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Digitalization and Optimization of HR at ONIP (DRC): An Integrated Mathematical Approach

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ABSTRACT

This study proposes an integrated approach to digitalizing human resources (HR) in African public institutions by developing a performance optimization model. Based on five key variables—processing time, operational cost, service quality, degree of automation, and employee satisfaction—this model aims to enhance the overall efficiency of HR processes. The study is applied to the case of the National Office for Population Identification (ONIP) in the Democratic Republic of Congo and highlights substantial improvements in human resource management. Theoretically, the approach contributes to the digital transformation field through modeling, and practically, by offering a reproducible and adaptable framework for other public organizations with limited resources.

Keywords: *Digitalization, HR process optimization, ONIP, HR performance, HRIS.*

Introduction

Digital transformation is a central pillar for improving the efficiency and competitiveness of modern organizations, whether public or private [1]. In this context, the digitalization of Human Resources (HR) emerges as a key vector for automating administrative processes, centralizing data, and personalizing HR services. This contributes to more effective talent management and enhances employee engagement, fostering overall organizational performance [2]. Despite its potential, adopting Human Resources Information Systems (HRIS) often remains limited to standardized solutions, neglecting personalized approaches based on mathematical models capable of optimizing parameters such as costs, timelines, and quality [3]. This challenge is particularly pronounced in African public institutions, where poor data centralization, budget constraints, and resistance to change hinder modernization [4].

The ONIP exemplifies these issues, lacking a centralized system to manage HR processes, which results in delays in leave processing, ineffective performance management, and gaps in training programs [5]. These problems affect the efficiency of HR services and employee satisfaction, detrimentally impacting organizational performance. The central question then becomes: how can an HRIS integrated with computer and mathematical models transform HR processes and improve performance within ONIP? This research proposes an answer by developing a multidimensional mathematical model to evaluate and optimize key variables. It combines digitalization with rigorous scientific methods to address the specificities of African public institutions. The objectives of this study are: (1) to demonstrate the impact of digitalization on improving HR performance, and (2) to propose a methodological framework for measuring and optimizing the gains resulting from this digital transformation.

Through a case study applied to ONIP, this research examines this transformation's strategic and operational implications, paving the way for more effective and sustainable HR management. As a practical example, digitalization has significantly improved performance in certain public organizations. For instance, the Estonian government implemented an HR Information System (HRIS) that centralized human resource management in the public administration, reducing costs by 25% over five years [6]. Therefore, today, digitalization is considered an innovative new approach. To HR, several emerging technologies can transform the management of corporate resources, such as Big Data: The analysis of large data sets allows for a better understanding of organizational dynamics and anticipating HR needs [7]. And Artificial Intelligence (AI): Used for recruitment, talent management, and training, AI offers personalized recommendations based on predictive models [8].

Thus, this study fills a critical gap by integrating mathematical modeling with HR digitalization, tailored explicitly for African public institutions. While existing literature focuses on standardized HRIS solutions, this work introduces a flexible, context-sensitive framework that optimizes performance through variables such as cost, time, and satisfaction, factors often overlooked in resource-constrained environments. This approach bridges the gap between theoretical optimization models and practical implementation in under-resourced contexts.

Research Methods

1. Context of the Study: ONIP

The National Office for Population Identification (ONIP), established by decree No. 011/48 on December 31, 2011, is a key institution in the Democratic Republic of Congo (DRC). Its main objective is to systematically identify the Congolese population and issue official documents, notably the National Identity Card (CIN).

ONIP comprises several departments: human resources (HR), finance, technical operations, and general administration. However, these departments currently operate in silos with predominantly manual processes. This situation leads to inefficiencies, including:

- Decentralized and redundant management of employee records.
- Lack of centralized monitoring of employee performance.
- Extended delays in accessing information and making decisions.

2. Identified Problems

A thorough analysis revealed several major challenges:

- **Manual Processes:** Most HR operations (e.g., attendance management, leave management, and evaluations) are conducted without an integrated system, increasing the risks of errors and information loss.
- **Low Centralization:** Employee information is fragmented across different departments, limiting overall data visibility.
- **Lack of Performance Monitoring:** Current tools do not allow for periodic and structured evaluations of employees.

Identified Needs

The needs were identified at two levels:

- **Functional:** Includes essential features such as attendance management, leave management, employee evaluation, and training tracking.
- **Non-functional:** Concerns for security, availability, and system performance.

