Evaluation of cctv placement in industrial areas using the simple additive weighting method

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Abstract— Determining the optimal placement of CCTV cameras in industrial environments is a critical challenge, often complicated by complex layouts, varying operational requirements, and limited resources. This study applied the Simple Additive Weighting (SAW) method to evaluate and prioritize camera placement in four main zones: Production Process Zone, Product Storage Zone, Product Loading Zone, and Access Door/Perimeter. Three multi-criteria decision-making factors were considered: area coverage, installation cost, and operational efficiency of surveillance. The SAW method allows for structured and data-driven analysis, normalizing and weighting each criterion to calculate a final score for each zone. The results revealed that the Product Storage Zone achieved the highest priority score (0.99), followed by the Product Loading Zone (0.84), Access Door/Perimeter (0.77), and Production Process Zone (0.71). These priorities are not in line with the results of the security officer preference survey, but are in line with the opinions of CCTV experts and company managers according to the operational needs of the zones. These findings underscore the effectiveness of the SAW method in providing objective and transparent decision-making for CCTV placement. By integrating quantitative analysis into the design of surveillance systems, this approach optimizes resource allocation and enhances industrial safety. Future research is encouraged to explore the integration of SAW with advanced technologies, such as artificial intelligence and the Internet of Things (IoT), for dynamic and real-time surveillance solutions.

Keywords— Simple Additive Weighting, CCTV Placement, Multi-Criteria Decision-Making, Industrial Security

1. INTRODUCTION

Industrial companies demand a strong security system to ensure the safety and security of property assets, employee or workforce assets, and the continuity of business operations[1]. One of the security systems used by industrial companies is the Closed-Circuit Television (CCTV) System as the foundation of modern surveillance infrastructure, which enables real-time monitoring, anomaly detection, and incident prevention[2] [3].

However, designing and implementing an effective CCTV system in a complex industrial layout poses various challenges, including optimal placement, resource constraints, and security operational requirements[4]. The following are some of the challenges in CCTV placement, including:

Complex Layout: Industrial facilities often consist of several zones with unique operational activities, such as production process areas, production storage areas, and production loading areas, as well as, no less importantly, factory access/perimeter doors. Each zone has different security needs, so it must be addressed through strategic CCTV camera placement[5].

Resource Limitations: Budget constraints and the high cost of installing CCTV require efficient resource allocation. Suboptimal placement can result in excessive hardware costs or inadequate coverage[4].

Subjectivity in Manual Design: Traditional methods for determining camera placement rely heavily on subjective judgment and trial and error, which are prone to inefficiency and inconsistency[6].

Multi-Criteria Decision Making with MCDM Method offers a structured approach to evaluate alternatives based on multiple criteria. This method is useful in scenarios that require prioritizing conflicting objectives, such as maximizing area coverage while minimizing installation costs[7] [8]. The Simple Additive Weighting (SAW) method as one of the MCDM techniques is used and is known for its simplicity and effectiveness. Where SAW normalizes the criteria values to a common scale and applies weights to reflect their relative importance. Then the final score for each alternative is calculated as the sum of the weights of the normalized values. So this study will use the Simple Additive Weighting (SAW) method [7] [8].

In the context of CCTV placement, SAW is used as a form of objective evaluation to ensure that all criteria are assessed impartially, transparent in providing reasons behind prioritization, and Flexible so that it can adapt to various industrial scenarios through adjustments to criteria and weights.

This study applies the SAW method to evaluate and prioritize CCTV placement in industrial facilities. The goal is to identify the optimal CCTV camera placement based on three main criteria: coverage area, installation cost, and operational efficiency of surveillance in addressing the challenges of CCTV system design in complex industrial environments. So that it can provide a data-based framework as a basis for decision making for industrial security.

This study also bridges the gap between theoretical MCDM models and their practical applications in surveillance system design. It is hoped that integrating SAW into the CCTV camera placement decision-making process can improve security outcomes while optimizing the allocation of security resources in industrial areas. In addition, the use of CCTV placement evaluation using the SAW method can provide reliable and objective results.

