Optimizing the Compliance of Critical COVID-19 Preventive Measures in Airport Facilities Layout: A Hybrid Approach Using VIKOR, SLP, and CRAFT

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Abstract

Due to the COVID-19 pandemic, measures were enforced on air travel to limit the spread of the virus as a step towards mitigating health and financial risks. This study aims to reveal the most critical COVID-19 measures in airports that effectively reduce potential risks. In addition, the study aims to put forward a framework to redesign internal airports facility layouts that facilitate reducing passengers' cycle time and ensure optimal compliance with the revealed measures based on their priorities. A compiled list of imposed preventive measures is used for the design of a questionnaire survey targeting the opinions of experts in the fields of epidemiology and infectious diseases, as well as airport managers and operational staff for the collection of measures' importance weights and rating data. The internal facility layout of a typical domestic medium-sized airport in Saudi Arabia was also captured, along with its pertaining data were also collected. A hybrid approach was followed using: the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) technique in Serbian, which means: Multicriteria Optimization and Compromise Solution, the Systematic Layout Planning (SLP) procedure, and the Computerized Relative Allocation of Facilities Technique (CRAFT) to generate airport facility layout alternatives. Results of the study revealed a prioritized set of critical COVID-19 preventive measures within airports. Furthermore, an optimal internal layout redesign of an airport facility is developed based on the revealed set of prioritized measures. Implications of this study include the proposed hybrid approach of the used methods and the revealed set of prioritized COVID-19 preventive measures in airports. Which can assist decision-makers and responsible authorities of airports in increasing the compliances with enforced measures through optimized layout designs of airports limiting the spread of viruses and pandemics.

Keywords

Airports; COVID-19 Measures; Layout; Optimization; Saudi Arabia

1. Introduction

Since the World Health Organization (WHO) declared COVID-19 a pandemic in late March 2020, the global economy has undergone the largest economic shock ever experienced in decades according to World Bank's latest reports (World Bank, 2020), despite the efforts of governments to counter the downturn with fiscal and monetary policy support. As global supply chains are disrupted, unemployment rates are increasing and a drop in consumer spending in an unprecedented manner, forecasts of Gross Domestic Product (GDP) growth rates for the world's economy have significantly plummeted (Fund, 2020).

On a local scale, on March 23, Saudi Arabia has imposed a complete lock-down in addition to the prior partial lock-down which resulted in negative economic implications on the kingdom, namely, a drop by 4.2 percent in real annual GDP growth rate in the third quarter of 2020 (Ministry of Finance, 2020). Most sectors have been affected since the start of the pandemic. However, the travel and tourism industry has been one of the most affected sectors of the economy as the travel ban took place and more preventive measures are introduced (Ministry of Health, 2020).

Hence, the objective of this study is to reveal a prioritized set of the critical COVID-19 preventive measures that will assist in minimizing the spread of the virus in airports between passengers. Moreover, to optimize the compliance of the revealed set of critical COVID-19 measures in airport facilities' internal layout in terms of time reduction to decrease the chance of getting exposed to the virus and to ensure that the most crucial measures are implemented.

2. Literature Review

Before the World Health Organization (WHO) declared COVID-19 as a pandemic in March 2020, In December 2019, several cases suffering from pneumonia were recorded in Wuhan the capital of Hubei province in China (Liu, Kuo, and Shih, 2020). According to (Hang et al, 2019) the recent cluster of pneumonia cases at the time was experiencing fever, malaise, dry cough, and dyspepsia. Consequently, the disease was called out in the Chinese press as the "Wuhan Pneumonia" (WHO Disease outbreak news, 2020) and the sequencing results have shown that the causative agent is a novel coronavirus. Up to date, the novel coronavirus, also broadly known as COVID-19, and its variant mutations have infected millions of people, some of them recovered, and took the lives of others (Worldmeters, 2021).

