FACILITY LAYOUT OPTIMIZATION AND SIMULATION FOR OPERATIONAL EFFICIENCY AND CUSTOMER EXPERIENCE

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Abstract - This study addresses facility layout optimization in conveyor-belt buffet restaurants, where stochastic customer and staff movements limit the effectiveness of static evaluation methods. An integrated framework combining ALDEP for initial layout generation, CRAFT for iterative improvement, and discrete-event simulation for dynamic validation is proposed. A case study applies REL charts and From–To matrices to quantify spatial relationships and movement intensity. Results show that the CRAFT-optimized layout reduces the Volume Distance Product by 33.4% and significantly shortens travel distances. Simulation results further confirm reduced congestion and improved operational efficiency. The study's novelty lies in integrating design, optimization, and simulation into a unified framework for service systems.

Key words - Facility layout; conveyor belt buffet restaurant; ALDEP; CRAFT; optimization

1. Introduction

The rapid growth of the food and beverage industry in recent years has intensified competition, particularly in major urban areas [1, 2]. In this context, service enterprises face not only rising operating costs but also the need to meet increasing customer expectations for service speed, ease of movement, and spatial experience [3]. Therefore, effective facility layout planning has become a strategic factor that directly influences operational efficiency and restaurants' competitive capability [4, 5].

In conveyor-belt buffet restaurants, operational characteristics require continuous, simultaneous movement of both customers and staff across multiple functional areas [6]. However, in practice, facility layout design in many establishments is still based mainly on experience or intuition, lacking a quantitative analytical foundation [1, 2]. As a result, issues such as narrow walkways, excessive travel distances, and congestion at food pickup areas arise, leading to reduced service efficiency and negatively affecting customer experience, particularly during peak hours [7].

In the field of facility layout research, algorithms such as ALDEP (Automated Layout Design Program) and CRAFT (Computerized Relative Allocation of Facilities Technique) have been proven effective in optimizing movement flows and reducing operating costs; however, most existing studies focus primarily on industrial manufacturing contexts [8]. The number of studies applying these algorithms to service systems, particularly conveyor-belt buffet restaurants characterized by complex and highly stochastic movement flows, remains limited. Furthermore, many studies have not fully integrated initial layout design with subsequent layout improvement, thereby preventing a comprehensive evaluation of the effectiveness of layout optimization [9].

Moreover, most existing studies rely mainly on static performance indicators, such as travel distance or cost measures, which are insufficient to capture dynamic operational behaviors in service systems. In conveyor-belt buffet restaurants, stochastic customer arrivals, simultaneous staff–customer interactions, and congestion-sensitive pathways make system performance highly dependent on real-time conditions. Therefore, discrete-event simulation (DES) has emerged as an effective tool for modeling such dynamic behaviors and evaluating layout performance under realistic operating scenarios [22]. However, the integration of layout optimization and simulation-based validation within a unified framework remains limited in the literature.

To address these limitations, this study proposes an integrated framework that combines ALDEP for initial layout generation, CRAFT for iterative improvement, and DES for dynamic performance evaluation. The ALDEP algorithm generates an initial layout based on the adjacency relationships among functional areas [10, 11], while the CRAFT algorithm refines it by minimizing total travel distance [12, 13]. By incorporating simulation-based validation, this study provides both analytical and dynamic evidence of layout performance. The findings are expected to contribute to facility layout design in service systems and to support data-driven decision-making in restaurant operations.

2. Theoretical Background

2.1. Facility layout in service systems

Facility layout refers to the arrangement of functional areas and resources within a system to optimize flow efficiency and operational performance [14]. In service systems, facility layout not only affects operating costs but also directly influences the customer experience through accessibility, convenience, and perceived spatial quality.

In high-interaction service systems such as conveyor-belt buffet restaurants, facility layout plays a critical role in reducing conflicts in customer and staff movement, minimizing congestion, and maintaining the continuity of the service process [15]. However, because service system flows are stochastic and highly dependent on customer behavior, facility layout problems in this sector are often more complex than those in manufacturing systems [14].

2.2. Types of facility layouts

Common types of facility layouts include product layout, process layout, cellular layout, project layout, and hybrid layout [16]. Each layout type is suitable for different operational characteristics, including levels of standardization, flexibility, and system scale [17].

In the food and beverage service sector, particularly in conveyor-belt buffet restaurants, hybrid layouts are commonly adopted to combine the continuity of service flows with flexibility in spatial organization. Selecting an appropriate layout type is an essential foundation for subsequent facility layout analysis and optimization [9].

2.3. Performance indicators for facility layout evaluation

To evaluate and compare alternative facility layout configurations, quantitative indicators are commonly used to reflect the efficiency of movement flows within the system [12, 16]. Among these, the VDP is a widely used indicator that represents the product of movement frequency and travel distance between functional areas over a specified period.

The VDP indicator enables the evaluation of the overall level of movement within the system, thereby reflecting operating costs and the rationality of the facility layout. In addition, qualitative factors such as walkway openness and the ability to reduce movement flow conflicts are also considered when assessing the practical feasibility of service operations [18].

2.4. ALDEP and CRAFT algorithms in facility layout design

ALDEP is a heuristic algorithm that generates an initial facility layout based on the adjacency relationships among functional areas [10, 11]. This algorithm offers advantages such as a simple procedure, ease of implementation, and suitability for the preliminary design stage, particularly in systems with multiple spatial constraints [19].

