

# ***Redesign of the Cash Reconciliation Process in a Banking Institution through the Application of the SMED Methodology***

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**Abstract** — *Banking institutions require efficient and reliable operational processes to ensure financial accuracy and strong internal control. Cash reconciliation is a critical daily process that is traditionally performed at the end of the workday, often resulting in long closing times and increased risk of errors. This study presents the redesign of the cash reconciliation process in a banking institution using the Single-Minute Exchange of Die (SMED) methodology [1]. Although originally developed for manufacturing, this approach was adapted to redistribute reconciliation activities throughout the day through partial cash counts and continuous controls. A before-and-after analysis was conducted using time measurements and statistical evaluation. Results show a 27.63 percent reduction in total reconciliation time and improved process stability. Hypothesis testing confirmed that the reduction was statistically significant. The findings demonstrate that SMED can be effectively applied to financial service processes to enhance operational efficiency without weakening internal controls [2] [3].*

**Keywords:** *SMED, Lean Manufacturing, Changeover Time Reduction, OEE, Banking operations, Cash reconciliation, Process improvement.*

## **INTRODUCTION**

Cash reconciliation is a fundamental operational process in banking institutions because it ensures that physical cash balances match system records, supporting financial reliability and asset protection. Traditionally, this process is performed at the end of the workday, concentrating multiple validation activities into a short period. This practice often leads to extended closing times, operational pressure, and late detection of discrepancies.

Lean methodologies have been widely used to reduce waste and improve efficiency in manufacturing environments [4]. One of these methodologies, SMED, focuses on reducing changeover time by separating internal and external activities [1]. In service environments, the concept of “changeover” can be interpreted as operational transitions such as end-of-day closings [2].

This project applies SMED principles to redesign the cash reconciliation process in a banking institution. The objective was to reduce closing time while strengthening internal control through continuous verification instead of relying solely on end-of-day corrective actions, aligning with modern internal control frameworks [3].

To support the achievement of this purpose, the project is guided by a set of targeted actions that structure the analysis, implementation, and evaluation of the redesigned cash reconciliation process, as outlined below:

- Measure and compare the execution time of each step in the reconciliation process before and after the implementation of the redesigned methodology.
- Document and analyze the existing cash reconciliation process in the banking institution, identify task sequence, responsibilities, and time distribution across all steps.
- Apply SMED principles by separating internal and external activities and redistributing reconciliation tasks throughout the workday using partial cash counts and continuous controls [1].
- Evaluate the statistical significance of time reductions for each process step and for the total reconciliation of time through hypothesis testing.

- Assess the impact of the redesigned process on internal control, focusing on early detection of discrepancies and reduction of end-of-day error accumulation in alignment with recognized control frameworks [3].
- Demonstrate the applicability of SMED methodology in a financial services environment as a tool to improve operational efficiency without compromising control reliability [5].

## LITERATURE REVIEW

SMED was developed to minimize downtime by converting internal tasks into external ones and standardizing procedures [1]. Although originally designed for manufacturing, several authors have highlighted its adaptability to service processes where delays and operational bottlenecks are common [2] [4].

In financial services, process efficiency must coexist with strict internal control requirements. Lean service research indicates that redistributing workload and implementing continuous controls can improve efficiency without compromising accuracy [2]. In banking operations, reconciliation and closing processes are particularly suitable for this type of redesign due to their traditionally concentrated structure.

Furthermore, internal control frameworks emphasize the importance of timely detection of discrepancies and reliable financial reporting [3]. Therefore, applying SMED to cash reconciliation aligns with both Lean service principles and internal control practices.

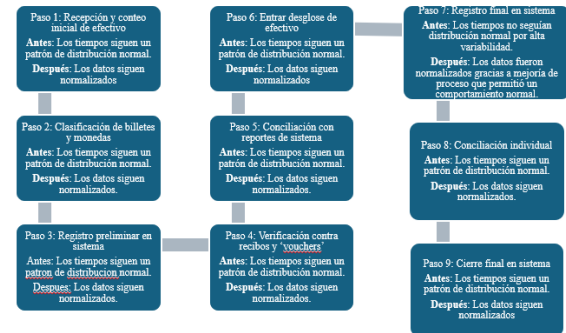
## METHODOLOGY

This study followed an applied, quantitative, and non-experimental before-and-after design aimed at evaluating the effect of a process redesigning on cash reconciliation time in a banking institution.

