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OPTIMIZATION OF SURVEILLANCE SYSTEMS IN INDUSTRIAL AREAS USING CCTV DESIGN TOOLS

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Abstract

Designing CCTV systems presents its own challenges, especially in choosing the right and accurate design tools. This study highlights the utilization of CCTV Design Tools, specifically the System Design Tool (SDT), in designing surveillance systems in complex industrial environments. SDT is used to simulate camera coverage, identify blind spots, and determine the optimal configuration of the system. The case study was conducted at a metal smelting plant that has four crucial areas: Production Zone, Storage Warehouse, Loading Dock, and Access Door/Perimeter. Simulation results show that the use of SDT can increase surveillance coverage by 92.5%, reduce blind spots by 7.5%, and optimize the number of cameras required by 20%. With a technical data-driven approach and precise visualization of camera placement, SDT proved effective in improving the efficiency of surveillance system design. These findings confirm the importance of using simulation technology in the development of reliable, efficient, and field-appropriate industrial security systems.

Keywords: CCTV Design Tools, Surveillance Systems, Optimization, Industrial Security

Introduction

CCTV-based surveillance systems are a primary need in the industrial sector to improve security and operational efficiency. A study confirmed that CCTV-based surveillance is effective in reducing property crimes such as vehicle theft and property damage (Aziz et al., 2024). Then Cuevas et al. (2016) revealed that CCTV plays a role in preventing crimes against people and property, especially in monitoring suspicious activity and recording incidents to help solve cases. While Teixeira et al. states that real-time CCTV surveillance can improve operational efficiency in security surveillance, thereby facilitating security response. And Kurnia (2021) mentions the role of CCTV in counter-terrorism, especially in increasing situational awareness and providing visual evidence. From these studies, it is enough to make industrial company security managers adopt CCTV surveillance in monitoring industrial security and operations. Industrial areas are places where industrial activities are concentrated which are equipped with supporting facilities and infrastructure developed and managed by industrial area companies (Amalia, 2018). Industrial areas have diverse area complexities with facilities and infrastructure as well as building structures of various dimensions and sizes. This is a challenge in placing CCTV cameras in industrial areas (Gyamfi & others, 2022).

Ensuring security and operational efficiency is a top priority in modern industrial settings. Surveillance systems based on Closed-Circuit Television (CCTV) are vital for monitoring activities, detecting anomalies, and preventing potential threats (Heyns, 2021; Piza et al.,

2016; Piza & Welsh, 2019). However, designing an effective CCTV system for industrial areas presents several challenges:

Complex Layouts: Industrial facilities often consist of intricate layouts with various zones of activity, such as production areas, storage warehouses, and loading docks. Each of these zones has unique surveillance requirements to ensure adequate monitoring and risk mitigation (Drahansky & others, 2016).

Blind Spots: Poorly planned camera placement frequently results in unmonitored areas, reducing system effectiveness and exposing facilities to vulnerabilities. These blind spots are often identified only after incidents occur, highlighting the need for better planning tools (Choi et al., 2022; Goldstein et al., 2019).

Resource Constraints: Designing an optimal surveillance system requires balancing budget limitations and performance expectations. Cost-effectiveness without compromising security is a major concern for industries (Piza et al., 2016; Schilling & Werners, 2015).

Manual Design Challenges: Traditional design methods often rely on manual calculations and iterative approaches, which are time-consuming and prone to inaccuracies. These methods may not adequately address the dynamic needs of complex industrial environments (Singhal et al., 2016).

To address these issues, CCTV Design Tools (SDT) have emerged as an innovative solution. These tools offer a technology-driven approach to designing surveillance systems by simulating camera coverage, identifying blind spots, and optimizing camera placement based on specific parameters. Unlike manual methods, SDT provides a data-driven and automated process, significantly reducing time and effort while improving accuracy and effectiveness (Chmielewska et al., 2015; De Bruyne et al., 2023; Gyamfi et al., 2022; Kostal et al., 2022; Turtiainen et al., 2022).

