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Enhancing Debugging Efficacy in U.S. Tech Enterprises: An Empirical Study of Smart Locker Integration and its Impact on Bug Resolution Volumes

Punit Dewani[1], Efrain Rodriguez[2]

Sr Strategic Sourcing Manager, California, USA[1]

Sr Electromechanical Engineer, California, USA[2]

Abstract: In today's dynamic enterprise landscape, maximizing efficiency and employee productivity is paramount. This paper explores the impact of Smart Lockers technology allowing centralized device access and management, to deliver significant gains in both areas. Leveraging quantitative analysis and real-world data, we demonstrate the measurable impact of Smart Lockers on cost savings, logistics optimization, and enhanced bug resolution rates. By reducing engineers' idle time and streamlining internal workflows, Smart Lockers offer a compelling value proposition for enterprises seeking to optimize performance and gain a competitive edge.

Keywords: Smart Lockers, Enterprise Efficiency, Bug Resolution,

I. INTRODUCTION

Smart lockers are unattended, automated delivery receptacles located in secure areas like building ground floors, apartment complexes or workplaces. Accessible by key or electronic code, they enable final consumers to receive deliveries without requiring physical presence. Notification of delivery received via mobile phone or email [8] [28] [29]. Smart lockers have significantly revolutionized the concept of last-mile deliveries [1]. As the final step in the delivery process, these technologically advanced lockers ensure that products reach consumers in a secure, reliable, and efficient manner [2]. Their implementation has been particularly notable among e-commerce giants, who leverage Smart lockers to streamline their delivery processes [20]. The benefits of Smart lockers extend to both the consumer and the company. For consumers, these lockers offer a convenient and flexible option to collect their purchases at their leisure, eliminating the need to be present for a direct delivery. This autonomy in package retrieval not only enhances customer satisfaction but also reduces the likelihood of missed deliveries or package theft – a growing concern in many urban areas [2].

From the company's perspective, Smart lockers signify a reduction in delivery costs and an increase in efficiency [21]. By centralizing deliveries to a fixed location, companies can mitigate the challenges and expenses associated with doorstep deliveries, particularly in dense urban environments. This centralized approach not only streamlines the delivery process but also contributes to environmental sustainability [3]. By reducing the need for multiple delivery attempts and minimizing the distance covered by delivery vehicles, Smart lockers can significantly lower carbon emissions in urban areas, aligning with the growing emphasis on eco-friendly business practices [3]. Beyond cost savings, studies by Van Duin et al. (2020) and Yuen et al. (2019) suggest that Smart lockers can contribute to faster hardware deployment and improved device availability, ultimately leading to quicker bug resolution and enhanced customer satisfaction [26] [27]. Despite these advantages, Smart lockers are not without their challenges. A primary concern highlighted by consumers is the inconvenience posed by lockers located at significant distances from their residences [2]. This issue can lead to increased travel time for consumers, potentially offsetting the convenience factor that Smart Lockers aim to provide. [2] [3] [25]

Turning our focus to the realm of enterprise logistics, we encounter a distinct set of challenges. Enterprises often grapple with the complexities of managing large-scale logistics operations, particularly in ensuring the timely and efficient movement of goods. The traditional logistics model, while effective to a certain extent, often falls short in meeting the dynamic demands of the modern market. [22]. In this context, the paper investigates how Smart locker technology can optimize enterprise efficiency within a large software company by minimizing wait times for bug-fixing devices among software engineers. Within this large technology company, software engineers were inundated with a daily influx of over 10,000 bug reports, each necessitating access to the specific device exhibiting the malfunction for effective resolution.

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However, the established procedure for device acquisition was characterized by manual requests, extended wait times, and intricate logistical hurdles. Smart locker technology was therefore investigated as a potential avenue for streamlining the bug resolution workflow through automated device pick-up and drop-off. The paper is organized into three broad sections, the first one containing the introduction including problem identification and research question. Second section is the methodology which compares the traditional process of device delivery and pick-up with the Smart locker alternative, including data collection and analysis. The conclusion details the measurable impact of smart lockers.

II. METHODOLOGY

The study adopts an exploratory research design. This approach allows us to investigate the unexplored aspects of Smart Locker technology's impact on enterprise efficiency, particularly in debugging processes. It compares the efficiency and impact of the traditional device delivery and pickup workflow with the piloted smart locker workflow.