The original reconciliation process was observed directly in the operational environment. Each activity was documented, including sequence, responsible personnel, and required resources. The

process consisted of nine main steps executed primarily at the end of the workday. This structure concentrated most verification tasks into a short time window, increasing operational pressure and the likelihood of delayed discrepancy detection.

A process flow diagram (Figure 1) was developed to visualize task dependencies and identify activities that could potentially be executed earlier without compromising control requirements.



**Figure 1**  
Process Flow Diagram for the 9 Steps

The redesign was based on the Single-Minute Exchange of Die (SMED) methodology, which focuses on reducing changeover time by converting internal activities (those that can only be performed when the process is stopped) into external activities (those that can be performed while the process continues) [1].

In this study, the “changeover” will be measured as the end-of-day reconciliation period. Activities previously performed only during closing were analyzed to determine whether they could be safely executed earlier in the day. As a result, partial cash counts and continuous verification tasks were introduced, redistributing workloads and reducing the concentration of activities at closing time.

Standard operating procedures were updated to ensure consistency in the execution of the redesigned steps.

Time measurements were collected in seconds for each of the nine process steps as well as for the total reconciliation time. Five observations were recorded under the original process conditions and five under the redesigned process. Observations were conducted under normal operating conditions

to ensure that the data reflected typical daily performance.

The same measurement method and criteria were used in both scenarios to maintain consistency and comparability. Statistical analyses will be used to assess if the changeover was effective.

## ANALYSIS AND RESULTS

Descriptive statistics, including mean and standard deviation, were calculated for each step and for the total process time. To validate the use of parametric tests, normal probability plots were generated. Despite the small sample size ( $n = 5$  per scenario), the data showed an approximately linear pattern, indicating behavior consistent with a normal distribution.

The following tables showed the measurement phase of the study. Table 1 represents the data collected during 5 days of the existing reconciliation process of the bank. The table shows the time of each step, the average, standard deviation and the Variation coefficient.

**Table 1**  
**Original Cash Reconciliation Process Flow**

CUADRE DE BANCO AL FINAL DEL TURNO DE TRABAJO									
FECHA	11/3/2025	11/4/2025	11/5/2025	11/6/2025	11/8/2025				
OPERADOR	Dennis	Dennis	Dennis	Suley	Dennis				
PASO	Segundos	Segundos	Segundos	Segundos	Segundos	Average	Std Dev	Cv	
1	182	181	158	184	127	166.4	24.4	14.7%	
2	137	202	136	186	139	158.0	33.7	21.3%	
3	606	663	491	657	598	603.0	69.1	11.5%	
4	950	838	1023	944	962	943.4	66.8	7.1%	
5	483	645	592	511	548	555.8	64.5	11.6%	
6	220	153	129	122	216	168.0	47.1	28.0%	
7	72	71	73	93	73	76.4	9.3	12.2%	
8	65	90	67	86	66	74.8	12.2	16.2%	
9	122	134	93	94	131	114.8	19.9	17.4%	
Total Seg	2837	2977	2752	2877	2860	2860.6	80.9	2.8%	
Total min	47.3	49.6	45.9	48.0	47.7	47.7	1.3	2.8%	

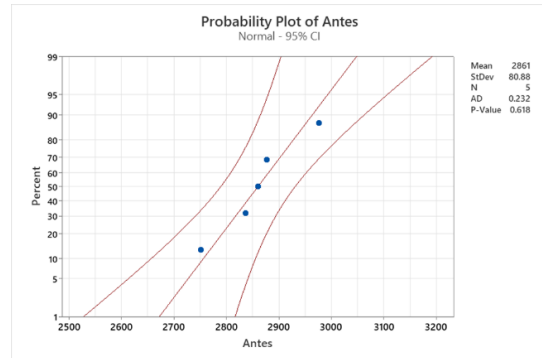
  

Paso	Paso 1	Paso 2	Paso 3	Paso 4	Paso 5	Paso 6	Paso 7	Paso 8	Paso 9
Dia 1	182	137	606	950	483	220	72	65	122
Dia 2	181	202	663	838	645	153	71	90	134
Dia 3	158	126	491	1023	592	129	73	67	93
Dia 4	184	186	657	944	511	122	93	86	94
Dia 5	127	139	598	962	548	216	73	66	131