CRAFT is an improvement-oriented heuristic algorithm that uses data on movement frequency and travel distance to iteratively exchange the positions of functional areas, aiming to reduce total material-handling or travel costs [12, 13, 20, 21]. Because CRAFT's performance depends on the initial layout, it is commonly combined with ALDEP to leverage the strengths of both methods, thereby forming a comprehensive facility layout optimization procedure [8, 9].

2.5. DES in facility layout evaluation

DES is a computer-based modeling approach used to represent real-world systems and analyze their dynamic behavior under various operating conditions [22]. In facility layout studies, DES enables the evaluation of layout alternatives by simulating movement flows, identifying bottlenecks, and testing improvement scenarios without disrupting actual operations [5, 22, 23].

In service systems such as conveyor-belt buffet restaurants, customer movement patterns and service interactions are highly variable and complex to assess using static analytical indicators alone. DES provides a powerful tool for modeling these dynamic characteristics, enabling researchers to examine customer travel distance, waiting time, congestion levels, and resource utilization under realistic demand scenarios.

In this study, DES implemented in Arena is integrated with facility layout optimization algorithms to validate and compare the performance of the current layout, the ALDEP-based layout, and the CRAFT-optimized layout under identical operating conditions. By combining analytical optimization with simulation-based evaluation, the proposed approach improves the reliability of layout design decisions and ensures that optimized layouts are operationally feasible in practice.

2.6. Review of related studies

Previous studies have shown that facility layout optimization methods such as ALDEP, CRAFT, TCR, and SLP have been widely applied in manufacturing systems to reduce material handling costs, improve space utilization, and increase productivity. As summarized in Table 1, most published applications focus on production environments, where flows are relatively structured, and movement patterns are more stable and predictable.

Table 1. *Related studies*

Author	Year	Algorithm	Main Finding
[18]	2016	TCR + SLP	Reduced material handling costs, minimized bottlenecks, improved space utilization, and increased labor productivity.
[13]	2019	CRAFT	Improved coordination among production stations, increased productivity, and reduced internal waste.
[11]	2023	ALDEP	Increased productivity and reduced internal transportation costs.
[10]	2024	ALDEP	Optimized space utilization and significantly reduced internal travel costs.
[24]	2025	ALDEP	Optimized workforce utilization and reduced reliance on temporary labor during peak periods.
This study		ALDEP–CRAFT + DES	Reduced travel distance and VDP while improving operational efficiency and congestion in a conveyor-belt buffet restaurant.

Although these studies confirm the effectiveness of heuristic layout optimization algorithms, their findings are primarily limited to manufacturing settings. In contrast, service systems, particularly conveyor-belt buffet restaurants, present additional complexity due to stochastic customer arrivals, simultaneous staff–customer interactions, and congestion-sensitive pathways. These characteristics make the facility layout problem more dynamic and behavior-driven than traditional material-handling systems.

Many previous studies apply ALDEP or CRAFT as standalone approaches and evaluate performance mainly through static cost indicators (e.g., travel distance or handling cost). Only a limited number of studies integrate constructive layout generation, iterative improvement, and discrete-event simulation into a unified framework that can capture operational feasibility under realistic service conditions.

To address these limitations, this study proposes an integrated framework combining ALDEP for initial layout generation, CRAFT for iterative refinement, and DES for performance validation. By applying the proposed approach to a conveyor-belt buffet restaurant case study, this research extends the application of manufacturing-oriented layout heuristics to service systems. It provides evidence that simulation-based validation is essential for evaluating congestion and customer experience outcomes.

3. Research methodology

This study adopts a case study approach that integrates facility layout optimization techniques with DES to comprehensively evaluate alternative layout configurations. The proposed methodology not only facilitates the development of optimized layouts using quantitative algorithms but also verifies their feasibility and performance under simulated operating conditions that closely resemble real-world conditions. As shown in Figure 1, the research framework consists of five sequential stages.

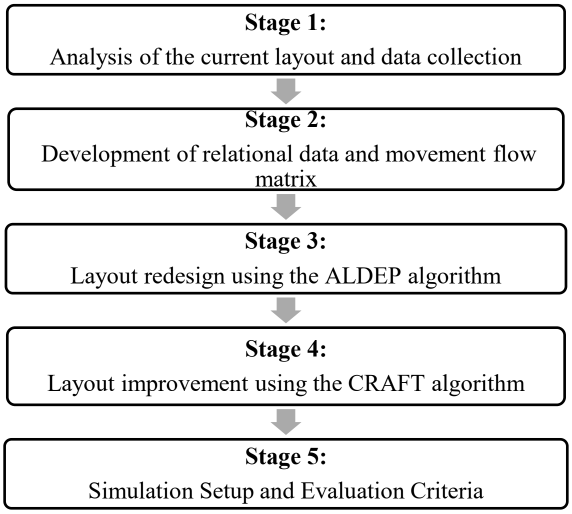


Figure 1. *Research process*

In the first stage, data were collected through on-site observation, layout measurement, and analysis of the operational processes of an anonymous conveyor-belt buffet restaurant. The collected data include the dimensions and locations of functional areas, customer and staff movement flows, and the frequency of movements between zones during a typical operating period. These data were used to establish a baseline dataset representing the current layout and its associated operational inefficiencies, which serves as the foundation for subsequent analysis.

Based on the baseline dataset, a From–To matrix was constructed to quantify movement frequencies between functional areas within the system. Adjacency relationships among these areas were then identified and converted into a relationship (REL) chart, reflecting the relative importance of spatial proximity between functional zones. This step establishes the link between empirical data analysis and the application of quantitative optimization methods.

Using the REL chart and considering spatial constraints, the ALDEP algorithm was applied to generate an initial facility layout. The algorithm prioritizes placing highly related functional areas in proximity to enhance overall movement flow efficiency. The resulting layout satisfies spatial constraints and functional adjacency requirements, serving as the initial solution for further optimization.