This study explores the potential of SDT to optimize surveillance system design in industrial areas. A case study was conducted in three critical zones of a manufacturing facility: the Production Zone, Storage Warehouse, and Loading Dock. The objectives of this research are as follows: To evaluate the effectiveness of SDT in improving area coverage and minimizing blind spots. To determine the optimal configuration of surveillance systems using SDT-generated insights. To analyze the impact of SDT on design efficiency and resource utilization

The findings from this study provide actionable insights into how SDT can revolutionize surveillance system design, making it more efficient, accurate, and adaptable to the complex needs of industrial environments. This research contributes to the growing body of knowledge on the application of advanced simulation tools in enhancing security infrastructure.

Research Method

CCTV Design Tools (SDT) are used to simulate and visualize camera placements, coverage areas, and potential blind spots within a given industrial layout. These tools support precise calculations based on parameters such as camera specifications, layout

dimensions, and coverage requirements. The primary functions of CCTV design tools include camera placement visualization, area coverage calculation, image quality simulation, and infrastructure planning. Camera placement visualization allows users to position cameras on a site plan and observe their coverage areas, enabling designers to identify blind spots and optimize the number and placement of cameras. The area coverage calculation feature ensures that each camera's effective coverage is determined based on its technical specifications, such as viewing angle and focus distance, guaranteeing comprehensive monitoring without redundancy. Additionally, some design tools provide image quality simulation, allowing users to assess the image quality under specific lighting conditions. Image quality in CCTV surveillance is defined by pixels per meter (ppm), with standards set at 250 ppm for identification, 125 ppm for recognition, 62 ppm for observation, 25 ppm for detection, and 12 ppm for monitoring. Infrastructure planning is another crucial aspect, as SDT aids in designing cable routes, data storage locations, and integration with other security systems, ensuring efficiency and ease of installation.

The use of CCTV Design Tools offers several advantages, including time and cost efficiency, planning accuracy, and comprehensive documentation. By utilizing these tools, designers can reduce planning time and avoid errors that may lead to additional costs. The software ensures optimal camera placement, preventing unmonitored areas and redundancy. Furthermore, SDT provides features for generating reports and documentation essential for system installation and maintenance. The Panasonic CCTV System Design Tool (SDT) offers a structured framework for surveillance system design, incorporating features such as camera coverage simulation, storage requirement calculations, and automated report generation. These functionalities enhance efficiency and ensure that the resulting design is relevant to the specific needs of the site. In this study, SDT served as the primary tool to achieve an accurate, efficient, and well-documented surveillance system design.

The use of SDT begins with the Data Input process including:

Facility Layout: Floor plans of the industrial areas, including the Production Zone, Storage Warehouse, and Loading Dock.



Figure 2.a Facility Layout of Industrial Area

Legend: Red box as Production Zone, Yellow box as Storage Warehouse, Blue box as Loading Dock, and green box as Access / perimeter door.
Camera Specifications: outdoor or indoor, fixed or PTZ, resolution 1920x1080 or higher, PPM 12 – 250ppm.

Operational Requirements: Minimum coverage percentage required ≥85%, acceptable blind spot thresholds≤15%, and critical zones identified by the facility management team are Production Zone, Storage warehouse, Loading dock, and Access / Perimeter door.

Software Environment: The simulations were conducted using proprietary SDT software integrated with a 2D and 3D visualization platform, enabling real-time adjustments to the design.

Simulation Procedure

The simulation process consisted of three primary steps: Data Input and Preprocessing, Simulation and Analysis, and Validation and Final Design. In the first step, the facility layout and camera specifications were digitized and uploaded into SDT. The layout was divided into zones based on operational functions, with each zone's dimensions calibrated in the software. Operational parameters, such as desired coverage levels and monitoring priorities, were configured for each zone to ensure alignment with security objectives.

During the Simulation and Analysis phase, SDT was utilized for Camera Placement Optimization, where the software iteratively simulated camera placements by computing the coverage area for each camera based on its field of view (FoV), resolution, and installation height. Additionally, Blind Spot Identification was conducted by overlaying coverage maps generated during the simulations. This process allowed for the visualization and quantification of blind spots, leading to adjustments in camera placement and specifications until blind spots were minimized to acceptable thresholds. To ensure Resource Optimization, the software calculated the minimum number of

cameras required to achieve target coverage levels, balancing performance and cost-effectiveness.

In the Validation and Final Design stage, simulation results were validated against operational requirements provided by the facility management team. The final designs included optimized recommendations for camera placement, camera type (fixed vs. PTZ), and configurations tailored for each zone.