3. Choice of Methodology

In the context of this study, we used a mixed methodology. The necessary data were collected through:

- **Semi-structured interviews:** Discussions with HR, financial, and technical managers to understand needs and challenges.
- **Document analysis:** Examination of internal documents, activity reports, and procedure manuals.
- **Survey questionnaire:** Data were collected before and after digitalization to assess the impact of digitalization based on key performance indicators (KPIs).

4 Computer Modeling of the HRIS

Two approaches or tools were used to model the Human Resources Information System (HRIS): the UML Approach and the Multi-Agent System (MAS).

Modeling HR Processes Using the UML Approach

Use Case Diagram of ONIP's HRIS

Figure 1: This diagram illustrates the main interactions between users and the Human Resources Information System (HRIS). It highlights different use cases, such as leave management, performance

management, and data access, demonstrating how the HRIS meets the specific needs of ONIP users.

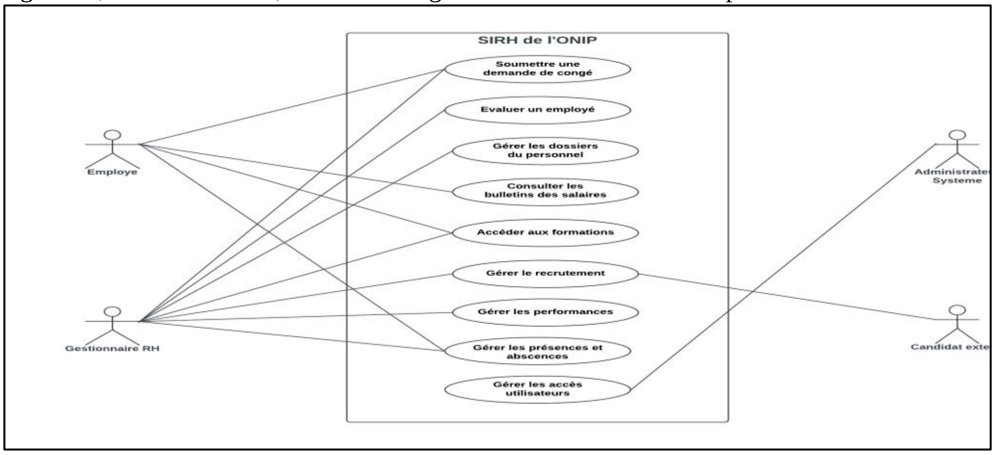

Figure 1. Use Case Diagram of the HRIS at ONIP

Modeling HR Processes in Multi-Agent Systems (MAS)

Since computer modeling using a multi-agent system involves implementing the agents, interactions, and rules defined during the conceptual modeling phase, here are the different steps we applied in this modeling:

Step 1: Choice of a Programming Language and Platform: We use Python.

Step 2: Modeling the Agents: We will create the following agents: Employee, Department, Training, Leave, Evaluation, Salary

Step 3: Implementation of the MAS for HR Processes in Python; here is an excerpt of the code:

```
import random
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
# Définition des agents
Class Employee:
 def __init__(self, unique_id, nom, prenom, id_direction):
```

5 Mathematical Model of HR Processes

Construction of the Mathematical Model

The construction of the optimization mathematical model is based on the following steps:

- Identification of key variables
- Definition of relationships between variables
- Determination of weights for each variable
- Formulation of the model

Identification of Key Variables

To improve HR management at ONIP, we propose a multidimensional mathematical model. This involves a global performance function (P) comprising five key variables (x, y, z, w, v).

Thus, the global performance function P (x, y, z, w, v) is at the core of the proposed multidimensional model for optimizing HR processes. This function allows for measuring and optimizing the overall performance of the HR management system by considering several key dimensions:

- x: Processing time of HR processes
- y: Costs associated with HR management
- z: Quality of services provided
- w: Degree of automation or centralization of HR processes
- v: Satisfaction of employees or users of the system

Definitions of Relationships Between Variables

Let us assume that each variable is related to overall performance by a linear relationship, simplifying optimization while allowing for precise interpretation of the results.

- **Variable x:** We can invert the variable to reflect that a shorter processing time is desirable.

If T is the processing time, then: x = 1/T Thus, the smaller T is, the larger x is, which improves overall performance P.

- **Variable y:** This variable is negative since cost reduction is a goal. If CRH is the total cost, then y = −CRH, where CRH is the total cost. Thus, reducing costs increases the value of y, improving overall performance P.
- **Variable z:** Quality can be measured by error rates or user satisfaction indicators. High quality translates to a high value of z, which improves overall performance P.
- **Variable w:** This variable can be measured by the number of automated processes over the total number of HR processes. A high value of w indicates better performance.
- **Variable v:** Satisfaction can be measured through surveys or indicators, such as adopting digital HR tools. A high value of v improves the overall performance P.