2. Previous Researches

Research on the use of multi-criteria decision-making (MCDM) methods such as Simple Additive Weighting (SAW) in CCTV surveillance system design has become a topic of interest for researchers. The following is a detailed review of relevant previous studies, structured to make it easier for readers to understand the contribution of each study.

[9] A study on CCTV placement design challenges highlights the difficulties in optimizing camera placement with complex layouts to meet diverse security needs. Traditional methods often fail to address blind spots and resource inefficiencies due to relying on manual and heuristic approaches.

In terms of the use of analysis tools [10] introduces a blind spot analysis tool in the monitoring system. This study emphasizes the importance of integrating simulation-based tools with decision-making frameworks to ensure comprehensive monitoring.

Meanwhile, in terms of Cost-Effective Implementation strategies, [11] analyzes strategies to balance security performance and budget constraints in CCTV implementation. This study underlines the need for data-driven methodologies to optimize camera placement and resource allocation.

Multi-Criteria Decision Making in Surveillance Systems as Security Optimization such as SAW, AHP (Analytic Hierarchy Process), and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) have been widely adopted in security design. [7] compared these methods, and concluded that SAW is very effective for applications that require simplicity and scalability.

Then in the Alternative Location evaluation method, [8] applied SAW to evaluate alternative locations for CCTV placement in densely populated areas. The study showed the effectiveness of the method in balancing conflicting objectives, such as cost and coverage.

The use of SAW for CCTV placement on complex infrastructure has been carried out by [8] to prioritize surveillance zones in smart city public facilities. This study highlights the method's ability to provide transparent, objective, and replicable results, making it ideal for dynamic environments. The use of CCTV in Critical Infrastructure Protection has been reviewed [12] in an effort to protect critical infrastructure, such as airports and industrial plants.

Thus, the reviewed research confirms the suitability of SAW for evaluating CCTV placement in various domains, including industrial facilities, public spaces, and critical infrastructure.

3. METHOD

This section details the methodology used to evaluate optimal CCTV placement in industrial environments using the Simple Additive Weighting (SAW) method. The methodology is designed to address the challenges of multi-criteria decision-making (MCDM) by structuring the evaluation process and ensuring objectivity in decision-making.

3.1. Multi-Criteria Decision-Making Framework

The SAW method provides a systematic approach to evaluate alternative locations for CCTV placement based on multiple criteria. It involves normalizing decision criteria to ensure comparability and applying weights to reflect their relative importance. The final score for each alternative is calculated as a weighted sum of normalized criteria values.

3.2. Evaluation Criteria

This evaluation considers three main criteria relevant to CCTV placement in industrial facilities.

- Area Coverage (Benefit): measured by the percentage of the area monitored by CCTV cameras. The value of this criterion is determined from the results of the coverage area simulation generated from the CCTV design tool. A higher value indicates better surveillance effectiveness.
- Installation Cost (Cost): Represents the total cost required for camera installation, including hardware, software, and labor costs. This value is taken from the estimated cost of the simulation results per camera placement point. A lower value is preferred to minimize expenses.
- Operational Efficiency (Benefit): Reflects the ability of the system to function optimally with minimal manual intervention. This criterion is measured from the pixel density of each camera according to the simulation results on the CCTV design tool. This is used as a reference for CCTV surveillance operators in an effort to detect an object according to the CCTV monitor. A higher value indicates greater efficiency.

3.3 Data Collection and Normalization

Data for each criterion was gathered from facility operational data, vendor specifications, and industry standards:

- Coverage Area: Simulated using CCTV Design Tools (SDT) for each location.
- Installation Cost: Estimated based on vendor bids and historical installation data based on simulated camera specifications.
- Operational Efficiency: Assessed through CCTV surveillance operator input focusing on the pixel density of the image captured by each simulated camera specification..

Then to ensure comparison between criteria, the raw data is normalized using the following formula:

- For Benefit Criteria: $Rij = \frac{Xij}{Xmax}$
- For Cost Criteria: $Rij = \frac{Xmin}{Xij}$

For criteria with benefits, namely area coverage and operational efficiency, normalization is done by dividing the value of each alternative by the maximum value of the criteria. While for criteria with costs, namely installation costs, normalization is done by dividing the minimum value of the criteria by the value of each alternative.

