology could be adapted to the company's reality, which did not have an IT department or the possibility of purchasing commercial solutions. For further research it is proposed to delve in-depth in FI and MMs for DTP to develop new tools that are closer in resources requirements to SME in emerging countries reality.

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