In the subsequent stage, the CRAFT algorithm was employed to improve the ALDEP-based layout. This improvement process involves iterative exchanges of functional area locations to minimize total travel distance, particularly between areas with high interaction frequency. Each exchange scenario was evaluated based on its impact on reducing travel distance, and the procedure continued until no further significant improvement could be achieved.

Finally, to evaluate the feasibility and operational performance of the alternative layouts, a discrete-event simulation model was developed for three scenarios: the current layout, the ALDEP-based layout, and the CRAFT-improved layout. The simulation model replicates customer movement flows under identical demand levels and operating time conditions, with standardized input parameters to ensure comparability. The effectiveness of each layout was assessed using quantitative performance indicators, including the VDP, average travel distance, and congestion levels at service areas. The simulation results enable a comparative evaluation of layout performance and provide a robust basis for identifying the optimal layout and supporting subsequent case study analysis and discussion.

4. Case study

4.1. Stage 1 - Current layout analysis and Data collection

This study investigates Branch A of a conveyor-belt hot pot buffet restaurant that frequently experiences movement bottlenecks during peak hours. To establish a baseline for layout optimization, data were collected through on-site layout measurements, direct observation, and tracking of customer and staff movement.

Observations were conducted during peak operating hours (18:00–20:00) over ten consecutive business days. Approximately 1,100 customer observations were recorded, along with staff movement activities between functional areas. The collected dataset includes (i) facility dimensions and functional area locations, (ii) customer and staff movement paths, and (iii) movement frequencies between areas, which were later used to construct the From–To matrix and support the REL chart development.

Table 2. *Description of identified problems*

Problem	Impact	Level
Improper layout of areas (dining tables are located far from food counters)	Long walking distances, increased food collection time, and reduced customer experience	High
Dining rows are placed too close to each other.	Narrow aisles, obstruction of serving staff, and congestion during peak hours	High
Some dining tables are located at the corners of the conveyor belt rows	Difficult food access and bottlenecks near conveyor areas	Medium

The current layout contains multiple functional areas operating simultaneously within a limited space. The baseline analysis indicates excessive travel distances between high-interaction areas, narrow aisles, and frequent congestion during peak periods. The main layout-related problems are summarized in Table 2.

For clarity and consistency, abbreviations of functional areas used throughout the case study are provided in Table 3.

Table 3. *Abbreviations of functional areas*

No.	Abbreviation	Meaning
1	RD	Reception Desk
2	DC	Drink Counter
3	DS	Dessert
4	HF	Hot Food
5	CA	Conveyor Area
6	CPA	Children's Play Area
7	PL	Parking Lot
8	WA	Waiting Area
9	VIP	VIP Room
10	K	Kitchen
11	WH	Warehouse
12	RR	Restroom
13	SR	Staff Room
14	MO	Management Office
15	TA	Trash Area

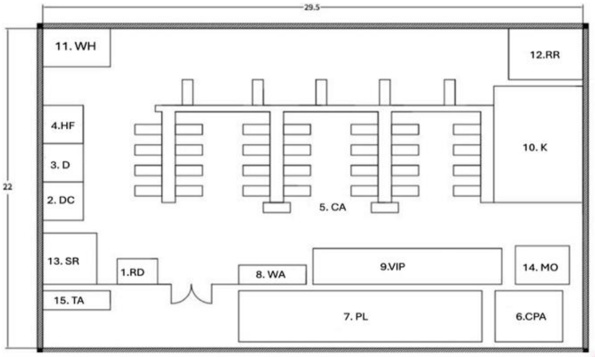


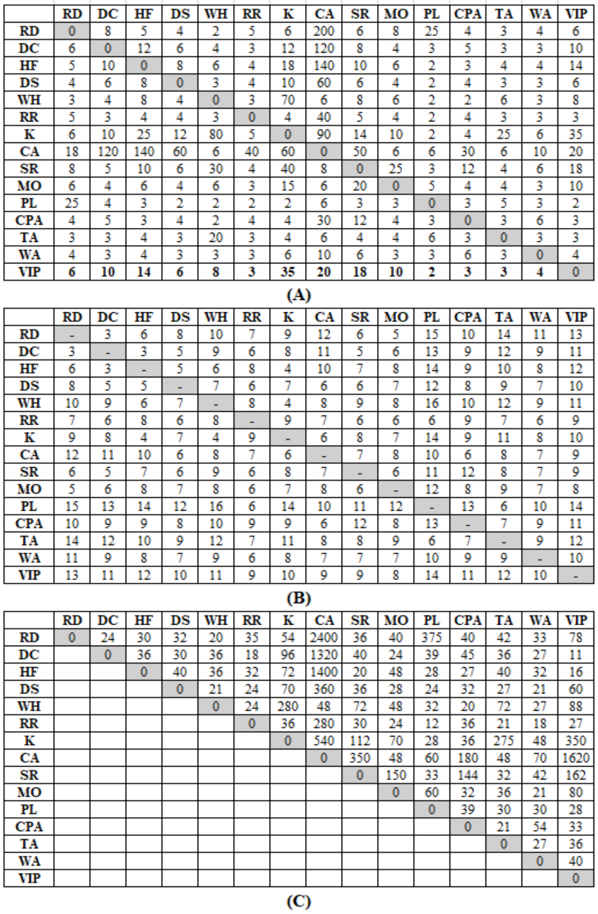
Figure 2. *Current layout of Restaurant A*

The existing facility layout of Restaurant A is illustrated in Figure 2. Overall, the baseline results confirm significant potential for improving operational efficiency and customer movement convenience through systematic facility layout redesign and optimization.