3.4. Weight Assignment

Weights were assigned to each criterion based on their relative importance, determined through consultations with security experts and facility managers as responden. Through the survey results of respondents, the following data was obtained:

Table 1. Preference value of each criterion based on survey results

Criteria	Preference Value	Weighting
Area Coverage	143	143/411 = 0.35
Installation Costs	129	129/411 = 0.31
Operational Efficiency	139	139/411 = 0.34
Total Value	411	1

The weights were normalized to ensure their total summed to 1. So for this study, the weights were:

- Area Coverage: 0.35

- : 0.31
- Operational Efficiency: 0.34

3.5. SAW Score Calculation

The final score for each alternative was calculated as:

$$Vi = \sum_{j=1}^{n} wj \, . Rij$$

Where: Installation Costs

Vi : Final score for alternative i

\n-wj : Weight of criterion j

Rij : Normalized value for alternative i under criterion j

Alternatives were ranked based on their Vi values, with higher scores indicating higher priority for CCTV placement.

3.6. Case Study: Four Zone Evaluation

The SAW method was applied to evaluate four critical zones in an industrial facility:

1. Production zone: High priority area requiring maximum coverage.
2. Product storage: Medium priority area requiring cost-effective solutions.
3. Product loading area: Dynamic area requiring high flexibility and reliability.
4. Access/perimeter: Restricted area where people, goods, and vehicles enter and exit.

Input data for each zone was collected, normalized, and evaluated to calculate the SAW score. The final ranking was used to prioritize CCTV placement.

3.7. Validation and Sensitivity Analysis

The results of the SAW recombination were further validated by comparing the SAW rankings with expert recommendations. Consistency between the two confirms the reliability of the methodology.

A sensitivity analysis was conducted to evaluate the impact of changing criterion weights on final rankings. This ensured the robustness of the decision-making process.

3.8. Limitations

This study assumes static environmental conditions and does not account for real-time changes, such as lighting variations or obstacles. Then expert or respondent bias may affect the weight assignment, requiring further standardization in future studies. Therefore, the evaluation is limited to four zones, and wider application is needed for generalization.

4. RESULT AND DISCUSSION

This section presents the results of applying the Simple Additive Weighting (SAW) method to evaluate and prioritize CCTV placement in an industrial facility. It also discusses the implications of these findings in optimizing surveillance system design and enhancing security outcomes.

4.1. Result

The following is the initial data obtained from the camera placement simulation using Panasonic's CCTV System Design Tool (SDT):