The pandemic has caused severe and direct impacts on the global economy and financial markets, causing significant reductions in income, rise in unemployment rates, disruption in supply chains, business closures, and the decimation of entire industries such as the travel and tourism industry (Pak et al, 2020). The travel and tourism industry has been one of the most affected sectors of the economy as the travel ban took place and more preventive measures are introduced (Ministry of Health, 2020). Compliance with enforced preventive measures especially in airports plays a vital role in limiting the spread of viruses. Hence, it is vital to redesign airport internal layouts in a way that facilitates compliance with such preventive measures.

Significant advancements in multicriteria decision-making models have been made over the years, optimization problems involving multiple criteria and several alternatives, arise in many fields e.g., economics, healthcare, engineering to name a few. (Opricovic, 1998) proposed multicriteria decision-making (MCDM) technique for selecting the optimal civil engineering systems, which opened the door for this technique to be utilized by more researchers. This method determines the compromise solution and the weight intervals for preference stability of the obtained compromise solution (Opricovic and Tzeng, 2004). As in the case of identifying the critical Covid-19 measures in airports, Samanlioglu, 2019, utilized a Fuzzy AHP-VIKOR in evaluating and ranking Influenza intervention strategies. In contrast, (Samanlioglu and Kaya, 2020) proposed a Fuzzy Analytic Hierarchy Process (FAHP) approach to evaluate the importance of intervention strategy alternatives adopted by various countries amid the pandemic.

While, in the case of any Facility Layout Problem (FLP), we usually seek to find the optimal facility arrangement in the existing layout to increase throughput rates, reduce times, or increase machine/labor utilization. Then, an optimal layout is achieved such that a set of criteria are met and/or some objectives are optimized, and it's considered a fundamental optimization problem encountered in many organizations regardless of their sector (Kuan and Wong, 2010). For instance, (Yen et al, 2019) generated eight layout alternatives for Taiwan's International Airport, then the optimal layout is selected through a developed mathematical programming formulation that aims to minimize the flow distance of passengers in the departing terminal. Muther (1973), developed a general methodology to solve a facility layout problem, which can be used as a framework for generating facility layout alternatives based on: the flow of materials, activity relationships, space requirements, and the space available. Moreover, a manufacturing plant layout was improved utilizing the CRAFT technique by determining the suboptimum relative location in each iteration until a final layout was proposed. (Armour, et al., 1963) On the other hand, the same technique has been utilized in various contexts. For instance, an improvement in theatre design using facilities layout planning has enabled a more efficient flow within the theatre hall (Assem, Ouda, and Abdel Wahed, 2012). In contrast, the aim is to utilize this technique to generate a set of alternative layout plans and identify the optimal alternative using the rankings and time.

This study aims to reveal the most critical COVID-19 measures in airports that effectively reduce potential risks. In addition, the study aims to put forward a framework to redesign internal airports facility layouts that facilitate reducing passengers' cycle time and ensure optimal compliance with the revealed measures based on their priorities. To achieve these objectives, a hybrid approach was followed using: the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) technique in Serbian, which means: Multicriteria Optimization and Compromise Solution, the Systematic Layout Planning (SLP) procedure, and the Computerized Relative Allocation of Facilities Technique (CRAFT) to generate airport facility layout alternatives.

3. Methodology

To achieve the objectives of this study, a hybrid approach was followed using: the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) technique in Serbian, which means: Multicriteria Optimization and Compromise Solution which is classified as a multicriteria decision making (MCDM) technique, the Systematic Layout Planning (SLP) procedure, and the Computerized Relative Allocation of Facilities Technique (CRAFT) to generate airport facility layout alternatives. This is to find the optimum airport facility layout alternative that complies with a prioritized set of critical COVID-19 measures imposed on airports. A typical domestic medium-sized airport in Saudi Arabia was selected to be the focus of this study for the application of the aforementioned approach.

Due to the pandemic, air travel, airports, and airlines suffered great financial losses. Therefore, as proof of the status quo, we captured flights data of the selected airport in this study as illustrated in (Table 1**)**. This is to compare the number of daily flights and passengers before and after the pandemic which shows the need for the study.