From this table the process showed a time average of 47.7 minutes with a deviation of 1.3 minutes and a variation coefficient of 2.8 %. This procedure was done individually, and step 6 is the least consistent, while 4 becomes the more consistent. Step 4 has the highest duration and step 8 has the lowest.

To verify if the steps have a normal process behavior a probability plot was down for each step (Figure 2). All showed a normal behavior for the existing process. The following figure shows the

result of the total process. Since P value is higher than alpha of 5%, the behavior remains within a normal pattern.



**Figure 2**  
**Probability plot for Existing Process**

The following Table 2 shows the process changes to improve the change over of the reconciliation bank tasks.

**Table 2**  
**Process Changes per Step**

STEP 1	The daily transaction report and check list are removed. This allows for the initial count. Applying the strategy in step 4 speeds up the start of the count because only the data matching needs to be verified.
STEP 2	The system removes the documentation of withdrawals and deposits made by the dispenser.
STEP 3	The data summation between checks and the dispenser begins. Since the strategy was already applied in step 4, it can simply be verified that the count is equal to the sum that was started previously.
STEP 4	Withdrawal slips, deposit slips, and all cash are totaled. This must match the report. To optimize the process, it was decided that before the designated end-of-day closing time, the slips and all cash would be totaled. The strategy is that by doing this, any counting errors will be minimized, and the remaining steps will be expedited because this step will already be under control.
STEP 5	Money must be received or returned to the vault as needed; this is to balance the cash register with the petty required for the next day. Once the count is in order, using the strategy established in the previous step, the necessary change to withdraw or return to the vault can be determined.
STEP 6	The cash breakdown is entered into the system; this is to verify how many bills of each denomination are in the cash register.
STEP 7	The cash register closing process begins in the system, where all previously collected data must be documented. Since the other steps have already been streamlined with the strategy, and the data obtained is documented before the end of the day, significant progress is made in this step. Furthermore, each cashier is able to incorporate a better documentation pace into the system, which helps in all the other steps already explained.
STEP 8	The report from step 7 is printed and each individual transaction is validated.
STEP 9	In the dispenser system, each recorded transaction is "cleaned" and it is ensured that the vault has the same amount as indicated by the system.
	By adjusting step 4, we can observe how the other steps tend to change in timing, since by advancing the cash count, the closing process can begin more quickly. Counting errors will be reduced, and each step will run more smoothly. This step is directly proportional to steps 1, 3, 5, and 7, where we see that before implementing the strategy, each cashier took a different amount of time to complete it, affecting the normality of the procedure. By improving step 4 and having everything ready for the count, step 7 becomes standardized, and steps 1, 3, and 5 are performed more efficiently.

As a result of these changes a second set the data was collected to verify if the changeover was effective. Table 2 shows an average total time of 34.5 minutes with a deviation of 1. Minutes and a variation coefficient of 3.1%. Keeping step 4 with the highest time and changing the step.

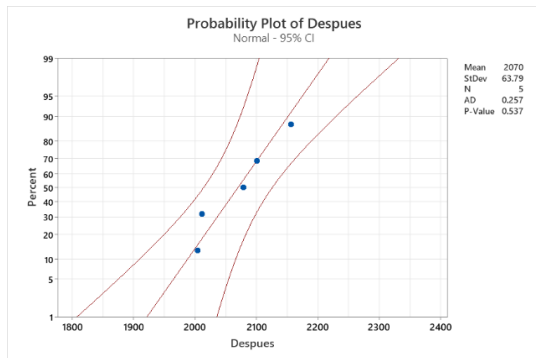
**Table 3**  
**New Cash Reconciliation Process Flow**