4.2. Stage 2 - Development of From-To matrix and REL chart

Based on the recorded movement flows, a From–To matrix was developed to quantify movement frequencies between functional areas. This matrix captures the interaction intensity between customers and staff across the 15 zones and serves as the primary input for facility layout evaluation and optimization.

Using the centroid coordinates of each functional area, rectilinear travel distances were calculated for all zone pairs. The baseline layout performance was then evaluated using the VDP, which reflects the combined effect of movement frequency and travel distance. The From–To matrix, the initial inter-area travel distances, and the corresponding VDP results are presented in Figure 3.



	RD	DC	HF	DS	WH	RR	K	CA	SR	MO	PL	CPA	TA	WA	VIP
RD	0	8	5	4	2	5	6	200	6	8	25	4	3	4	6
DC	6	0	12	6	4	3	12	120	8	4	3	5	3	3	10
HF	5	10	0	8	6	4	18	140	10	6	2	3	4	4	14
DS	4	6	8	0	3	4	10	60	6	4	2	4	3	3	6
WH	3	4	8	4	0	3	70	6	8	6	2	2	6	3	8
RR	5	3	4	4	3	0	4	40	5	4	2	4	3	3	3
K	6	10	25	12	80	5	0	90	14	10	2	4	25	6	35
CA	18	120	140	60	6	40	60	0	50	6	6	30	6	10	20
SR	8	5	10	6	30	4	40	8	0	25	3	12	4	6	18
MO	6	4	6	4	6	3	15	6	20	0	5	4	4	3	10
PL	25	4	3	2	2	2	2	6	3	3	0	3	5	3	2
CPA	4	5	3	4	2	4	4	30	12	4	3	0	3	6	3
TA	3	3	4	3	20	3	4	6	4	4	6	3	0	3	3
WA	4	3	4	3	3	3	6	10	6	3	3	6	3	0	4
VIP	**6**	**10**	**14**	**6**	**8**	**3**	**35**	**20**	**18**	**10**	**2**	**3**	**3**	**4**	0

(A)

	RD	DC	HF	DS	WH	RR	K	CA	SR	MO	PL	CPA	TA	WA	VIP
RD	-	3	6	8	10	7	9	12	6	5	15	10	14	11	13
DC	3	-	3	5	9	6	8	11	5	6	13	9	12	9	11
HF	6	3	-	5	6	8	4	10	7	8	14	9	10	8	12
DS	8	5	5	-	7	6	7	6	6	7	12	8	9	7	10
WH	10	9	6	7	-	8	4	8	9	8	16	10	12	9	11
RR	7	6	8	6	8	-	9	7	6	6	6	9	7	6	9
K	9	8	4	7	4	9	-	6	8	7	14	9	11	8	10
CA	12	11	10	6	8	7	6	-	7	8	10	6	8	7	9
SR	6	5	7	6	9	6	8	7	-	6	11	12	8	7	9
MO	5	6	8	7	8	6	7	8	6	-	12	8	9	7	8
PL	15	13	14	12	16	6	14	10	11	12	-	13	6	10	14
CPA	10	9	9	8	10	9	9	6	12	8	13	-	7	9	11
TA	14	12	10	9	12	7	11	8	8	9	6	7	-	9	12
WA	11	9	8	7	9	6	8	7	7	7	10	9	9	-	10
VIP	13	11	12	10	11	9	10	9	9	8	14	11	12	10	-

(B)

	RD	DC	HF	DS	WH	RR	K	CA	SR	MO	PL	CPA	TA	WA	VIP
RD	0	24	30	32	20	35	54	2400	36	40	375	40	42	33	78
DC		0	36	30	36	18	96	1320	40	24	39	45	36	27	11
HF			0	40	36	32	72	1400	20	48	28	27	40	32	16
DS				0	21	24	70	360	36	28	24	32	27	21	60
WH					0	24	280	48	72	48	32	20	72	27	88
RR						0	36	280	30	24	12	36	21	18	27
K							0	540	112	70	28	36	275	48	350
CA								0	350	48	60	180	48	70	1620
SR									0	150	33	144	32	42	162
MO										0	60	32	36	21	80
PL											0	39	30	30	28
CPA												0	21	54	33
TA													0	27	36
WA														0	40
VIP															0

(C)

Figure 3. *(A) From–To matrix, (B) inter-area distances, (C) VDP results*

To support the ALDEP layout generation, From–To frequencies were converted into qualitative closeness relationships using standard SLP notation: A (Absolutely necessary), E (Especially important), I (Important), O (Ordinary), U (Unimportant), and X (Undesirable). The conversion thresholds used in this study are provided in Table 4.

Table 4. *MACR-based frequency conversion*

Relationships	Frequencies
A	> 150
E	100 – 150
I	50 – 100
O	15 – 50
U	5 – 15

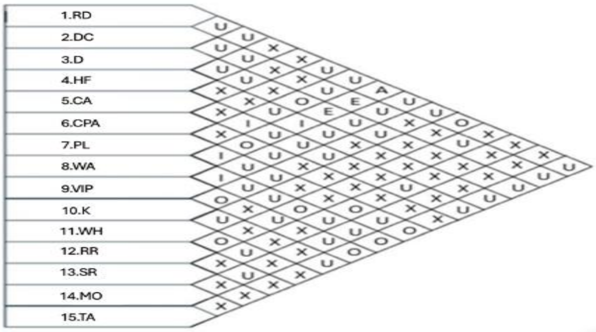


Figure 4. *REL Chart*

Based on these relationships, a REL chart was constructed to visualize spatial proximity priorities among functional areas. The REL chart shows that several high-interaction zones in the current layout are not positioned next to one another, resulting in longer travel distances and congestion during peak hours. The resulting REL chart is illustrated in Figure 4.