Table 1. Number of daily flights and passengers in a domestic medium-size airport in Saudi Arabia before and during the pandemic (Flightradar 24, Nov. 2020)

	Before	**During**
Daily flights	6	6
Daily passengers	2328	1178

However, to limit the spread rates of the virus in airport facilities, COVID-19 preventive measures were imposed on air travel, airports, and airlines worldwide. Therefore, preventive measures imposed on air travel in Saudi Arabia based on which this study is conducted were compiled as listed in (Table 2).

Table 2. COVID-19 measures imposed on air travel (GACA, 2020)

Code	**Measure**
M1	Travel history disclosure
M2	Regulating access from/to airport's facilities
M3	2-hour arrival before take-off
M4	Electronic tickets & payments
M5	Thermal screening devices
M6	Face and iris recognition technologies (instead of finger biometric authentication)
M7	Isolation areas for suspected cases
M8	Covid-19 checks
M9	Baggage limitation (1 piece)
M10	50% capacity through airport facilities
M11	Cart and facility equipment disinfection
M12	Glass barriers
M13	Face masks
M14	Gloves
M15	Hand sanitization & hygiene
M16	Social distancing
M17	Indicative floor posters
M18	Health tracking app (Tawakkalna)

To reveal the priorities of the critical COVID-19 preventive measures (Table 2), we adopted the VIKOR technique. The essence of this technique is to rank and select from a set of alternatives in the presence of conflicting criteria (Opricovic, 1998). Therefore, a questionnaire survey was designed using the compiled measures (Table 2) targeting the opinions of 18 experts in the fields of epidemiology and infectious diseases, as well as airport managers and operational staff. On a 5-point Likert scale (i.e., extremely important, important, neither important nor unimportant, unimportant, extremely unimportant) the experts were asked to rate the importance of the imposed measures in limiting the spread rates of the virus in airport facilities. This is to obtain importance weights of the preventive measures, which will be used as a set of prioritized criteria for selecting an alternative airport facility layout that optimizes compliance with the imposed measures. To find out the expert opinion-based prioritized set of critical COVID-19 preventive measures, the following VIKOR algorithm (Opricovic, 1998) was applied.

For a decision matrix D (1) of participant respondents as follows, where *i* represents COVID-19 measures, and *j* represents the experts. Furthermore, x_{ij} represent the score of each COVID-19 measure *i* for expert *j*:

$$D = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$$

$$\text{where, } X = (x_{ij}, \dots, n). \qquad (1)$$

To determine the best f_i^+ and the worst f_i^- numbers of criterion measure using (2).

$$f_i^+ = \max x_{ij}, \quad f_i^- = \min x_{ij} \qquad (2)$$

To calculate S_i and R_i using (3) and (4), where $i = 1, 2, \dots, m$ and $j = 1, 2\dots, n$.

$$S_i = \sum_{i=0}^{n} \frac{W_j(x_i^+ - x_{ij})}{(x_i^+ - x_i^-)} \qquad (3)$$

$$R_i = \max_j \left[W_j \frac{(x_i^+ - x_{ij})}{(x_i^+ - x_i^-)} \right] \qquad (4)$$

Since W_j represent the weighted measures given by the experts.

To calculate Q_i, which will give a list of ranked COVID-19 measures

$$Q_i = \upsilon(\frac{(S_i - S^*)}{(S^- - S^2)} + (1-\upsilon)\frac{(R_i - R^*)}{(R^- - R^*)} \qquad (5)$$

Where $\boldsymbol{\upsilon}$, is the weight of Covid-19 measures or so-called the maximum group utility, which normally has a value of 0.5.

Where these variables can be found using (6).

$$S^* = \min_i S_i, \quad S^- = \max_i S_i, \qquad (6)$$

$$R^* = \min_i R_i, \quad R^- = \max_i R_i,$$

Finally, the measures are ranked using S_i, R_i, and Q_i in descending order. Therefore we then can list a ranking of the critical COVID-19 measures based on two conditions which are acceptable advantages (C1), and acceptable stability in decision making (C2) using the relation:

$$\text{(C1):} \quad Q(A^2) - Q(A^1) \geq DQ; \quad DQ = \frac{1}{j-1} \qquad (7)$$

where *j* is the number of measures (j=18).