Evaluation Metrics

The effectiveness of SDT was assessed based on three key metrics: Coverage Percentage, which measured the proportion of the total area monitored by the proposed CCTV system in percentages; Blind Spot Reduction, which evaluated the extent to which blind spots were minimized compared to the initial layout; and Resource Utilization, which analyzed the total number of cameras used versus the area covered, reflecting the efficiency of the surveillance design.

Case Study: Industrial Facility

This methodology was applied to a manufacturing facility comprising four critical zones:

1. Production Zone – A high-priority area requiring 90% coverage with minimal blind spots. Fixed cameras with wide FoV were utilized to maximize surveillance efficiency.
2. Storage Warehouse – A moderate-priority area also requiring 90% coverage but with a cost-effective approach. A combination of fixed and low-resolution cameras was implemented.
3. Loading Dock – A dynamic environment requiring 85% coverage with comprehensive supervision due to the movement of heavy equipment used to transport production materials.
4. Access/Perimeter Door – A security-sensitive area demanding 90% coverage with effective solutions. A mix of outdoor and indoor fixed cameras was deployed to ensure robust surveillance.

Limitations

The simulation process was based on static facility layouts, which may not fully account for future structural modifications within the facility. Additionally, environmental factors such as lighting conditions, weather variations, and physical obstructions were not comprehensively simulated in this study, potentially affecting real-world performance. Future research should focus on integrating dynamic environmental variables and real-time adaptability to enhance system accuracy.

Result and Discussion

Camera Placement and Coverage

The simulations performed with SDT yielded optimized camera placement for each zone, achieving the desired level of area coverage while minimizing blind spots. The following are the simulation results and CCTV area coverage produced by Panasonic's SDT (System Design Tool) CCTV design tool:



Figure 3.a Camera Placement and Coverage of Production Zone

Table 1. Camera Placement Specifications of Production [20]

No	Area	Model	Type	Name	Height	Distance	Viewing Angle	Zoom Ratio	PPM	Tilt Angle	Camera Unit Angle	Resolution
1	Production Zone	WV-S2236LA	Indoor Fixed Dome	Camera 1	2.59 m	58.71 m	90	1,65	17	26,09	58,71	1920x1080
2	Production Zone	WV-S2236LA	Indoor Fixed Dome	Camera 2	2.59 m	30.43 m	90	1,65	32	26,8	30,43	1920x1080
3	Production Zone	WV-S2236LA	Indoor Fixed Dome	Camera 3	2.59 m	30.53 m	50,3	2,72	67	15,63	30,53	1920x1080
4	Production Zone	WV-S6130	Indoor PTZ	Camera 4	2.59 m	28.95 m	74	1	44	22,38	28,95	1920x1080
5	Production Zone	WV-S2236LA	Indoor Fixed Dome	Camera 5	2.59 m	20.65 m	90	1,65	47	27,51	20,65	1920x1080
6	Production Zone	WV-S1136	Indoor Fixed Box	Camera 6	2.59 m	33.58 m	89,7	1	29	26,58	33,58	1920x1080
7	Production Zone	WV-S15500-V3L	Outdoor Bullet	Camera 7	2.59 m	30.99 m	90	1,47	50	26,78	30,99	3072x1728
8	Production Zone	WV-S2236LA	Indoor Fixed Dome	Camera 8	2.59 m	42.54 m	90	1,65	23	26,38	42,54	1920x1080