CUADRE DE BANCO AL FINAL DEL TURNO DE TRABAJO									
FECHA	11/28/2025	12/1/2025	11/25/2025	11/26/2025	11/10/2025				
OPERADOR	Denisse	Denisse	Denisse	Denisse	Denisse				
	Segundos	Segundos	Segundos	Segundos	Segundos	Average	Std Dev	Cv	
1	99	113	109	101	133	111	13.6	12.2%	
2	142	139	133	122	108	128.8	13.9	10.8%	
3	366	374	368	337	352	359.4	14.9	4.1%	
4	529	561	563	611	371	527	92.0	17.5%	
5	419	476	506	467	513	476.2	37.4	7.9%	
6	191	171	173	188	208	186.2	15.1	8.1%	
7	67	68	66	63	69	66.6	2.3	3.5%	
8	81	76	71	72	66	73.2	5.6	7.7%	
9	117	123	167	118	184	141.8	31.4	22.2%	
Total Seg	2011	2101	2156	2079	2004	2070.2	63.8	3.1%	
Total min	33.5	35.0	35.9	34.7	33.4	34.5	1.1	3.1%	

Paso	Paso 1	Paso 2	Paso 3	Paso 4	Paso 5	Paso 6	Paso 7	Paso 8
Dia 1	99	142	366	529	419	191	67	81
Dia 2	113	139	374	561	476	171	68	76
Dia 3	109	133	368	563	506	173	66	71
Dia 4	101	122	337	611	467	188	63	72
Dia 5	133	108	352	371	513	208	69	66

To confirm if the changes had an impact on the process behavior a probability plot was performed showing that the process remains with a normal pattern. Figure 3 showed a P value of 0.537 higher than alpha of 0.05.



**Figure 3**  
**Probability Plot for New Process**

Normal probability plots were used to evaluate the distribution of the data for both scenarios. Although the sample size was limited (n = 5 per condition), the points followed an approximately normal pattern with no strong outliers or curvature. This behavior supports the assumption of normality and justifies the application of parametric statistical tests.

Descriptive statistics were used to make a comparison of the metrics to observe variations. For example, before the average time for step 4 was 943 seconds and after the changeover shows an average of 527 seconds.

Hypothesis tests were then performed to compare mean times before and after the redesign. For each step and for the total process, the following hypotheses were evaluated:

- $H_0: \mu \text{ before} = \mu \text{ after}$
- $H_1: \mu \text{ before} > \mu \text{ after}$

A significance level of  $\alpha = 0.05$  was used. These tests allowed determination of whether observed reductions in time were statistically significant and attributable to the process redesign rather than random variation.

The analysis revealed a clear improvement in the performance of the cash reconciliation process after the implementation of the redesigned methodology.

Table 4 shows how each step change was evaluated to determine if the changeover was effective. If the results is “Miu Before is higher than Miu After” then the change is significant. If not, the average remains equal and the changeover did not make a significant change. Table 4 shows the total impact of the process and showed that there is a significant reduction in time, but its variation remains constant.

**Table 4**  
**Average Execution Time per Step Before and After Redesign**

Estadística Descriptiva para Proceso <i>Antes</i> del cambio												
Variabl	N	Mean	3E	Measr	StDev	CoefVa	Minimur	Q1	Median	Q3	Maximun	Range
Paso 1	5	166.4	10.9	24.4	14.7	127.0	142.5	181.0	183.0	184.0	57.0	
Paso 2	5	158.0	15.1	33.7	21.3	126.0	131.5	139.0	194.0	202.0	76.0	
Paso 3	5	603.0	30.9	69.1	11.5	491.0	544.5	606.0	660.0	663.0	172.0	
Paso 4	5	943.4	23.9	66.8	7.1	838.0	891.0	950.0	992.5	1023.0	185.0	
Paso 5	5	555.8	28.8	64.5	11.6	483.0	497.0	548.0	618.5	645.0	162.0	
Paso 6	5	168.0	21.1	47.1	28.0	122.0	125.5	153.0	218.0	220.0	98.0	
Paso 7	5	76.4	4.2	9.3	12.2	71.0	71.5	73.0	83.0	93.0	22.0	
Paso 8	5	74.8	5.4	12.2	16.3	65.0	65.5	67.0	88.0	90.0	25.0	
Paso 9	5	114.8	8.9	19.9	17.4	93.0	93.5	122.0	132.5	134.0	41.0	