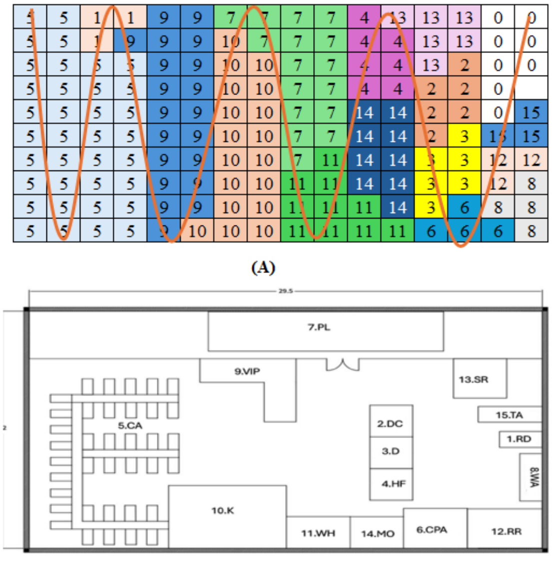
4.3. Stage 3 - Layout redesign Using the ALDEP algorithm

Based on the REL chart developed in Stage 2, the ALDEP was applied to generate an initial alternative facility layout. ALDEP is a constructive heuristic that sequentially assigns functional areas by prioritizing adjacency requirements, aiming to place highly related regions close together while satisfying spatial constraints.

The input data for ALDEP include the list of 15 functional areas, their required space, the REL chart closeness ratings, and physical constraints such as building boundaries and fixed zones. The layout generation process begins by selecting the functional area with the highest total closeness score as the starting department. Remaining areas are then assigned iteratively by selecting, at each step, the area that maximizes the cumulative closeness score with the already placed areas. When multiple candidate areas yield similar scores, feasibility with respect to space availability and operational logic is used as the tie-breaking criterion.

The ALDEP implementation procedure used in this study can be summarized as follows:

1. Input functional areas, space requirements, and REL chart ratings.
2. Compute the total closeness score for each area.
3. Select the area with the highest score as the initial placement.
4. Iteratively assign remaining areas based on maximum cumulative closeness to placed areas.
5. Check spatial feasibility and adjust placement if required.
6. Output the initial layout solution.



5	5	1	1	9	9	7	7	7	7	4	13	13	13	0	0
5	5	1	9	9	9	10	7	7	7	4	4	13	13	0	0
5	5	5	5	9	9	10	10	7	7	4	4	13	2	0	0
5	5	5	5	9	9	10	10	7	7	4	4	2	2	0	
5	5	5	5	9	9	10	10	7	7	14	14	2	2	0	15
5	5	5	5	9	9	10	10	7	7	14	14	2	3	15	15
5	5	5	5	9	9	10	10	7	11	14	14	3	3	12	12
5	5	5	5	9	9	10	10	11	11	14	14	3	3	12	8
5	5	5	5	9	9	10	10	11	11	11	14	3	6	8	8
5	5	5	5	9	10	10	10	11	11	11	11	6	6	6	8

(A)

(B)

Figure 5. *ALDEP-based layout optimization*
(A) relationship-weighted adjacency matrix, (B) ALDEP layout

The resulting ALDEP-based layout is illustrated in Figure 5, which shows improved adjacency among high-interaction functional areas compared with the current layout. The initial solution generated by ALDEP provides a feasible, structured layout configuration; however, because the algorithm is constructive, global optimality is not guaranteed. Therefore, the ALDEP-based layout is used as the starting solution for further refinement using the CRAFT algorithm in the subsequent stage.

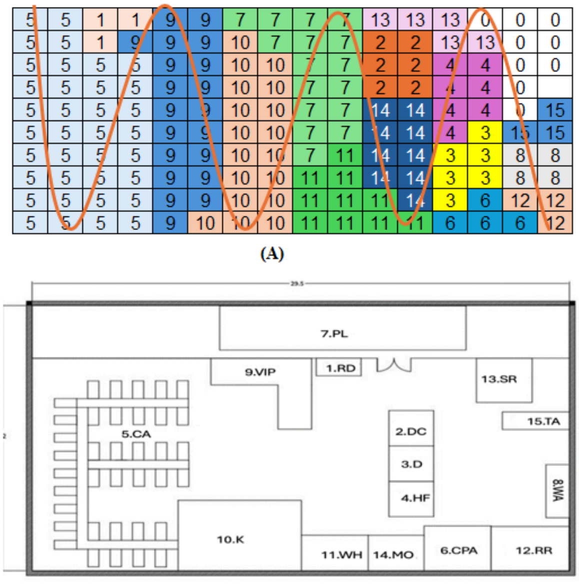
4.4. Stage 4 – Facility layout Improvement using the CRAFT algorithm

Starting from the initial layout generated by the ALDEP algorithm, the CRAFT was applied to further improve the facility layout. CRAFT is an improvement-based heuristic that iteratively exchanges the positions of functional areas to minimize the total travel cost within the system.

In this study, the objective function of CRAFT is defined as the minimization of the total inter-area travel cost, calculated as the product of movement frequency and rectilinear distance between the centroids of functional areas. Candidate area pairs for exchange were identified by prioritizing areas with high interaction frequency, as indicated by the From–To matrix.