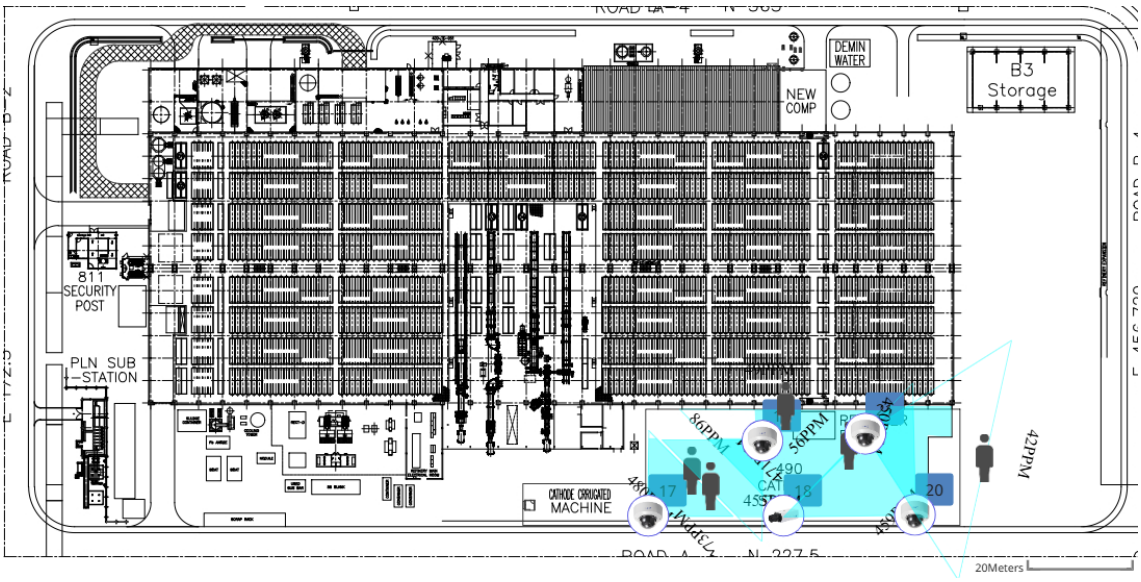


Figure 3. Camera Placement and Coverage of Storage Warehouse

Table 2. Camera Placement Specifications of Storage Warehouse [20]

No.	Area	Model	Type	Name	Height	Distance	Viewing Angle	Zoom Ratio	PPM	Tilt
1	Storage Warehouse	WV-S2236LA	Indoor Fixed Dome	Camera 9	2.59 m	11.21 m	90	1.65	86	**29.36**
2	Storage Warehouse	WV-S1136	Indoor Fixed Box	Camera 10	2.59 m	19.64 m	89.7	1.0	49	**27.54**
3	Storage Warehouse	WV-S2236LA	Indoor Fixed Dome	Camera 11	2.59 m	13.23 m	90	1.65	73	**28.74**
4	Storage Warehouse	WV-S2236LA	Indoor Fixed Dome	Camera 12	2.59 m	17.31 m	90	1.65	56	**27.93**
5	Storage Warehouse	WV-S2236LA	Indoor Fixed Dome	Camera 13	2.59 m	22.85 m	90	1.65	42	**27.3**

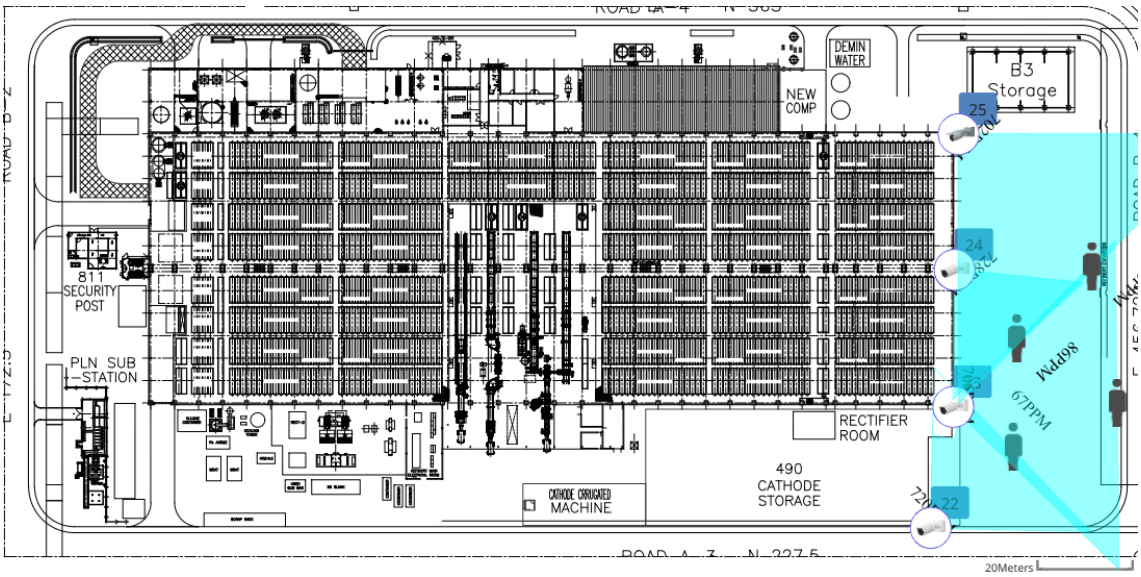


Figure 3. Camera Placement and Coverage of Loading Dock

Table 3. Camera Placement Specifications of Loading Dock [20]