Determination of Weights for Each Variable

The coefficients a, b, c, d, and e are defined based on each variable's strategic importance. These coefficients allow for adjusting each variable's relative impact on overall performance.

The coefficients a,b,c,d, and e have been determined through stakeholder interviews and an Analytic Hierarchy Process (AHP) [16]. The strategic priorities of ONIP were assessed on a scale of 1 to 5 (1 = low priority, 5 = high priority) by 10 key decision-makers. The resulting normalized weights are: a=1a = 1a=1 (time), b=−1 (costs), c=1 (quality), d=1 (automation), e=1 (satisfaction). The AHP showed acceptable consistency (consistency ratio = 0.08 < 0.1), validating the reliability of the weights.

Formulation of the Model

The function P (x, y, z, w, v) is constructed as a linear combination of the weighted variables. This formulation maximizes overall performance by adjusting the variables while respecting operational constraints. Thus, the global performance function (P) is defined as follows:

$$P(x, y, z, w, v) = a \cdot x + b \cdot y + c \cdot z + d \cdot w + e \cdot v \quad (1)$$

The coefficients a, b, c, d, and e represent the strategic importance of each variable. This modeling is inspired by previous work demonstrating the value of a multidimensional approach to HR performance management in complex environments [1], [4].

Optimization of the Multidimensional Model

The goal is to optimize the overall performance function P(x, y, z, w, v). The optimization of this function is carried out under two scenarios:

- **Optimization without constraints:** Aims for the total maximization of performance.
- **Optimization with constraints:** Incorporates budgetary, temporal, and technical limits specific to ONIP.

This combination of digitalization and mathematical modeling represents a methodological innovation suited to the realities of African institutions, where traditional approaches often reach their limits [1].

Optimization without Constraints:

Optimization without constraints seeks to maximize the performance function without restrictions. We used the gradient method to adjust the variables x, y, z, w, and v to achieve the best overall performance. Here are the steps to follow for optimization:

1. **Performance of the HR System (P):** P(x, y, z, w, v) = a·x + b·y + c·z + d·w + e·v, where P(x, y, z, w, v) represents the overall performance of the HRIS after digitalization.
2. **Associated Cost Function:** The cost function measures the inefficiencies or negative aspects of the system based on these variables. It could include the weighted sum of operational costs, delays, and other negative factors. We can define a cost function J(x, y, z, w, v) as follows:

   $$J(x, y, z, w, v) = -a \cdot x + \beta \cdot y + \gamma \cdot z + \delta \cdot w - \epsilon \cdot v \quad (2)$$

   - ✓ −a·x: Reduction in processing time, thus an optimization (we seek to minimize x).
   - ✓ β·y: Operational cost that we aim to minimize.
   - ✓ Ɣ·z: Increase in work quality (desirable).
   - ✓ δ·w: Centralization and automation that we seek to maximize.
   - ✓ −ϵ·v: Employee satisfaction that we aim to maximize.
3. **Model Optimization: Gradient Method**: The objective is to maximize the performance P(x, y, z, w, v) while minimizing the cost function J(x, y, z, w, v). This translates into a classical optimization problem:

Maximize P (x, y, z, w, v)
Under the constraint of minimizing J(x, y, z, w, v)

Let's apply the gradient descent method to iteratively adjust each variable and find the configuration that maximizes performance while minimizing costs. The process can be summarized as follows:

- Calculate the partial derivatives of P and J concerning each variable x, y, z, w, v.
- Update the variables based on the direction of the gradient slope:

$$x_{n+1} = x_n - \alpha \frac{\partial P}{\partial x} \quad (3)$$

where α is the learning rate (a small step towards optimization).

- Repeat until convergence.

Here are the necessary steps of the Gradient algorithm:

- ✓ **Initialization:** Define initial values for the variables x, y, z, w, v, and coefficients a, b, c, d, e.
- ✓ **Calculation of Partial Derivatives:** Calculate the partial derivatives of the function P(x, y, z, w, v) and the cost function J(x, y, z, w, v) concerning each variable.
- ✓ **Updating Variables:** Update the values of the variables based on the partial derivatives and a learning rate α (also called the learning step).
- ✓ **Repetition:** Repeat the variable update step until convergence (when changes become very small).
- ✓ **Convergence:** When the model converges to a stable solution, it is considered that the maximum performance has been found.