The CRAFT improvement procedure used in this study is summarized as follows:

1. Input the initial ALDEP-based layout and the From–To matrix.
2. Compute the total travel cost of the current layout.
3. Identify candidate pairs of functional areas for swapping.
4. Perform pairwise exchanges and recalculate the total travel cost.
5. Accept an exchange if it reduces the total cost.
6. Update the layout and repeat the process.



5	5	1	1	9	9	7	7	7	7	13	13	13	0	0	0
5	5	1	9	9	9	10	7	7	7	2	2	13	13	0	0
5	5	5	5	9	9	10	10	7	7	2	2	4	4	0	0
5	5	5	5	9	9	10	10	7	7	2	2	4	4	0	
5	5	5	5	9	9	10	10	7	7	14	14	4	4	0	15
5	5	5	5	9	9	10	10	7	7	14	14	4	3	15	15
5	5	5	5	9	9	10	10	7	11	14	14	3	3	8	8
5	5	5	5	9	9	10	10	11	11	14	14	3	3	8	8
5	5	5	5	9	9	10	10	11	11	11	14	3	6	12	12
5	5	5	5	9	10	10	10	11	11	11	11	6	6	6	12

(A)

(B)

Figure 6. *CRAFT-based layout optimization*
(A) adjacency matrix, (B) optimized layout

The iteration process was terminated when no further exchange produced a meaningful reduction in total travel cost. In this study, the stopping criteria were defined as either (i) no improvement observed after evaluating all feasible pairwise exchanges or (ii) an improvement smaller than 1% of the total travel cost in two consecutive iterations.

The final CRAFT-optimized layout is illustrated in Figure 6. Compared with the ALDEP-based layout, the CRAFT solution further improves the adjacency of high-interaction areas, resulting in shorter travel distances, reduced congestion potential, and enhanced overall layout efficiency. The optimized layout obtained through CRAFT was subsequently evaluated using DES in Stage 5.

4.5. Stage 5 - Simulation Setup and Evaluation Criteria

To validate the feasibility and operational performance of the proposed layouts, a DES model was developed in Arena for three scenarios: the current layout, the ALDEP-based layout, and the CRAFT-optimized layout. All scenarios were simulated under identical demand levels, service logic, and staffing conditions, with only the spatial configuration (area locations and travel distances) varied to ensure comparability.

Customer arrivals were modeled as a Poisson process with an average arrival rate of 55 customers per hour, corresponding to exponentially distributed interarrival times with a mean of 65.45 seconds. Service processes were represented using probability distributions estimated from observation and staff consultation, including reception processing time UNIF(30, 60) seconds, food pickup time at each counter UNIF(20, 40) seconds, dining duration TRIANG(45, 50, 60) minutes, and payment processing time UNIF(45, 90) seconds.

The facility layout was digitized to obtain centroid coordinates (x, y) for eight main functional areas: entrance, reception, conveyor area, drink counter, hot food, dessert, payment counter, and restroom. These coordinates were used to compute rectilinear travel distances and define customer movement paths within the simulation model.

Each layout scenario was simulated using 30 independent replications, and performance indicators were reported as mean values with standard deviations and 95% confidence intervals. The DES model assumes independent service times, sufficient seating capacity, and constant staffing levels during the simulation horizon. Congestion effects were captured through queue formation and waiting delays at high-demand service points.

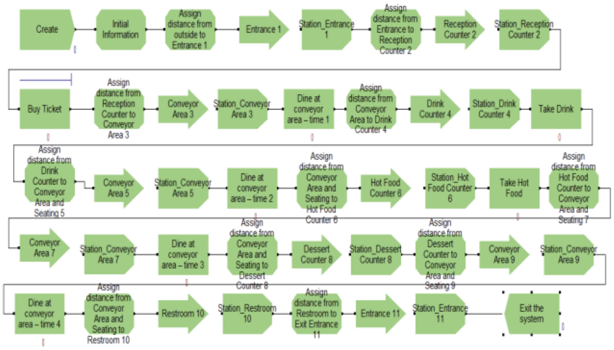


Figure 7. *DES model structure*

Layout performance was evaluated using the VDP, average travel distance, congestion level, and operational efficiency. The overall structure and logic of the simulation model, including customer arrival, movement, service interactions, and performance measurement points, are illustrated in Figure 7.

5. Results and Discussion

5.1. Facility layout Optimization results

This section presents the analytical results of the ALDEP and CRAFT layout optimization. The ALDEP-based layout results are shown in Figure 8, while the first CRAFT improvement step is illustrated in Figure 9, highlighting the reduction in inter-area travel cost.

	RD	DC	HF	DS	WH	RR	K	CA	SR	MO	PL	CPA	TA	WA	VIP
RD	0	6	8	4.5	10.5	4.5	8	8.5	9.5	5	13.5	7.5	7.5	10	12
DC		0	6	5.5	8.5	2.5	6	10.5	9.5	11	11.5	6.5	5.5	8	12
HF			0	7.5	2.5	4.5	8	12.5	11.5	9	5.5	0.5	2.5	2	14
DS				0	6	8	3.5	5	5	8.5	9	7	5	7.5	7.5
WH					0	7	5.5	10	9.5	7	3	2	3	2.5	11.5
RR						0	8.5	13	12	9.5	10	5	4	6.5	14.5
K							0	4.5	3.5	5	5.5	7.5	5.5	8	6
CA								0	3	6.5	7	12	10	12.5	5.5
SR									0	3.5	6	11	9	11.5	2.5
MO										0	3.5	8.5	6.5	9	5
PL											0	5	6	5.5	8.5
CPA												0	2.5	2.5	11.5
TA													0	2	0.5
WA														0	14
VIP															0