(C2): A^1 must be also the most compromised ranked by S or R.

If one of the conditions is not satisfied, the set of compromise solutions is a stand-in. For instance, alternatives A^1 and A^2 if only condition C2 is not satisfied, or alternatives: A^1, A^2, …., A^m if condition C1 is not satisfied; and A^m is determined by the relation in (8).

$$Q(A^M) - Q(a^1) \geq DQ \tag{8}$$

After applying the above algorithm, a list of prioritized Covid-19 preventive measures in airports will be revealed. the resulting ranked list of measures will be based on their respective importance weighted and rated by experts opinions data collected using a 5-point Likert scale questionnaire survey.

Subsequently, the SLP methodology developed by Muther (1973) (Figure 1), was used to find alternative layouts that minimize passengers' time in the facility and thus the level of exposure to the virus. Therefore, we visited the selected airport to capture the currently adopted internal facility layout, and to identify the input data and activities involved, the flow of passengers, activity relationships, space requirements, and the space available.

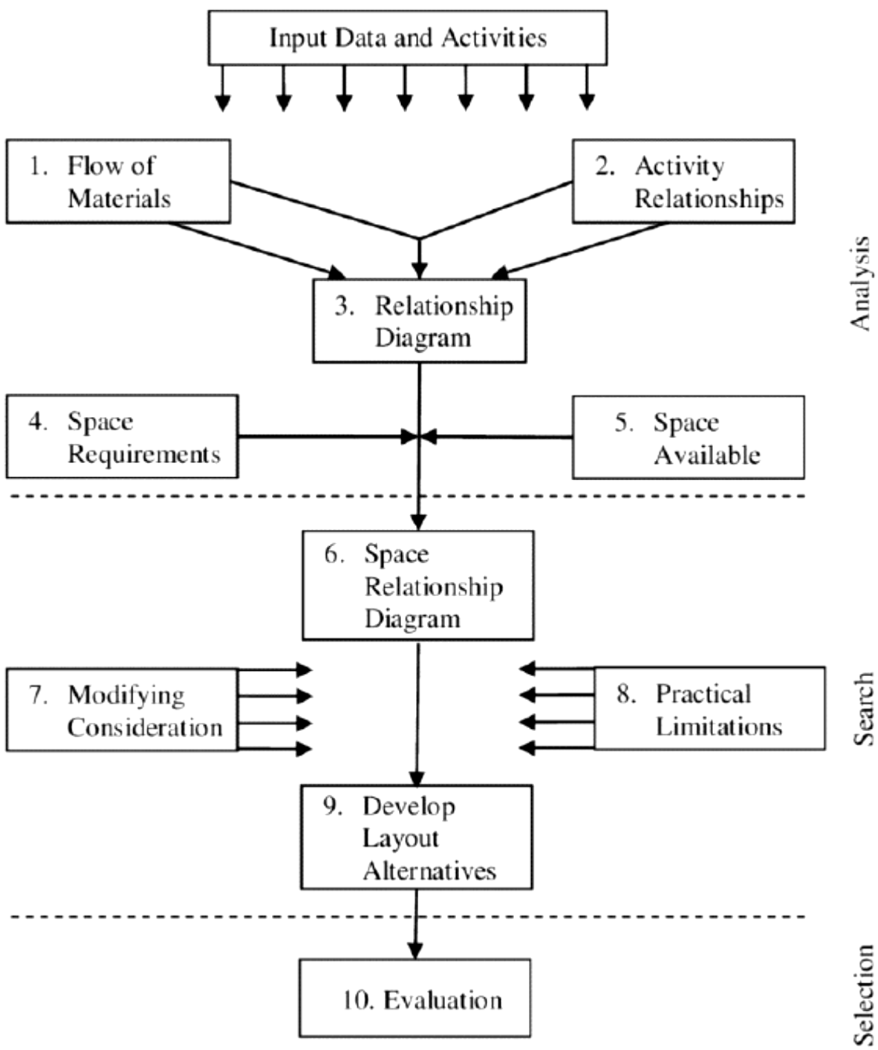


Figure 1: Muther's systematic layout planning (SLP) framework (Muther, 1973).