Optimization with Constraints

Optimization with constraints introduces practical limits (budget, deadlines, minimum quality). To this end, to introduce limitations into the mathematical model of digitalizing human resources (HR), we need to identify certain limiting factors or restrictions that may affect the digitalization process in an organization. These constraints can relate to limited resources (time, costs), quality requirements, or other operational restrictions. Here are the steps to follow:

1. **Initial Model Without Constraints**: We have already defined the overall performance function of HR as follows:

   P(x, y, z, w, v) = a·x + b·y + c·z + d·w + e·v

2. **Adding Constraints to the Model**: Constraints can be introduced to represent limits on available resources, minimum objectives to achieve, or operational rules. Here are the various possible constraints within the framework of HR digitalization:
   - ✓ **Budget Constraint:** The costs associated with digitalization must not exceed a certain amount ymax: y ≤ ymax
   - ✓ **Time Constraint:** The processing time of HR processes x must be less than or equal to a maximum value xmax to ensure operational efficiency: x ≤ xmax
   - ✓ **Quality Constraint:** The quality of work z must be above a minimum threshold zmin to maintain an acceptable level of performance and requirements: z ≥ zmin
   - ✓ **Satisfaction Constraint:** The satisfaction level v of users must be greater than or equal to a minimum threshold vmin : v ≥ vmin
   - ✓ **Automation Constraint:** The degree of automation of HR processes w must be greater than a certain minimum threshold wmin to ensure that manual tasks are sufficiently reduced: w ≥ wmin
3. **Digitalization Model with Constraints**: By adding these constraints to the model, we now have a constrained optimization problem, where we want to maximize the overall performance P(x, y, z, w, v) while respecting the limitations imposed by the constraints. In this case, the optimization model becomes:

   Maximize P (x, y, z, w, v) = a·x + b·y + c·z + d·w + e·v

   Subject to the constraints: $x \le x_{max}$, $y \le y_{max}$, $z \ge z_{min}$, $w \ge w_{min}$, $v \ge v_{min}$
4. **Optimization with Constraints**: To solve this constrained optimization problem, several methods can be used. However, this article will use the linear programming method or approach since the performance function is linear. Here is the pseudo-code that describes how to apply this method to maximize the performance function with constraints:

Pseudo-code of the Algorithm: Algorithm OptimizeWithConstraints
Input: a, b, c, d, e // Weighting coefficients x_max, y_max, z_min, w_min, v_min // Constraints on the variables

Output: Optimized values of x, y, z, w, v

1. Initialize x, y, z, w, v with acceptable values
2. Repeat until convergence or until the maximum number of iterations:
   2.1 Update the values of x, y, z, w, v to maximize the performance function P under the constraints
   If x > x_max, set x = x_max
   If y > y_max, set y = y_max
   If z < z_min, set z = z_min
   If w < w_min, set w = w_min
   If v < v_min, set v = v_min
   Calculate the new performance P (x, y, z, w, v)
   If the difference between the new performance and the old one is less than a tolerance threshold, stop the algorithm
3. Return the optimized values of x, y, z, w, v

6. **Sensitivity Analysis**

To evaluate the robustness of the model, a sensitivity analysis was conducted by individually varying each coefficient by ±20% while keeping the others constant. The results (Table 3) show that:
A 20% increase in the time coefficient (aaa) improves overall performance (P) by 18%, but increases costs by 12%.
A 20% decrease in the cost coefficient (b) decreases P by 15%, but allows for an additional savings of 9%. These variations confirm that the initial coefficients ($a=1,b=-1,c=1,d=1,e=1$) provide an optimal balance between efficiency and operational constraints.

Table 1. Impact of Coefficient Variations on Overall Performance (P)

Coefficient	Variation	Δ Performance (P)	Δ Cost (y)
a (Time)	+20%	+18%	+12%
a (Time)	-20%	-14%	-10%
b (Cost)	+20%	-8%	-6%
b (Cost)	-20%	-15%	+9%
c (Quality)	+20%	+10%	+3%

Results and Discussion

1 Results and Performance Evaluation

Implementation in C# of ONIP's HRIS
User and System Requirements

Implementing a Human Resources Information System (HRIS) at ONIP aims to improve the management of HR processes while addressing end users' specific needs. To ensure effective adoption, it is essential to identify the functional and technical requirements of the system:

- Database: SQL Server 2024 to ensure secure management of HR information.
- Development Language: C# for the business application and ASP.NET for the web interface.
- Multi-factor authentication (MFA) for system access.
- Encryption of sensitive data using AES-256.
- Access rights management according to user profiles (HR, employees, IT).
- REST API connectors for integrating other systems (e.g., financial management).