(A)

	RD	DC	HF	DS	WH	RR	K	CA	SR	MO	PL	CPA	TA	WA	VIP
RD	0	48	20	28	8	45	36	1600	48	288	50	12	22.5	40	72
DC		0	72	33	34	7.5	72	1260	76	44	34.5	33	16.5	24	120
HF			0	60	15	18	144	1750	115	54	11	1.5	10	8	196
DS				0	18	32	35	300	30	34	18	28	15	22.5	45
WH					0	21	385	60	76	42	6	4	18	7.5	92
RR						0	34	520	60	38	20	20	12	19.5	43.5
K							0	405	49	50	11	30	138	48	210
CA								0	150	39	42	360	60	125	990
SR									0	87.5	18	132	36	69	45
MO										0	17.5	34	26	27	50
PL											0	15	30	16.5	17
CPA												0	7.5	15	34.5
TA													0	6	1.5
WA														0	56
VIP															0
VDP											12029.5				

(B)

Figure 8. *ALDEP-based layout evaluation*
(A) distance matrix, (B) VDP results

The centroid coordinates of all functional areas were updated according to the ALDEP-generated layout. These coordinates were then used to compute the rectilinear inter-area distance matrix presented in Figure 8(A). By combining the updated distances with the observed movement frequencies, the resulting From–To weighted cost matrix and the corresponding VDP value were obtained, as reported in Figure 8(B). The ALDEP-based layout yields a VDP of 12,029.5, indicating that the initial constructive layout design already provides a measurable reduction in total movement cost compared with the current layout.

The CRAFT improvement process is illustrated in Figure 9, which demonstrates the first exchange operation performed on the ALDEP-based layout. Specifically, Figure 9(A) presents the updated inter-area distance matrix after the first swap, while Figure 9(B) shows the updated weighted matrix and the resulting VDP value. This figure highlights the iterative nature of CRAFT, where layout quality is improved through systematic pairwise exchanges that reduce the total travel cost. The progressive reduction in VDP across iterations confirms that CRAFT effectively refines the initial ALDEP solution by improving adjacency among high-interaction areas and minimizing movement distance.

	RD	DC	HF	DS	WH	RR	K	CA	SR	MO	PL	CPA	TA	WA	VIP
RD	0	3	0	0	4	9.5	10.5	7.6	2.5	4.5	4.5	3.2	8.8	6	5.6
DC			3	9	7	13.5	13.5	11	7.5	7.5	10.5	2.2	11.8	12	8.6
HF				6	4	10.5	10.5	7.6	2.5	4.5	4.5	3.2	8.8	6	5.6
DS					4	4.5	4.5	6.4	8.5	1.5	1.5	6.8	2.8	2	2.4
WH						6.5	6.5	5.4	4.5	2.5	5.5	5.2	4.8	2	1.6
RR							4	6.9	9	6	3	6.2	1.7	4.5	4.9
K								2.9	6	8	5	11	4.3	4.5	4.9
CA									2.9	4	6	3	11.3	1.7	4.5
SR									0	1.1	3.1	0.1	8.4	1.2	1.6
MO										0	2	1	7.3	2.3	0.5
PL											0	3	5.3	4.3	1.5
CPA												0	8.3	1.3	1.5
TA													0	9.6	6.8
WA														0	2.8
VIP															0

(A)

	RD	DC	HF	DS	WH	RR	K	CA	SR	MO	PL	CPA	TA	WA	VIP
RD	0	24	0	0	8	48	63	1520	15	36	112.5	12.8	26.4	24	33.6
DC		0	36	54	28	41	162	1272	60	30	31.5	11	35.4	35.4	86
HF			0	48	24	42	189	1064	25	27	9	9.6	35.2	24	78.4
DS				0	12	18	45	384	51	6	3	27.2	8.4	6	14.4
WH					0	20	455	32.4	36	15	11	10.4	28.8	6	12.8
RR						0	16	276	45	24	6	24.8	5.1	13.5	14.7
K							0	261	84	80	10	45.2	107.5	27	172
CA								0	145	24	36	90	67.8	17	810
SR									0	27.5	9.3	1.2	33.6	7.2	28.8
MO										0	10	4	29.2	6.9	5
PL											0	9	26.5	12.9	3
CPA												0	24.9	7.8	4.5
TA													0	28.8	20.4
WA														0	11.2
VIP															0
VDP														**9295**	

(B)

Figure 9. *First CRAFT exchange results*
(A) distance matrix, (B) VDP results

The effectiveness of the proposed approach was evaluated using both analytical and simulation-based indicators, enabling a comprehensive comparison of layout performance. A qualitative and quantitative comparison of the current layout, the ALDEP-based layout, and the CRAFT-optimized layout is presented in Table 5.

Table 5. *Comparison of Current, ALDEP, and CRAFT facility layouts*

Criteria	Current Layout	ALDEP-Based Layout	CRAFT-Optimized Layout
Total travel distance	High	Reduced	Further reduced
Average travel distance between areas (unit)	1816	750	544
VDP (unit)	13,963	12,029.5	9,295
Employee movement convenience	Low	Moderate	High
Customer movement convenience	Low (high congestion)	Moderate	High (low congestion)

As shown in Table 5, the ALDEP-based layout improves the spatial arrangement by placing high-interaction functional areas closer together. This results in a substantial reduction in average inter-area travel distance, decreasing from 1,816 units in the current layout to 750 units. In addition, the VDP decreases from 13,963 to 12,029.5, indicating improved movement efficiency.