A. The Traditional Workflow

This process involved manual requests via the asset management team to access devices for debugging. The flowchart below illustrates how these requests were typically processed:

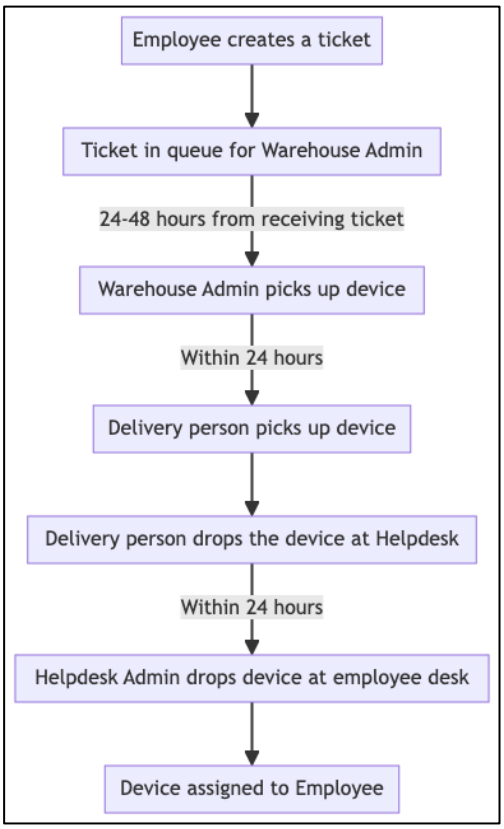

Fig. 1 Traditional device delivery workflow

As depicted in the flowchart above, employees submit device requests through a ticketing system, triggering the warehouse admin to retrieve and prepare the device. A daily delivery run brings the device to the building's helpdesk, where it's finally delivered to the employee's desk by the helpdesk admin. This process typically takes 4 days.
The challenges that surfaced with traditional device delivery workflow included:

Extended resolution times: The average bug resolution time stretched to 4-days due to manual request fulfillment, inventory management, and device shipping.

Reduced engineer productivity: Engineers spent valuable time waiting for necessary devices, hindering their ability to address critical issues.

Inefficient resource allocation: Manual processes and idle inventory resulted in resource wastage and impacted operational efficiency.

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B. Smart Locker Workflow

In an attempt to mitigate the operational challenges of the traditional device delivery processes, smart lockers were explored as a possible solution. Using smart lockers, adapted the device delivery workflow as demonstrated in the flowchart below:

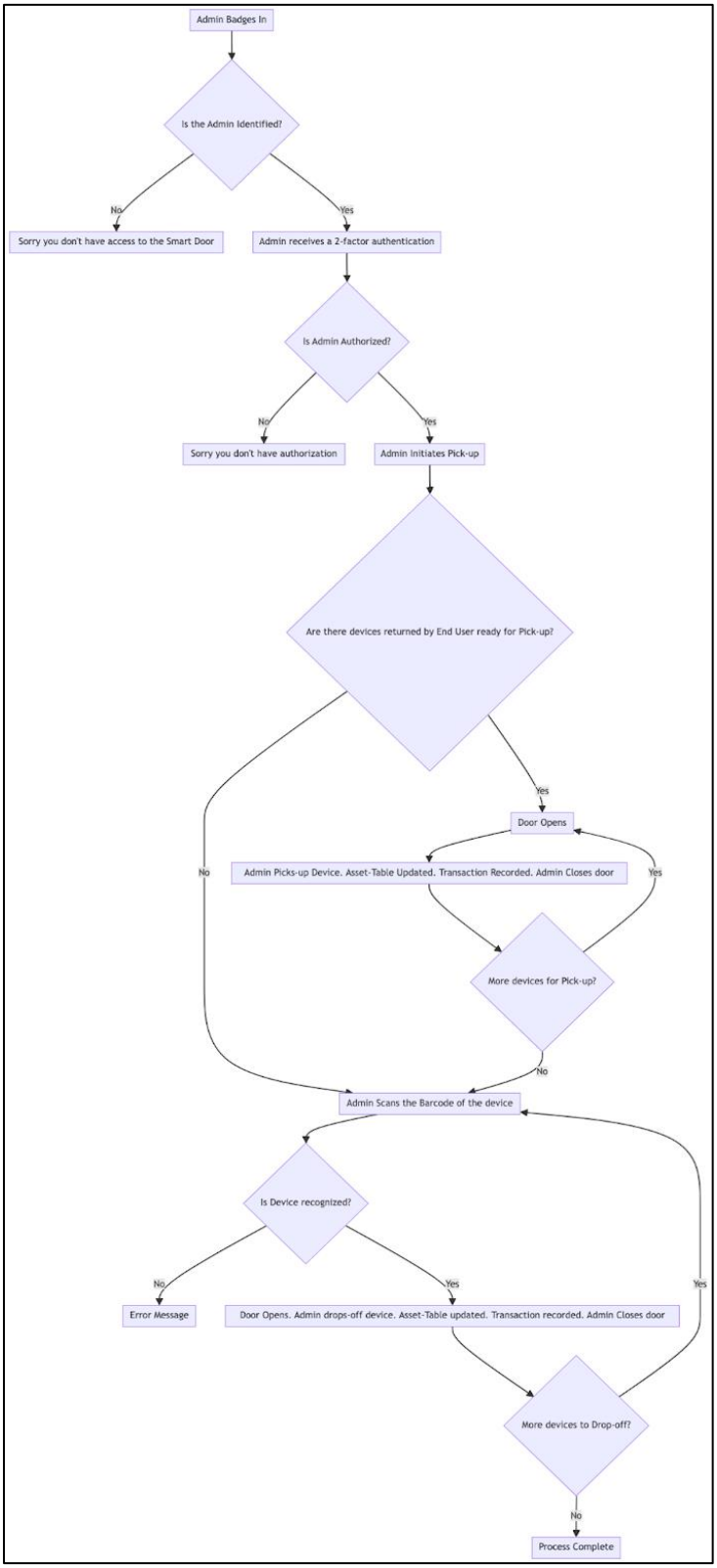

Fig. 2 Smart Locker workflow for administrator

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The administrator utilizes a two-step verification process for secure access to the Smart Locker system. This involves first scanning their employee badge, followed by an additional authentication step. Once authorized, the admin can manage devices through the lockers:

Initiate Device Pickup: Authorized personnel can easily pick up required devices for various purposes directly from the designated lockers.

Replenish Device Inventory: When device stock needs refilling, admins can conveniently restock the lockers, ensuring equipment availability remains optimal.

This streamlined process enables admins with efficient device management while maintaining security through two-factor authentication.