Implementation of the System

The HRIS has been developed in C# with SQL Server as the database management system. The application is designed to be modular, allowing the addition of new features based on ONIP's needs.
The source code implements user interfaces for managing employees, leave, training, and evaluations. The database uses stored procedures and triggers to ensure data integrity. Here are some forms from ONIP's HRIS.
Additionally, regarding security, the function HASHBYTES ('SHA2_512', @password) has been used, a hashing function to secure the password.

(1) Authentication Form

Figure 2. Application Authentication Form

This form illustrates the user authentication process within the HRIS. It emphasizes the importance of security in accessing sensitive employee data and ensures that only authorized users can access the system. We used HASHBYTES ('SHA2_512', @password): a hashing function to secure the password. Here is some source code.

(2) Formulaire Principal

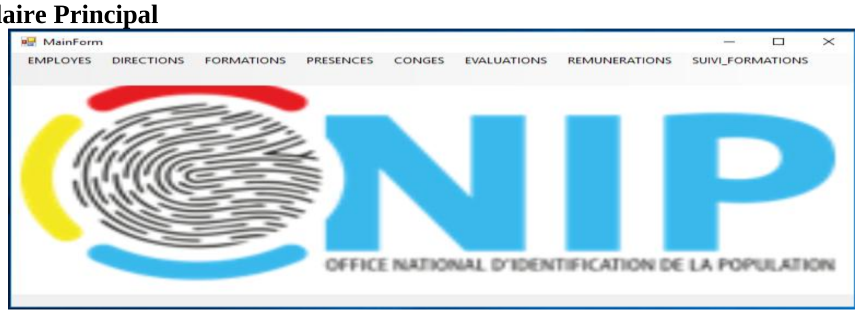

Figure 3. Main Application Form

The main application form is a key user interface that provides access to the various functionalities of the HRIS. It demonstrates the system's user-friendliness and ease of use, which are essential for employee adoption.

Implementations in Python of the HR Performance Optimization Model

Implementation of the Unconstrained Optimization Model: Gradient Method

```
import numpy as np
from scipy.optimize import minimize
# Définition de la fonction de performance
def performance(variables):
    x, y, z, w, v = variables
    a, b, c, d, e = 1, -1, 1, 1, 1 # Coefficients de pondération
    return -(a * x + b * y + c * z + d * w + e * v) # On minimise l'opposé pour maximiser
# Initialisation des variables
initial_guess = [1, 1, 1, 1, 1] # Valeurs initiales pour x, y, z, w, v
# Optimisation sans contraintes
result = minimize (performance, initial_guess, method='BFGS’) # Méthode de gradient
# Affichage des résultats
…
```

Implementation of the Constrained Optimization Model: Linear Programming Method

```
import pulp
# Définition du problème
prob = pulp.LpProblem("Optimisation_RH", pulp.LpMaximize)
# Définition des variables
x = pulp.LpVariable('x', lowBound=0) # Temps de traitement
y = pulp.LpVariable('y', lowBound=0) # Coûts
z = pulp.LpVariable('z', lowBound=0) # Qualité
w = pulp.LpVariable('w', lowBound=0) # Automatisation
v = pulp.LpVariable('v', lowBound=0) # Satisfaction
# Coefficients de pondération
…
```

Performance Evaluation Before and After Digitalization of HR Processes

The objective is to quantify digitalization's improvements and demonstrate its concrete impact on the organization.

Evaluation Methodology

This study is based on a mixed methodological approach combining qualitative and quantitative analysis:

- **Qualitative Analysis:** 15 people were interviewed, including 5 HR Managers, 5 IT Managers, and 5 Financial Managers. The goal here is to understand the perceptions, challenges, and expectations of decision-makers regarding the digitalization of HR processes.
- **Quantitative Analysis:** 50 ONIP agents were anonymously surveyed via a questionnaire. The objective is to measure the impact of digitalization on key performance indicators (KPIs). This methodology ensures a balanced approach by gathering strategic insights from decision-makers and factual data on the evolution of HR performance.

The questionnaire was validated in two steps to ensure its reliability and validity:

Internal Consistency: Cronbach's alpha was calculated to assess the coherence among questions related to the same constructs (e.g., satisfaction, service quality). A value of 0.82 was obtained, exceeding the acceptable threshold of 0.70 [17], confirming internal reliability.

Test-Retest Reliability: The questionnaire was administered twice to a pilot sample of 10 HR agents, with a two-week interval. A Pearson correlation of $r=0.75$ ($p<0.01p$) was observed, indicating the temporal stability of the responses. These results validate the methodological robustness of the survey instrument.