Next, a from-to chart and an activity-relationship chart were developed, and a relationship spatial diagram is drawn to visually represent the connection between the airport facility spaces. Subsequently, the Computerized Relative Allocation of Facilities Technique (CRAFT) is used to generate airport facility layout alternatives considering the following constraints/assumptions:

- The shape of the terminal and the departments within are rectangular and the area is known.
- All departments are unequal in size.
- All departments are declared to be fixed in sequence.
- Departments' shapes cannot be changed structurally.
- The terminal is a single-story building.
- Distances between departments are based on rectilinear distance.
- Only departing passengers are considered
- All passengers follow a predefined pattern or sequence in the departing terminal

4. Results

Results of the analyses both reveal the critical COVID-19 measures in Saudi Airports via VIKOR and generate layout alternatives to select the optimal layout. Given that the optimal layout is considered the layout that minimizes passengers' time within the facility and lowers the risks of getting infected by ensuring social distancing.

All survey inputs are calculated and returned out as shown in (Table 3). The weights are extracted from a survey that was distributed to experts in infectious disease and an average weight for each criterion is calculated. The listed criteria as previously mentioned are gathered from multiple reports around the world.

After gathering all the criteria (i.e., COVID-19 measures) an additional survey was handed out to prominent decision-makers within the General Authority for Civil Aviation (GACA) in Saudi Arabia to obtain the needed rates and take best/worst or max/min values as shown in (Table 3). Thereafter, the maximum (best x_i^+) and minimum (worst x_i^-) values for each criterion are recorded.

Table 3. Survey's responses from both medical experts and airport's authority

Weights	Criteria code	DM1	DM2	DM3	DM4	DM5	DM6	B (Xi^+)	W (Xi^-)
5.00	M1	5	2	5	4	3	4	5	2
4.67	M2	5	5	5	4	4	4	5	4
4.33	M3	5	4	4	4	4	4	5	4
4.00	M4	5	3	5	4	4	4	5	3
3.67	M5	5	5	4	4	3	4	5	3
3.33	M6	3	5	5	4	4	4	5	3
5.00	M7	5	3	5	4	3	4	5	3
4.33	M8	4	5	4	5	4	4	5	4
3.67	M9	4	4	1	3	4	4	4	1
4.67	M10	5	5	4	3	4	4	5	3
4.67	M11	5	4	5	4	4	4	5	4
5.00	M12	5	3	4	4	3	4	5	3
5.00	M13	5	5	5	3	4	4	5	3
3.67	M14	4	2	3	3	3	3	4	2
5.00	M15	5	5	5	4	4	4	5	4
5.00	M16	5	5	5	4	4	4	5	4
4.67	M17	5	4	5	4	4	4	5	4
4.45	M18	5	5	5	4	3	3	5	3

DM: decision-maker (participating expert in the study).