No	Area	Model	Type	Name	Height	Distance	Viewing Angle	Zoom Ratio	PPM	Tilt Angle	Camera Unit Angle	Resolution
1	Loading dock	WV-S15500-V3L	Outdoor Bullet	Camera 14	2.59 m	23.17 m	90	1,47	67	27,27	23,17	3072x1728
2	Loading dock	WV-S15500-V3L	Outdoor Bullet	Camera 15	2.59 m	33.62 m	90	1,47	46	26,66	33,62	3072x1728
3	Loading dock	WV-S15500-V3L	Outdoor Bullet	Camera 16	2.59 m	19.59 m	85,2	1,61	86	26,28	19,59	3072x1728
4	Loading dock	WV-S1550L	Outdoor Bullet	Camera 17	2.59 m	39m	90	1,47	40	26,48	39	3072x1728

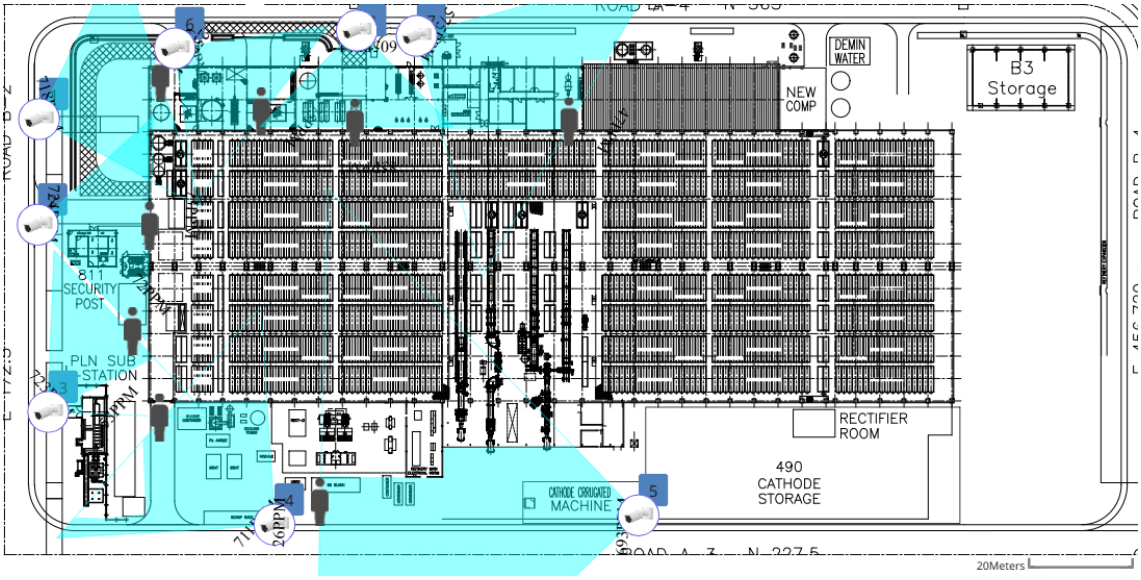


Figure 3.d Camera Placement and Coverage of Access / Perimeter Door [20]

Table 4. Camera Placement Specifications of Access Door / Perimeter [20]

#	Area	Model	Type	Name	Height	Distance	Viewing Angle	Zoom Ratio	PPM	Tilt Angle	Camera Unit Angle	Resolution
1	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 18	2.59 m	24.08m	93	1,4	61	28	24	3072x1728
2	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 19	2.59 m	21.15m	90	1,5	73	27	21	3072x1728
3	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 20	2.59 m	21.53m	90	1,5	72	27	22	3072x1728
4	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 21	2.59 m	29.11m	90	1,5	53	27	29	3072x1728
5	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 22	2.59 m	60.05m	90	1,5	26	26	60	3072x1728
6	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 23	2.59 m	20.62m	90	1,5	75	28	21	3072x1728
7	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 24	2.59 m	33.29m	90	1,5	47	27	33	3072x1728
8	Access / Perimeter Door	WV-S15500-V3L	Outdoor Bullet	Camera 25	2.59 m	18.12m	90	1,5	85	28	18	3072x1728