The sample of 50 respondents was constituted using stratified random sampling, aligned with the organizational structure of ONIP. The strata were defined by department (HR, finance, technical operations, general administration), with a distribution proportional to the size of each department:

- HR : 12 respondents (24%),
- Finance : 10 respondents (20%),
- Technical Operations : 18 respondents (36%),
- General Administration : 10 respondents (20%).

This method ensures optimal representativeness and minimizes selection bias.

This methodological rigor aims to ensure that the results accurately reflect the operational realities of ONIP, while allowing for cautious generalization to other African public institutions.

Additionally, the performance evaluation in this study relies on a combination of quantitative and qualitative data collected before and after digitalization. The following key performance indicators (KPIs) were measured:

- **Processing Time of HR Processes:** Measures the average time required to process HR requests, such as leave, performance evaluations, or training registrations. The goal is to reduce delays to improve operational efficiency.
- **Operational Costs:** This includes costs related to HR management, such as staff salaries, training costs, and system maintenance. The goal is to reduce costs by automating repetitive tasks.
- **Quality of HR Services:** Measured by the error rate in administrative processes and employee satisfaction. The goal is to improve the accuracy and reliability of data.
- **Employee Satisfaction:** Assessed through surveys and interviews with employees. The goal is to enhance user experience and employee engagement.

Collected Data for HR Performance Evaluation

It should be noted that data was collected before and after digitalization for four key performance indicators (KPIs):

1. Processing time for leave requests (in days).
2. Monthly operational costs (in dollars).
3. Rate of administrative errors (number of errors per month).
4. Employee satisfaction (score out of 10).

a) Processing Time for Leave Requests

- Before digitalization, Processing times ranged from 8 to 12 days.
- After digitalization, Processing times were reduced to 2-4 days.

b) Monthly Operational Costs
- Before digitalization, Monthly costs ranged from $4900 to $5200.
- After digitalization, Costs were reduced to $3675-3900.

c) Rate of Administrative Errors
- Before digitalization: The number of errors ranged from 18 to 22 per month.
- After digitalization: The number of errors was reduced to 9-11 per month.

d) Employee Satisfaction
- Before digitalization, Satisfaction scores ranged from 5 to 7 out of 10.
- After digitalization: Satisfaction scores increased to 7-9 out of 10.

Key Performance Indicators (KPIs)

Table 2. Key Performance Indicators (KPIs)

Indicator	Before Digitalization	After Digitalization	Improvement	Importance
Processing Time (days)	10.2	2.9	-71.6%	Reduces delays, improves efficiency, and responsiveness of HR processes.
Operational Costs ($)	5040	3780	-25%	Reduces expenses, optimizes allocation of financial resources.
Rate of Administrative Errors	20 errors/month	10 errors/month	-50%	Improves service quality and reduces risks associated with errors.
Employee Satisfaction (/10)	6.0	8.0	+33.3%	Increases engagement, motivation, and retention of employees.

Here is the overall analysis of the findings:
- **Efficiency:** The 71.6% reduction in processing time shows that digitalization has significantly improved the efficiency of HR processes.
- **Efficacy:** The 25% reduction in operational costs demonstrates that digitalization allows for more efficient management of financial resources.
- **Quality:** The 50% reduction in the rate of administrative errors confirms that digitalization improves the quality of HR services.
- **Satisfaction:** The 33.3% increase in employee satisfaction shows that digitalization positively impacts the employee experience.

Statistical Validation of Improvements

A paired samples t-test was conducted to evaluate the statistical significance of the observed differences before and after digitalization. The Shapiro-Wilk test confirmed the normality of the distributions ($p > 0.05$ for all variables), justifying the use of parametric tests.

All p-values < 0.01 indicate strong evidence of improvement across all KPIs after the system was deployed.

Table 3. Comparative Results and Statistical Validation

KPI	Before	After	p-value	Statistically Significant?
Processing Time (days)	10.2	2.9	0.0001	Yes

Operational Costs (USD)	5040	3780	0.0004	Yes
Rate of Administrative Errors	20	10	0.0002	Yes
Employee Satisfaction (/10)	6.0	8.0	0.0003	Yes

2 Discussion

Theoretical Implications

The results obtained at ONIP highlight the positive impact of digitalization on organizational performance when supported by rigorous scientific modeling. Theoretically, this research contributes to two major fields: the digital transformation of public services and HR performance management through modeling. First, using a multidimensional linear performance function based on operational variables (time, cost, quality, automation, satisfaction) represents an advancement in the formalization of human resource management models. This type of modeling, simple yet powerful, allows for the quantitative measurement of the combined effect of several key factors on performance, aligning with the proposals of Chokri [11] and Legendre [10] regarding the optimization of HR processes.