Estadística Descriptiva para Proceso <i>Despues</i> del cambio												
Variabl	N	Mean	3E	Measr	StDev	CoefVa	Minimur	Q1	Median	Q3	Maximun	Range
Paso 1	5	111.0	6.1	13.6	12.2	93.0	100.0	109.0	123.0	133.0	34.0	
Paso 2	5	128.8	6.2	13.9	10.8	108.0	115.0	133.0	140.5	142.0	34.0	
Paso 3	5	353.4	6.7	14.9	4.1	337.0	344.5	366.0	371.0	374.0	37.0	
Paso 4	5	527.0	41.1	92.0	17.5	371.0	450.0	561.0	587.0	611.0	240.0	
Paso 5	5	476.2	16.7	37.4	7.9	419.0	443.0	476.0	509.5	513.0	94.0	
Paso 6	5	186.2	6.7	15.1	8.1	171.0	172.0	188.0	199.5	208.0	37.0	
Paso 7	5	66.6	1.0	2.3	3.5	63.0	64.5	67.0	68.5	69.0	6.0	
Paso 8	5	73.2	2.5	5.6	7.7	66.0	68.5	72.0	78.5	81.0	15.0	
Paso 9	5	141.8	14.1	31.4	22.2	117.0	117.5	123.0	175.5	184.0	67.0	

The average total reconciliation time decreased from 2860.6 seconds under the original process to 2070.2 seconds after the redesign, representing a 27.63% reduction in total execution time. In addition, the standard deviation decreased from 80.88 seconds to 63.79 seconds, indicating improved process consistency and reduced variability. Table 5 summarizes the hypothesis tests results by step.

**Table 5**  
**Total Reconciliation Time Before and After Redesign**

Means Hypothesis		TOTAL				Variance Hypothesis									
Ho: $\mu$ antes		EQUALS TO		$\mu$ después		Ho: $\sigma$ a		EQUALS TO		$\sigma$ b					
Select one		MORE THAN		LESS THAN		NOT EQUAL		Select one		MORE THAN		LESS THAN		NOT EQUAL	
I = YES		I		I		I		I = YES		I		I		I	
H1: $\mu$ a		MORE THAN		$\mu$ b		Mean Hypothesis Test Results				H1: $\sigma$ a		MORE THAN		$\sigma$ b	
<b>Paso</b>	Antes	Después		Std. Dev.	80.9	63.8		Variance Hypothesis Test Results							
Día 1	2837	2011		X Bar	2860.6	2070.20		A		B					
Día 2	2977	2101		N	5	5		Sigma	80.9	63.8					
Día 3	2752	2156		T exp	17.16		V	4	4						
Día 4	2877	2079		V	8.0		F exp	1.61							
Día 5	2860	2004		Pvalue	0.0000		Pvalue	0.328							
N	5	5		Alpha	0.05		Alpha	0.05							
Miu	2860.6	2070.2		<i>Miu Antes es mayor que Miu Despues</i>				There is not enough evidence to reject Ho, Both Variances are equal							
Std Dev	80.9	63.8													
Means Hypothesis		TOTAL				Variance Hypothesis									

Prueba de Hipotesis de Promedio y Varianza para el Cambio de Proceso Bancario

Según resultados, el promedio del tiempo del proceso nuevo, es menor que el anterior. La varianza no sufrió cambios significativos.

At the step level shown in Table 6, the most time-consuming activities before the redesign were Steps 1, 3, 4, 5 and 7. These steps experienced the largest time reductions after SMED-based changes were implemented. Shorter-duration steps showed minimal variation between both scenarios, which is expected since SMED prioritizes improvements in high-impact activities [1].

Hypothesis tests comparing the mean execution times before and after the redesign were conducted for each of the nine process steps using a significance level of  $\alpha = 0.05$ .

Results showed statistically significant reductions in several of the longest steps, confirming that the redesign effectively targeted the primary contributors to total reconciliation time. Steps with shorter durations or minor changes did not show statistically significant differences, suggesting that their performance remained stable rather than negatively affected. This pattern aligns with SMED applications, where the greatest gains typically occur in the longest or most restrictive activities [1] [6].