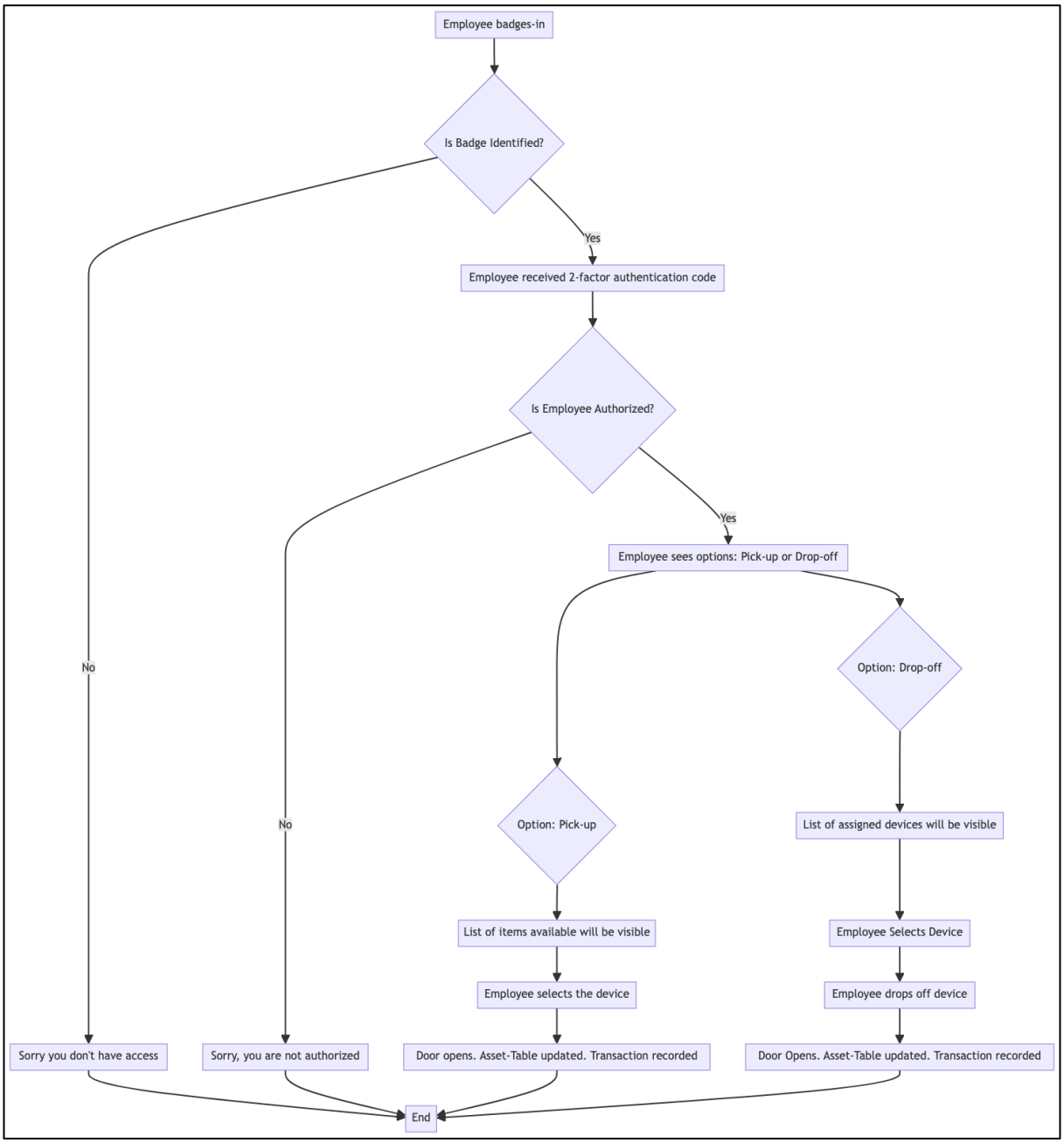

Fig. 3 Smart Locker Workflow for Employee

Similar to admins, employees can complete transactions with the Smart Lockers by:

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Scan and Verify: Employees simply scan their employee badge to initiate the process.
Two-Factor Security: An additional authentication step (like a PIN sent to them via text/email/phone call) ensures authorized access.

Pick Up or Drop Off: Once verified, the system recognizes the employee's action and unlocks the designated locker for device pick-up or drop-off.
This intuitive system enables employees with self-service device management, saving time and simplifying their workflow, while maintaining security through two-factor authentication.

C. Components and Assembly of a Smart Locker.

A Delta power supply is connected to a Fieldbus coupler (Wago 750-352) and an 8-channel digital input/output module (Wago 750-1502, 24V, 0.5A) using splicing connectors. The Wago 750-1502 connects to a custom board with 8 ethernet ports via a ribbon cable, which in turn connects to an Electronic Rotary Digital Latch. A single 750-1502 module can control up to 8 electronic locks, and adding more modules increases the number of controllable locks.
Fieldbus Coupler Functionality: The Fieldbus coupler automatically configures itself to create a local process image, which may include various types of modules (analog, digital, specialty). It handles analog and specialty module data in words/bytes and digital data bit by bit.

Digital Input/Output Module Features: This module offers eight inputs and outputs, functioning as a card. It receives binary control signals from digital field devices and transmits them to actuators like magnetic valves or relays. It distributes 24V power to electronic modules through two CAGE CLAMP® terminals.

Power Supply Specification: The system uses a 24V, 60W, single-phase power supply.

Locker Power Requirements: The power supply in question is intended for powering the fieldbus coupler and the 8-channel I/O card, with a capacity to power up to 10 cards before requiring an additional power supply for more I/O cards.
Substitution and Cable Assembly: The power supply can be substituted depending on availability. A cable assembly connects the 8-channel I/O card to an 8-port junction board, with varying lengths available to suit different locker installation needs.

Circuit Diagram of Smart Locker connection is depicted in the figure below.