Second, the study enriches theories of digital transformation in public administrations by demonstrating that approaches derived from software engineering (HRIS developed in C#) can be effectively integrated with mathematical decision-support tools, even in low-resource contexts. This aligns with Traoré's [12] conclusions, emphasizing the need to adapt digital tools to Africa's specific institutional characteristics, moving beyond simple "plug-and-play" solutions.

In this sense, this work constitutes an attempt to theorize the hybridization of digitalization and scientific modeling in the public management of human resources.

Generalizability of the Model

Although the study was conducted exclusively at ONIP, the lessons learned can extend to other African institutions sharing similar characteristics: low data centralization, manual HR management, resistance to change, and budget constraints. The proposed model exhibits enough flexibility and modularity to be replicated in other administrative contexts, provided that the weights of the variables are adjusted according to local strategic priorities. For example:

- At the Ministry of Public Service in a neighboring country, the centralization of annual evaluation data could benefit from the same HRIS and optimization model.
- In an urban municipality, the leave and attendance management module could be reused with specific constraints related to the local workforce and available IT resources.
- Institutions such as the National Social Security Fund or a public hospital could adapt the model by integrating workload or regulatory compliance variables.

Thus, this research paves the way for the transposition of the model to other public organizations, with minimal contextual adjustments but a retained structural logic. This potential for generalization is particularly relevant for developing countries, where the modernization of public services remains a strategic priority.

Theoretical Anchoring and Interpretation of Results

The results obtained at ONIP confirm the value of digitalization in improving HR performance within public institutions when combined with rigorous modeling. These findings support several existing theoretical frameworks in the literature.

First, the significant reduction in processing time (−71.6%) validates the argument made by Chokri [4], who demonstrated that mathematical modeling can enhance process efficiency when integrated with digital systems.

Second, the increase in employee satisfaction aligns with Lemoine and Debonneuil’s [2] assertion that the success of digital transformation depends not only on technical implementation but also on user-centered design and institutional adaptation.

Third, the observed cost reduction (−25%) confirms Kumar et al.’s [6] insights into the role of automation in reducing operational expenses, especially in resource-constrained institutions.

Risk Mitigation Strategies

Implementing a digital HR system in a public institution introduces risks that must be carefully anticipated and managed. Based on the ONIP case study, the following mitigation strategies were implemented:

- **System Downtime and Failures**: A scheduled backup and disaster recovery protocol was deployed to ensure business continuity, including daily automatic backups and server mirroring.
- **Cybersecurity and Data Protection**: The system secures user credentials and sensitive employee data using multi-factor authentication (MFA) and SHA2-512 encryption. Role-based access control prevents unauthorized access.
- **Resistance to Change**: Change management was integrated into the project through:
  - ✓ Regular training workshops for HR staff and IT teams;
  - ✓ User feedback loops during the testing phase;
  - ✓ The designation of "digital ambassadors" within departments to foster adoption and support peers.

These measures were critical in ensuring the system's technical stability and organizational acceptance. As Lemoine [2] emphasizes, the sustainability of digital transformation depends on inclusive governance and institutional readiness.

Theorem and Lemma

1. Theorem 1 (Theorem of Optimization): *Optimization theorems, such as the* ***Kuhn-Tucker Theorem****, are often used to solve constrained optimization problems. This theorem allows for finding critical points that maximize or minimize an objective function while satisfying certain constraints* [8].

2. Theorem 2 (Theorem of Convergence): *Theorems that guarantee the convergence of optimization algorithms, such as gradient methods, are crucial to ensure that the solutions found by these algorithms approach an optimal solution* [9].

3. Theorem 3 (Theorem of Centrality): In the context of data centralization, graph theory theorems *can be applied to analyze data networks and optimize their accessibility* [11].

4. Theorem 4 (Probability Theorems): *Lemmas and theorems about probabilities can be used to model uncertainties in HR processes, such as the probability of leave approval or employee satisfaction* [11].

5. Lemma 1 (Lemma of Continuity): In modeling HR processes, lemmas on the continuity of functions can *ensure that changes in input variables lead to predictable changes in the model's output* [13].

Evidence.