Further improvement is achieved through the CRAFT algorithm. By iteratively exchanging the positions of functional areas with high interaction frequency, the CRAFT-optimized layout reduces the average inter-area travel distance to 544 units and lowers the VDP to 9,295. The progressive reduction in VDP across layout alternatives is summarized in Table 6, showing that the CRAFT layout achieves a 33.4% improvement compared with the current layout, while the ALDEP layout provides a 14.0% improvement.

Table 6. *Comparison of VDP Across Layout Alternatives*

Layout alternative	VDP	Improvement Compared to Current Layout
Current	13.963	–
ALDEP	12.029,5	14,0%
CRAFT	9.295	33,4%

The results verify that ALDEP provides a feasible and structured initial solution, whereas CRAFT plays a critical role in further refining the layout and achieving superior performance in terms of travel distance and VDP.

5.2. Simulation Results and Operational Performance Comparison

To evaluate the feasibility and operational performance of the layout alternatives under dynamic service conditions, discrete-event simulation experiments were conducted for the three scenarios: the current layout, the ALDEP-based layout, and the CRAFT-optimized layout. Each scenario was simulated using 30 independent replications, and the results were summarized using mean values with variability measures (standard deviation and 95% confidence intervals).

Table 7. *Comparison of simulation results across the layout alternatives*

Indicator	Current	ALDEP	CRAFT
Average travel distance	100%	Reduced by approximately 70%	Reduced by more than 70%
Operation efficiency	-	Increased by approximately 3.93%	Increased by approximately 9.78%
Congestion level	High	Moderate	Low

The simulation outcomes are presented in Table 7. The results show a consistent improvement in operational performance from the current layout to the ALDEP-based layout and further to the CRAFT-optimized layout. In terms of customer movement, both optimized layouts significantly reduce travel distance compared with the current configuration. Specifically, the ALDEP-based layout reduces average travel distance by approximately 70%, while the CRAFT-optimized layout achieves a reduction of more than 70%, reflecting improved pathway clarity and shorter inter-area distances.

Operational efficiency also improves across the alternative layouts. As shown in Table 7, operational efficiency increases by 3.93% in the ALDEP-based scenario and by 9.78% in the CRAFT scenario under identical demand conditions. In addition, congestion levels at key service points, such as reception, food counters, and payment, decrease progressively across scenarios. The current layout exhibits high congestion during peak periods, whereas the ALDEP-based layout reduces congestion to a moderate level, and the CRAFT-optimized layout achieves the lowest congestion.

Overall, the simulation results confirm that the analytical improvements from ALDEP and CRAFT are operationally feasible and yield measurable performance gains when dynamic interactions between customers and service processes are considered.

5.3. Practical implications

The results from both the analytical evaluation and the DES demonstrate that facility layout optimization can significantly improve operational efficiency and customer convenience in conveyor-belt buffet restaurants. The consistent reduction in travel distance and VDP across the ALDEP and CRAFT stages confirms that spatial adjacency plays a critical role in minimizing unnecessary movement in high-interaction service environments.

The superior performance of the CRAFT-optimized layout can be explained by its iterative improvement mechanism, which explicitly accounts for movement intensity between functional areas. While ALDEP effectively generates a feasible initial layout based on qualitative adjacency relationships, it does not guarantee optimal placement of all high-flow zones. CRAFT addresses this limitation by systematically refining the layout through targeted exchanges of high-interaction areas, thereby further reducing travel distance and congestion. This finding is consistent with prior facility layout studies in manufacturing systems, which report that improvement-based heuristics outperform constructive methods when applied after an initial solution is established.

From a service-system perspective, the simulation results highlight the importance of validating the outcomes of layout optimization under dynamic operating conditions. Unlike manufacturing environments with relatively stable material flows, conveyor-belt buffet restaurants feature stochastic customer arrivals and simultaneous staff–customer interactions. The observed reduction in congestion and improvement in operational efficiency indicate that layout improvements identified through static indicators translate into tangible benefits when dynamic interactions are considered.

In practice, the findings suggest that restaurant operators can achieve meaningful efficiency gains through layout redesign without increasing staffing levels or altering service concepts. Academically, this study contributes by extending manufacturing-oriented layout optimization algorithms to service systems and demonstrating the value of integrating discrete-event simulation to capture congestion and customer experience effects. These insights support the broader applicability of hybrid optimization–simulation frameworks for complex service facility layout problems.

6. Conclusions

This study proposes an integrated facility layout optimization framework that combines ALDEP for initial layout generation, CRAFT for iterative improvement, and DES for performance validation in a conveyor-belt buffet restaurant. The case study results demonstrate substantial reductions in travel distance and the VDP, along with improved operational efficiency and reduced congestion under dynamic service conditions.

From a theoretical perspective, this research extends the application of manufacturing-oriented facility layout optimization algorithms to service systems characterized by stochastic customer movement and simultaneous staff–customer interactions. The findings provide empirical evidence that layout heuristics developed initially for manufacturing environments remain effective when adapted to complex service settings.

Methodologically, the study contributes a replicable optimization–simulation framework that integrates constructive layout design, iterative improvement, and discrete-event simulation within a unified process. This integrated approach enables both analytical evaluations using static indicators and dynamic validation of layout performance under realistic operating conditions.

From a practical standpoint, the proposed framework offers restaurant managers a data-driven decision-support tool for facility layout redesign. The results indicate that meaningful efficiency gains can be achieved through spatial reconfiguration without increasing staffing levels or modifying service concepts.

This study is limited to a single case, and future research should apply the proposed framework to multiple restaurants with varying layouts, demand patterns, and customer behaviors to further validate its generalizability and robustness.

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