Table 2. Initial Data Camera Placement Simulation SDT

#	Area	Model	Type	Use	Name	Camera Installation Cost (IDR Millio	Cost /Zone	Height	Distance	Viewing Angle	Tilt Angle	Oscillation Angle	Camera Unit Angle	Covered Area	Resolution	Zoom Ratio	PPM	Ave. PPM
1	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Observation	Camera1	17		2.59 m	24.08m	93	28,04	2,59	24,08	62	3072x1728	1,38	61	
2	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Observation	Camera2	17		2.59 m	21.15m	90	27,46	2,59	21,15	55	3072x1728	1,47	73	
3	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Observation	Camera3	17		2.59 m	21.53m	90	27,42	2,59	21,53	56	3072x1728	1,47	72	
4	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Observation	Camera4	17		2.59 m	29.11m	90	26,87	2,59	29,11	75	3072x1728	1,47	53	
5	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Detection	Camera5	17		2.59 m	60.05m	90	26,07	2,59	60,05	156	3072x1728	1,47	26	
6	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Observation	Camera6	17		2.59 m	20.62m	90	27,51	2,59	20,62	53	3072x1728	1,47	75	
7	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Detection	Camera7	17		2.59 m	33.29m	90	26,68	2,59	33,29	86	3072x1728	1,47	47	
8	Access/Perimeter	WV-S15500-V3L	Outdoor Bullet	Observation	Camera8	17	136	2.59 m	18.12m	90	27,82	2,59	18,12	47	3072x1728	1,47	85	62
9	Production Zone	WV-S2236LA	Indoor Fixed Dome	Monitoring	Camera9	9		2.59 m	58.71m	90	26,09	2,59	58,71	152	1920x1080	1,65	17	
10	Production Zone	WV-S2236LA	Indoor Fixed Dome	Monitoring	Camera10	9		2.59 m	30.43m	90	26,8	2,59	30,43	79	1920x1080	1,65	32	
11	Production Zone	WV-S2236LA	Indoor Fixed Dome	Observation	Camera11	9		2.59 m	30.53m	50,3	15,63	2,59	30,53	79	1920x1080	2,72	67	
12	Production Zone	WV-S6130	Indoor PTZ	Observation	Camera12	14		2.59 m	28.95m	74	22,38	2,59	28,95	75	1920x1080	1	44	
13	Production Zone	WV-S2236LA	Indoor Fixed Dome	Observation	Camera13	9		2.59 m	20.65m	90	27,51	2,59	20,65	53	1920x1080	1,65	47	
14	Production Zone	WV-S1136	Indoor Fixed Box	Detection	Camera14	9		2.59 m	33.58m	89,7	26,58	2,59	33,58	87	1920x1080	1	29	
15	Production Zone	WV-S15500-V3L	Outdoor Bullet	Observation	Camera15	17		2.59 m	30.99m	90	26,78	2,59	30,99	80	3072x1728	1,47	50	
16	Production Zone	WV-S2236LA	Indoor Fixed Dome	Monitoring	Camera16	9	85	2.59 m	42.54m	90	26,38	2,59	42,54	110	1920x1080	1,65	23	39
17	Product Storage	WV-S2236LA	Indoor Fixed Dome	Observation	Camera17	9		2.59 m	11.21m	90	29,36	2,59	11,21	29	1920x1080	1,65	86	
18	Product Storage	WV-S1136	Indoor Fixed Box	Detection	Camera18	9		2.59 m	19.64m	89,7	27,54	2,59	19,64	51	1920x1080	1	49	
19	Product Storage	WV-S2236LA	Indoor Fixed Dome	Observation	Camera19	9		2.59 m	13.23m	90	28,74	2,59	13,23	34	1920x1080	1,65	73	
20	Product Storage	WV-S2236LA	Indoor Fixed Dome	Detection	Camera20	9		2.59 m	17.31m	90	27,93	2,59	17,31	45	1920x1080	1,65	56	
21	Product Storage	WV-S2236LA	Indoor Fixed Dome	Detection	Camera21	9	45	2.59 m	22.85m	90	27,3	2,59	22,85	59	1920x1080	1,65	42	61
22	Product loading area	WV-S15500-V3L	Outdoor Bullet	Observation	Camera22	17		2.59 m	23.17m	90	27,27	2,59	23,17	60	3072x1728	1,47	67	
23	Product loading area	WV-S15500-V3L	Outdoor Bullet	Detection	Camera23	17		2.59 m	33.62m	90	26,66	2,59	33,62	87	3072x1728	1,47	46	
24	Product loading area	WV-S15500-V3L	Outdoor Bullet	Observation	Camera24	17		2.59 m	19.59m	85,2	26,28	2,59	19,59	51	3072x1728	1,61	86	
25	Product loading area	WV-S1550L	Outdoor Bullet	Detection	Camera25	20	71	2.59 m	39m	90	26,48	2,59	39	101	3072x1728	1,47	40	60
					Total Cost	**337**							**Total Coverage Area**	**1823**			**Average PPM**	**55**

Then according to the three predetermined criteria including: area coverage, installation costs, and operational efficiency. The following input data for each area:

Table 3. Input Data for Each Area

Alternative Location	**Criterion**		
	Area Coverage (m^2)	Installation Cost (IDR Million)	Operational Efficiency (ppm)
Access / Perimeter	590	136	62
Production Zone	716	85	39
Product Storage	218	45	61
Product Loading Area	299	71	60

The next stage, the input data needs to be converted to percentage units (%) for the Area coverage criteria and operational efficiency criteria, so that the following table is obtained:

Table 4. Value converting covered area

Alternative Location	**Maximum Area Coverage (m^2)**	**SDT Simulation Coverage Area (m^2)**	**Percentage Coverage Area**
Access / Perimeter	655	590	90%
Production Zone	795	716	90%
Product Storage	229	218	95%
Product Loading Area	352	299	85%
Total Area	2031	1823	Average = 90%

Table 5. Value Converting Operational Efficiency

Alternative Location	**Operational Efficiency Maximum**	**Operational Efficiency Simulation**	**Percentage Operational Efficiency**
Access / Perimeter	62	62	100%
Production Zone	62	39	63%
Product Storage	62	61	98%
Product Loading Area	62	60	97%
		Average Operational Efficiency	90%

While for the Installation Cost criteria, there is no need to convert the value, because in addition to being included in the cost category, the currency value does not need to be changed to a percentage because there is no maximum cost target.

So here is the SAW analysis data according to the input data after being converted:

Table 6. Data for Analysis SAW Method

Alternative Location	Criterion		
	Area Coverage (%)	Installation Costs (IDR Million)	Operational Efficiency (%)
Access / Perimeter	90	136	100
Production Zone	90	85	63
Product Storage	95	45	98
Product Loading Area	85	71	97

From the values in Table 6, the next step is to calculate the normalization according to the specified benefit and cost categories, with the following results:

Table 7. Normalization Score

Alternative Location	Area Coverage (%) *Benefit*	Installation Costs (IDR Million) *Cost*	Operational Efficiency **(%)** *Benefit*
Access / Perimeter	0,95	0,33	1
Production Zone	0,95	0,53	0,63
Product Storage	1,00	1,00	0,98
Product Loading Area	0,89	0,63	0,97

From the normalization results above, then do the calculation by multiplying the criteria value for each alternative by the criteria weight according to the following formula:

$$SAW\ Score = \sum(weights\ .normalization$$

So that the SAW score calculation table is produced as follows:

Table 9. SAW Score Calculation

Alternative Location	**Area Coverage (%)**	**Installation Costs (IDR Million)**	**Operational Efficiency (%)**	**SAW Score**	**Rank**
Access / Perimeter	0,33	0,10	0,34	0,77	3
Production Zone	0,33	0,16	0,21	0,71	4
Product Storage	0,35	0,31	0,33	0,99	1
Product Loading Area	0,31	0,20	0,33	0,84	2

4.2. Discussion

4.2.1 Prioritization of Zones

The SAW method successfully prioritizes zones based on their monitoring needs and operational characteristics:

- The Product Storage Zone received the highest ranking due to its important location storing high-value products with an area coverage of up to 95%. With a relative installation cost of around 45 million rupiah, it has an operational efficiency of up to 98%. This means that investment in this zone deserves to be a top priority.
- The Product Loading Area received the second ranking, a location closely related to the product storage zone that is able to balance the criteria of a medium area coverage of 85% with the second lowest installation cost, and an operational efficiency of 97% making it an effective monitoring target.
- The access/perimeter door area with monitoring of people, goods and vehicles entering and leaving as well as fence monitoring is ranked third because it has the lowest score in terms of installation costs, this is due to the selection of high-resolution cameras for recognizing people's faces and vehicle numbers. Although it has the highest operational efficiency of up to 100%, and an area coverage of up to 90%.
- The last priority or fourth rank for CCTV placement is actually in the production zone with the lowest level of operational efficiency of only around 63%, even though it has an area coverage of up to 90% and the second highest installation cost of around 85 million rupiah. This is because the placement of CCTV in this area functions as monitoring, not as a CCTV observation or recognition area.

4.2.2 Cost-Benefit Balance

The inclusion of installation costs as a criterion ensures a balance between performance and affordability:

The product's Storage Zones demonstrate that effective surveillance can be achieved with fewer cameras and at a lower cost.

For high priority zones such as access doors/perimeters, the higher cost is justified by the significant security benefits..

4.2.3 Objectivity in Decision-Making

The SAW method provided an objective framework for evaluating zones, eliminating biases inherent in manual decision-making. The normalization and weighting process ensured that all criteria were proportionally considered, leading to transparent and data-driven rankings.