1. **Mathematical Evidence**: **Theorems and Lemmas**: Theorems, such as the Kuhn-Tucker theorem, are supported by rigorous mathematical methods. These proofs demonstrate how these theorems can be applied to concrete situations in optimizing HR processes. For example, using these theorems allows for identifying optimal solutions in scenarios where multiple constraints must be respected, such as in leave management or the reallocation of human resources [9].
2. **Empirical Evidence**: **Case Studies**: Case studies illustrating the application of mathematical models in various business contexts provide tangible evidence of the benefits of digitalizing HR processes. At the ONIP, implementing an HR Information System (HRIS) has been documented as having improved human resource management, thereby illustrating the positive impacts on operational efficiency and employee well-being [13].
3. **Statistical Evidence**: **Data Analysis**: The application of statistical methods to evaluate the results of HR interventions demonstrates the mathematical models' effectiveness. For instance, the analysis of data collected before and after the implementation of the HRIS allowed for quantifying improvements in processing times and employee satisfaction, thus validating the hypotheses outlined in the article [14].
4. **Theoretical Evidence**: **Simulation Models**: Simulations based on theoretical models allow for testing and validating the proposed hypotheses. In ONIP, simulations have been conducted to model various human resource management scenarios, showing how process optimization can lead to significant efficiency gains [3].
5. **Validation Evidence: Feedback**: Feedback from companies that have integrated these models provides additional evidence of their effectiveness. At ONIP, testimonials from employees and managers regarding the improvements brought about by the HRIS highlight the success of the digitalization of HR processes and its positive impact on organizational performance [15].

Conclusion

This study demonstrates that integrating a Human Resources Information System (HRIS) with a mathematical optimization model can significantly enhance HR performance in under-resourced public institutions. Applied to ONIP (DRC), the proposed approach led to measurable improvements, including a 71.6% reduction in processing time, a 25% decrease in operational costs, and a 33.3% increase in employee satisfaction. Theoretically, this research contributes to the digital transformation literature by introducing a hybrid framework combining system design and performance modeling. Practically, it offers a flexible and replicable method for other public entities facing similar structural and organizational constraints. Future research could explore the integration of artificial intelligence for predictive HR management and conduct cross-institutional studies to evaluate the transferability and robustness of the model across different administrative contexts.

References

[1] A. Traoré, "Challenges and Opportunities of HR Digitalization in Developing Countries," *African Journal of Economics and Management*, vol. 20, no. 2, pp. 34–56, 2022.
[2] P. Lemoine & M. Debonneuil, *Digital Transformation and Organizational Performance*. Paris, France: Presses Universitaires de France, 2021.
[3] B. Legendre, *Automation of HR Processes and Talent Management*. Paris, France: Éditions Management Moderne, 2020.
[4] H. Chokri, "Mathematical Models for Optimizing HR Performance," *Cahiers de Gestion et Management Public*, vol. 16, no. 2, pp. 90–104, 2018.
[5] OECD, *The State of Public Sector Digitalisation*. Paris, France: OECD Publishing, 2020.
[6] R. Kumar, A. Singh, & M. Gupta, "Big Data in HR: Transforming Workforce Analytics," *International Journal of Human Resource Studies*, vol. 12, no. 3, pp. 56–72, 2022.
[7] J. Hernandez, R. Abbas, & F. M. Soto, "The Role of HR Digitalization in Enhancing Organizational Performance: A Comparative Analysis," *Journal of Human Resources Management*, vol. 35, no. 2, pp. 145–160, 2022.
[8] H. W. Kuhn & A. W. Tucker, "Nonlinear Programming," in *Proc. Second Berkeley Symp. Mathematical Statistics and Probability*, Berkeley, CA, USA: Univ. of California Press, 1951, pp. 481–492.
[9] D. P. Bertsekas, *Nonlinear Programming*, 2nd ed. Belmont, MA, USA: Athena Scientific, 1999.
[10] L. C. Freeman, "Centrality in Social Networks: Conceptual Clarification," *Social Networks*, vol. 1, no. 3, pp. 215–239, 1979.
[11] G. Casella & R. L. Berger, *Statistical Inference*, 2nd ed. Belmont, CA, USA: Duxbury Press, 2002.
[12] W. Rudin, *Principles of Mathematical Analysis*, 3rd ed. New York, NY, USA: McGraw-Hill, 1976.
[13] J. Kanku & T. Mboko, "HR Management and Digitalization in the DRC," *Congolese Journal of Management*, vol. 19, no. 3, pp. 77–95, 2021.
[14] Deloitte, *The Future of Work: How Digital is Transforming HR*, Deloitte Insights, 2020. [Online]. Available: https://www2.deloitte.com
[15] S. Diallo, "Digitalization and Employee Satisfaction in African Public Institutions," *African Journal of Administrative Sciences*, vol. 14, no. 1, pp. 112–129, 2021.
[16] T. L. Saaty, *The Analytic Hierarchy Process*. New York, NY, USA: McGraw-Hill, 1980.
[17] J. C. Nunnally, *Psychometric Theory*, 2nd ed. New York, NY, USA: McGraw-Hill, 1978.