This result confirms that the observed improvement is not due to random operational fluctuations but is directly associated with the implementation of the redesigned process. The combination of reduced mean time and lower variability suggests a more efficient and stable reconciliation operation.

The findings of this study demonstrate that SMED principles can be successfully adapted beyond manufacturing environments into financial

service operations. By interpreting the end-of-day reconciliation as a “changeover” period, it was possible to identify internal activities that could be converted into external tasks performed earlier in the day. This redistribution of workload significantly reduced the operational burden at closing time.

**Table 6**  
**Summary of Hypothesis Test Results**

Hypothesis Tests Summary		
Step	Mean Change	Variation Change
Step 1	Significant Reduction	Consistency Remains
Step 2	Average Remains	Consistency Remains
Step 3	Significant Reduction	Significant Reduction
Step 4	Significant Reduction	Consistency Remains
Step 5	Significant Reduction	Consistency Remains
Step 6	Average Remains	Significant Reduction
Step 7	Significant Reduction	Significant Reduction
Step 8	Average Remains	Consistency Remains
Step 9	Average Remains	Consistency Remains
Total	Significant Reduction	Consistency Remains

The results are consistent with Lean service literature, which highlights that efficiency improvements should not only reduce processing time but also enhance process predictability and flow [2] [4]. In this case, the reduction in variability indicates that the process became more stable and less dependent on last-minute corrective actions.

From an internal control perspective, the redesigned process represents a shift from a corrective to a preventive control model. Continuous and partial verifications throughout the day allow discrepancies to be detected earlier, reducing the risk of error accumulation and supporting more reliable financial reporting. This aligns with established

internal control frameworks that emphasize timely detection and monitoring activities [3].

Furthermore, the study shows that efficiency and control are not conflicting objectives. Instead, when process improvements are based on structured methodologies and data analysis, both operational performance and control reliability can be enhanced simultaneously.

Overall, the results suggest that similar SMED-based approaches could be applied to other banking processes characterized by workload concentration at specific times, such as end-of-day settlements or reporting activities. This expands the practical applicability of SMED into the financial services sector and contributes to the growing body of knowledge on Lean ss in non-manufacturing environments.

## CONCLUSION

This study demonstrated that the application of SMED methodology to a banking cash reconciliation process can significantly improve operational efficiency while strengthening internal control. The redesigned process achieved a 27.63% reduction in total reconciliation time, and statistical analysis confirmed that this reduction was significant at a 95% confidence level. These findings validate that the observed improvement was the result of the structured process redesign rather than random variation.

One of the most important contributions of this project is the successful reinterpretation of the SMED concept of “changeover” within a financial services context. By treating the end-of-day reconciliation period as a changeover phase, it became possible to separate activities that truly required end-of-day conditions from those that could be performed earlier. This redistribution of tasks through partial cash counts and continuous controls reduces workload concentration and improved operational flow.

The reduction in process variability further indicates that the redesigned method enhanced process stability. A more predictable reconciliation

process reduces operational stress, lowers the likelihood of rushed errors, and contributes to more consistent performance over time.

From an internal control perspective, the redesigned process represents a transition from a predominantly corrective model to a preventive one. Continuous verification throughout the day supports earlier discrepancy detection, reduces the accumulation of errors, and aligns with recognized internal control principles that emphasize monitoring and timely intervention [3]. This confirms that process efficiency and control reliability can be improved simultaneously when redesign efforts are based on structured methodologies and data-driven analysis.

Additionally, this study expands the application of SMED beyond its traditional manufacturing roots [1]. The results provide practical evidence that Lean tools can be adapted effectively to administrative and financial processes, contributing to the growing body of knowledge on Lean implementation in service environments [2] [4]. Banking operations that experience workload peaks at specific times—such as closings, settlements, or reporting cycles—may benefit from similar approaches.

In conclusion, the project demonstrates that SMED is not only a time-reduction tool but also a strategic framework for process restructuring. Its application in the cash reconciliation process resulted in measurable efficiency gains, improved process stability, and strengthened internal controls, making it a viable improvement strategy for financial institutions seeking operational excellence.

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