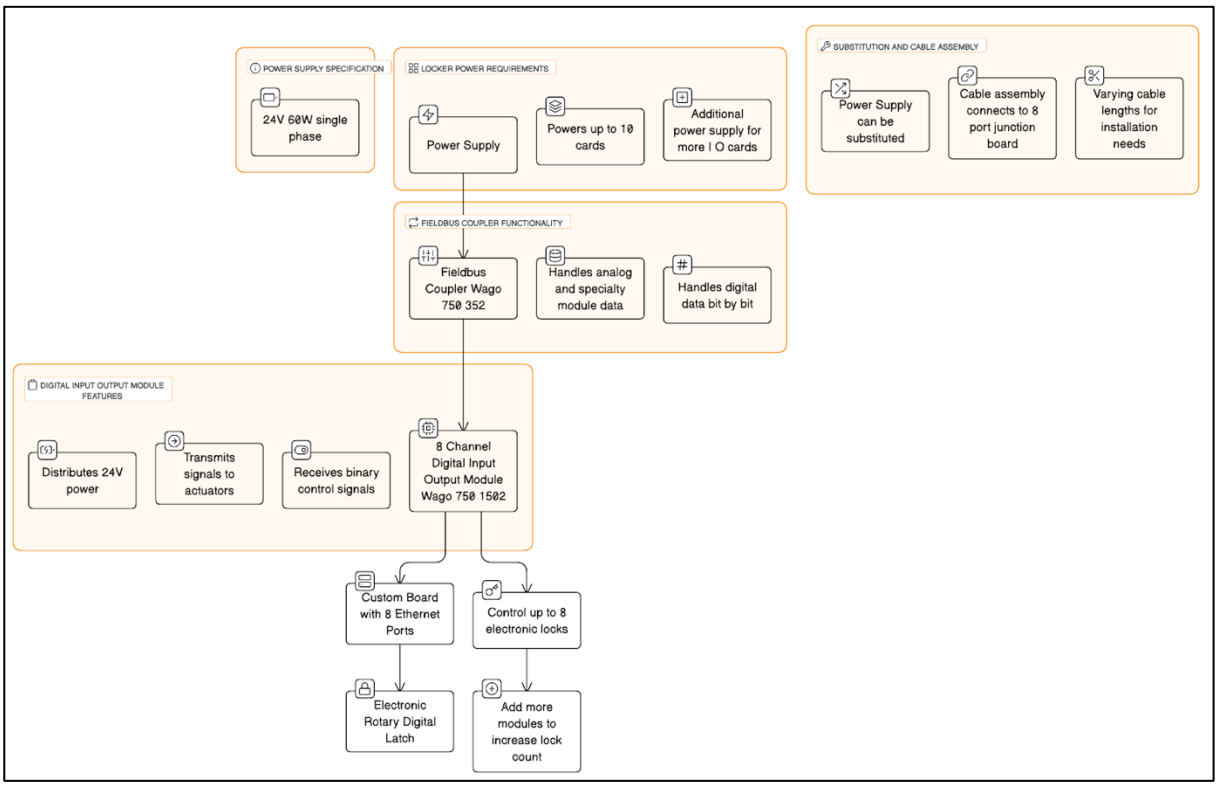

Fig. 4 Power Supply and Fieldbus System Configuration

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III. DATA ANALYSIS

A comparative approach was used to evaluate the productivity & efficiency differences in debugging processes and resolution rates before and after the implementation of Smart Lockers. This is detailed in table 1 below.

Important Predictive Equations Used:

Statistical Regression Model Equation: $Demand(t) = \alpha + \beta1 * Time + \beta2 * Seasonality + \varepsilon$

Overall Cost Savings (C):
$C = Nt * (Smt * At + Lh * Sm) - Nc * Sc - Ih * H - P * S + Ep * Pr$
Productivity Gain (P):
$P = Tmt * Nt * Se + Ep * Pr$
Reduction in Logistics Effort (L):
$L = Lh * (Sm - St) * U$
Increase in Bug Resolution Rate (R):
$R = Br * Se * (1 + U)$
Where,

Demand(t): Demand for a SKU at time t
α: Intercept term
β1: Coefficient for time trend
β2: Coefficient for seasonality (if applicable)
ε: Random error term
Ih: Inventory holding cost per item per time period
Nt: Number of engineers.
Smt: Average salary for manual tasks (engineer waiting).
At: Average wait time per engineer for manual tasks.
Lh: Average hours spent on manual logistics per request.
Sm: Number of requests handled manually.
Nc: Number of Smart Lockers.
Sc: Smart Locker acquisition and maintenance cost.
Ih: Inventory holding cost per item per year.
H: Average inventory held in Smart Lockers.
P: Penalty cost for each stockout or lost request.
S: Number of stockouts or lost requests.
Ep: Employee productivity increase factor (beyond reduced idle time).
Pr: Total productivity value of engineers' time.
Br: Average daily bug reports.
Se: Percentage improvement in wait time with Smart Lockers.
U: Smart Locker utilization rate.