The following table summarizes the key results:

Table 5. Summarize Result from SDT CCTV Design Tools

Area	Number of Cameras	Camera Type	Area Coverage (%)	Blind Spots
Production Zone	8	Fixed & PTZ	95	Minimal - 5%
Storage Warehouse	5	Fixed	90	Moderate – 10%
Loading Dock	4	Fixed	90	Moderate – 10%
Acces/Perimeter Door	8	Fixed	95	Minimal -5%
Total Cameras	25	Fixed & PTZ	**92.5%**	**7.5%**

A total of 25 cameras, comprising both fixed and PTZ types, were installed, achieving an overall coverage of 92.5% with 7.5% remaining uncovered. The Production Zone reached the highest coverage at 95% through strategically placed fixed and PTZ cameras, given its critical operational importance. The Storage Warehouse and Loading Dock each attained moderate coverage levels of 90%, utilizing a minimal number of fixed cameras to optimize resource use while maintaining essential surveillance. The Access/Perimeter Door, identified as a security priority area, also achieved 95% coverage by deploying high-resolution outdoor fixed cameras designed to effectively identify individuals and vehicles entering the premises.

Blind spots were effectively minimized across all zones. With average covered area about 92.5% (previous target ≥85%) and blind spot about 7.5% (previous target ≤15%). The simulation identified areas requiring adjustment in camera angles or placement to eliminate vulnerabilities. The use of wide-angle lenses in fixed cameras and rotational capabilities of PTZ cameras contributed to significant blind spot reduction.

The initial requirement for cameras was 31 cameras in all zones in the traditional estimate. However, after SDT calculated the optimal number of cameras needed as 25 cameras for each zone, there was a significant reduction. This optimization resulted in a reduction of about 20% in the total number of cameras compared to the traditional design method, which means cost savings in hardware and installation.

The study demonstrated that SDT significantly enhances the efficiency of surveillance system design. By automating the placement and coverage analysis, SDT reduces the time required for system configuration from weeks to a few days. This efficiency is particularly valuable in industrial settings where downtime can have high financial implications.

SDT's ability to simulate and visualize camera coverage ensures comprehensive monitoring of critical zones. The achieved coverage level (up to 92.5%) exceeds the initial requirement (85%) of area coverage in industrial surveillance, thus ensuring minimal security gaps. The increased coverage directly contributes to reducing risks such as theft, accidents and unauthorized access.

By determining the exact number and type of cameras needed, SDT helps avoid unnecessary expenditures on excess equipment. For example, in the Loading Dock,

achieving 90% coverage with only four cameras reduced costs without compromising security.

SDT's simulation capabilities enable easy adaptation to changes in facility layouts or operational priorities. This flexibility ensures that the surveillance system remains effective even as the industrial environment evolves. Comparison of CCTV Design Tools with Traditional Methods shows that Traditional methods rely heavily on trial-and-error, resulting in suboptimal designs and longer project timelines. While the SDT Approach uses automated Simulation, thus providing objective recommendations based on data, ensuring higher accuracy, and better performance.

Conclusion

CCTV Design Tools (SDT) significantly enhance industrial surveillance by optimizing camera placement, reducing blind spots, and improving resource efficiency. This study, conducted across four critical zones Production Zone, Storage Warehouse, Loading Dock, and Access/Perimeter Door demonstrates SDT's ability to automate surveillance system design, reducing labor while ensuring accuracy. SDT maximized area coverage, achieving up to 95% in high-priority zones while minimizing blind spots in dynamic areas like the Loading Dock. It also optimized resource allocation, achieving 90% coverage in the Loading Dock with just four high-resolution cameras, reducing costs without compromising security. SDT's adaptability allows seamless reconfiguration in response to operational changes, making it invaluable for industries such as manufacturing, logistics, and energy. Additionally, it provides actionable insights for strategic decision-making, helping stakeholders prioritize security investments. While promising, further research could explore integrating SDT with AI and IoT for enhanced real-time adaptability. This study confirms SDT's role as a powerful tool for improving security and efficiency in industrial surveillance.

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