4.2.4 Adaptability of SAW

The adaptability of SAW was evident in its ability to evaluate diverse zones with varying security requirements. This flexibility makes it applicable to other industrial environments or sectors, such as logistics or public infrastructure.

4.3. Comparison with Traditional Methods

The manual approach relies heavily on subjective judgment based on individual experience and often produces inconsistent results due to trial and error without initial calculation analysis. Thus requiring significant time and resources to evaluate each alternative.

With the SAW method approach, it has been proven to offer a structured and reproducible process that is faster and more reliable, allowing sensitivity analysis to evaluate the impact of changes in criteria weights.

Previously, with the traditional method by surveys, the priority of CCTV placement was obtained based on interview data from different company security personnel compared to after calculating the priority with the SAW method. The following is a comparison table of the results:

Table 10. Comparison beetwen Survey Method and SAW Method for CCTV Priorities Placement

Alternative Location	Traditional Method	Priority Ranking	SAW Method	Priority Ranking
Access / Perimeter	0.85	1	0.77	3
Production Zone	0.71	2	0.71	4
Product Storage Area	0.56	3	0.99	1
Product Loading Area	0.53	4	0.84	2

The results of this comparison show that significant differences occur between the results of the traditional and SAW methods.

4.4. Key Insights

From a strategic perspective, the SAW methodology provides actionable insights for resource allocation, ensuring investments are directed to zones with the greatest security impact.

From a scalability perspective, the methodology can be easily scaled to include additional zones or criteria, making it versatile for a variety of applications.

From an integration perspective, combining SAW with technologies such as IoT and AI can enhance adaptability and real-time response in dynamic industrial environments.

5. CONCLUSION

This study demonstrates the effectiveness of the Simple Additive Weighting (SAW) method in optimizing CCTV placement within industrial environments. By systematically evaluating multiple criteria and providing data-driven prioritization, SAW offers a structured approach to addressing the challenges of surveillance system design. Below are the key findings and insights drawn from this research:

1. Objective and Transparent Decision-Making

The SAW method ensures that decisions are made based on quantifiable data, eliminating biases associated with manual or subjective approaches. By normalizing and weighting criteria, such as area coverage, installation costs, operational efficiency, technological reliability, and system flexibility, the methodology provides a clear framework for prioritizing surveillance zones.

2. Prioritization of Critical Zones

The study successfully prioritized four industrial zones:

The product storage area received the highest priority score because it stores high-value products and requires comprehensive monitoring.

The product loading area ranked second, reflecting a balance between cost-effectiveness and operational efficiency.

The access door/perimeter area, although dynamic, ranked third because it scored slightly lower in terms of installation costs.

While the production area ranked fourth in the final SAW score despite its wide area coverage, its low efficiency level still requires further handling.

This ranking is in line with the practical security needs of each zone, demonstrating the application of the SAW method in various environments.

3. Potential for Integration with Advanced Technologies

While the SAW method provides a robust framework for decision-making, its integration with emerging technologies, such as artificial intelligence (AI) and the Internet of Things (IoT), could further enhance its capabilities. For example: AI algorithms could dynamically adjust criteria weights based on real-time data. And IoT sensors could provide continuous updates on environmental conditions, improving decision accuracy.

4. Contributions to the Field

This research bridges the gap between theoretical decision-making frameworks and practical applications in industrial surveillance. By demonstrating the SAW method's ability to optimize CCTV placement, the study contributes to the broader adoption of data-driven approaches in security system design.

5. Limitations

The study assumes static conditions and does not account for real-time changes in lighting, obstructions, or environmental factors. Expert-Dependent Weighting: The assignment of weights relies on expert input, which may introduce subjectivity.

The Simple Additive Weighting method provides a practical, scalable, and transparent solution for optimizing CCTV placement in industrial environments. Its ability to balance multiple criteria ensures efficient resource allocation and improved security outcomes. By integrating SAW into surveillance system design, organizations can enhance their decision-making processes, reduce vulnerabilities, and create safer industrial facilities.

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