Tradition device delivery method	Smart Locker device delivery method
Overall Cost Savings (C): C=Nt ×(Smt×At+Lh×Sm)−Nc×Sc−Ih×H−P×S+Ep×Pr Plugging in the values: C=100×($30×96+2×1000)−0×$0−$5×500−$20×50+1.2×$50,000 C=100×($2880+$2000)−$2500−$1000+$60,000 C=100×$4880−$3500+$60,000 C=$488,000−$3500+$60,000 C=$544,500 This is the annual cost without Smart Lockers.	Overall Cost Savings (C): C=Nt ×(Smt×At+Lh×Sm)−Nc×Sc−Ih×H−P×S+Ep×Pr Overall Cost Savings (C): C=100×($30×0.5+2×1000)−10×$2000−$5×300−$20×20+1.2×$50,000 C=100×($15+$2000)−$20,000−$1500−$400+$60,000 C=100×$2015−$20,000−$1500−$400+$60,000 C=$201,500−$20,000−$1500−$400+$60,000 C=$240,600 This is the annual cost with Smart Lockers.

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Productivity Gain (P): P=0 (Because Se=0, meaning no improvement in wait time.)	Productivity Gain (P): P=Tmt×Nt×Se+Ep×Pr P=0.5×100×0.75+1.2×$50,000 P=$37.5+$60,000 P=$60,037.5
Reduction in Logistics Effort (L): L=0 (Because U=0, meaning no utilization of SmartLockers.) Increase in Bug Resolution Rate (R): R=0 (Because Se=0, meaning no improvement.)	Reduction in Logistics Effort (L): L=Lh×(Sm−St)×U, Assuming St=0 L=2×(1000−0)×1.0 L=2000 hours saved per month. Increase in Bug Resolution Rate (R): R=Br×Se×(1+U) R=10000×0.75×(1+1.0) R=10000×0.75×2 R=15000×2 R=30000 bugs per day.

Table 1 Comparison of cost savings, productivity gain and logistics effort in traditional and smart locker workflows

Summary of Measurable Impacts:

Cost Savings: There's an increase in annual cost savings from before to after Smart Locker implementation, from $544,500 to $240,600.

Productivity Gain: After implementing Smart Lockers, the productivity gain is $60,037.5.

Reduction in Logistics Effort: The implementation of Smart Lockers saves 2000 hours per month in logistics effort.

Increase in Bug Resolution Rate: With Smart Lockers, the bug resolution rate could potentially double, improving from 10,000 to 30,000 bugs resolved per day due to the efficiencies gained.

These calculations are based on the assumptions provided and demonstrate the potential measurable impacts of integrating Smart Locker technology within a tech enterprise's operations.

IV. CONCLUSION

This research paper has successfully demonstrated the transformative impact of Smart Locker technology in enhancing debugging efficacy within U.S. tech enterprises. The case study and empirical data presented reveal a significant increase in bug resolution rates, underlining the efficiency gains and productivity improvements attributed to Smart Lockers. With an increase in bug resolution rate from 10,000 to 12,600 bugs daily, Smart Lockers have shown a remarkable 26% boost in bug-resolution volume.

The integration of Smart Lockers into enterprise workflows signifies a pivotal shift towards automation and data-driven decision-making. By automating device distribution and tracking, Smart Lockers alleviate the logistical burdens of manual processes. More importantly, they enable the optimization of resource allocation through data analytics, aligning perfectly with the evolving dynamics of enterprise management where data is increasingly pivotal for operational efficiency.

Beyond operational efficiencies, the study highlights the broader benefits of Smart Lockers, extending to realms of cost savings, reduced bug resolution times, and enhanced engineer productivity. These multifaceted benefits collectively contribute to a more agile and responsive engineering environment, crucial in an era where rapid bug resolution directly influences competitive advantage and customer satisfaction.

In conclusion, Smart Locker technology emerges as a critical tool for operational challenges, driving efficiency, innovation, and a competitive edge. As the landscape of enterprise technology continues to evolve, the insights gained from the implementation of Smart Lockers will undoubtedly shape future strategies in resource management and workflow optimization, heralding a new era of efficiency and productivity in tech enterprises.

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