Table 4. The ranked list of COVID-19 measures

Weights	Code	DM1	DM2	DM3	DM4	DM5	DM6	S_i	R_i	Q_i	Rank
5.00	M1	0.00	5.00	0.00	1.67	3.33	1.67	11.66666667	5	0.067857	9
4.67	M2	0.00	0.00	0.00	4.67	4.67	4.67	14	4.666666667	0.653571	10
4.33	M3	0.00	4.33	4.33	4.33	4.33	4.33	21.66666667	4.333333333	0.800000	4
4.00	M4	0.00	4.00	0.00	2.00	2.00	2.00	10	4	0.325000	14
3.67	M5	0.00	0.00	1.83	1.83	3.67	1.83	9.166666667	3.666666667	0.198214	16
3.33	M6	3.33	0.00	0.00	1.67	1.67	1.67	8.333333333	3.333333333	0.071428	18
5.00	M7	0.00	5.00	0.00	2.50	5.00	2.50	15	5	0.785714	6
4.33	M8	4.33	0.00	4.33	0.00	4.33	4.33	17.33333333	4.333333333	0.521485	12
3.67	M9	0.00	0.00	3.67	1.22	0.00	0.00	4.888888889	3.666666667	0.100000	17
4.67	M10	0.00	0.00	2.33	4.67	2.33	2.33	11.66666667	4.666666667	0.653571	11
4.67	M11	0.00	4.67	0.00	4.67	4.67	4.67	18.66666667	4.666666667	0.803571	3
5.00	M12	0.00	5.00	2.50	2.50	5.00	2.50	17.5	5	0.866071	1
5.00	M13	0.00	0.00	0.00	5.00	2.50	2.50	10	5	0.705357	5
3.67	M14	0.00	3.67	1.83	1.83	1.83	1.83	11	3.666666667	0.257142	15
5.00	M15	0.00	0.00	0.00	5.00	5.00	5.00	15	5	0.785714	8
5.00	M16	0.00	0.00	0.00	5.00	5.00	5.00	15	5	0.785714	7
4.67	M17	0.00	4.67	0.00	4.67	4.67	4.67	18.66666667	4.666666667	0.803557	2
4.45	M18	0.00	0.00	0.00	2.23	4.45	4.45	11.12745098	4.450980392	0.425000	13

DM: decision-maker (participating expert in the study).

Consequently, the sum of unity measure values S_i, and the minimum individual regret of the opponent R_i are obtained as illustrated in (Table 4), which leads us to calculate Q_i. The COVID-19 measures are ordered by sorting the values of S_i, R_i, and Q_i in ascending order. As a result, we have the rankings are shown in (Table 4) reflect the participants' responses but also seem representative and common sense. It could be seen that the top five measures are glass barriers, floor posters, cart & facility disinfection, 2-hour arrival in prior, and face masks.

Facility-wise, the layout planning was according to Muther's framework (Figure 1) as previously discussed in the methodology. As shown, the from-to matrices (Tables 5 and 6) and the objective function (9) are incorporated accordingly.

$$Minimize \quad z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij}\, c_{ij}\, d_{ij} \qquad (9)$$

where,

z = Total time within the facility (Departing terminal)
m = Number of departments
f = The flow from department i to department j
c_{ij} = Required time for a passenger to travel from department i to department j
d_{ij} = Rectangular distance between departments i and j

As shown in (Figure 2), using the CRAFT technique, we captured the initial layout which resulted in 75.7 minutes (Figure 2 – a). On the first iteration, an exchange between (Boarding and Waiting Hall 3) has been made and the result is 67.3 minutes (Figure 2 – b). The second iteration where an exchange (Customs check and Waiting Hall 3) which resulted in 62.2 minutes (Figure 2 – c). Finally, although the third iteration (64.7 minutes) (Figure 2 – d) is not showing an improvement in time (z), nevertheless, it can be a better candidate when evaluating it against how it complies with COVID-19 preventive measures. Further, by removing department A (COVID-19 check area) from the first initial layout. Thus, will result in even less time taken by the passengers within the facility. The second initial layout as illustrated in (Figure 3 – a), was replaced with a dummy department (I) to fill the irregularities in the design. Also, both the new distance matrix and cost matrix were obtained and illustrated in (Figure 3). The first iteration (Figure 3 – b) would consider the pairwise exchange between departments (D-H). The second iteration (Figure 3–c) will consider the pairwise exchange between departments (C-H). The third iteration (Figure 3 – d) will consider the pairwise exchange between departments (C-D). Therefore, reaching an optimal internal layout that facilitates compliance with social distancing through reducing the time to travel between departments to 39.6 minutes which was originally 75.7 minutes in the initial layout.

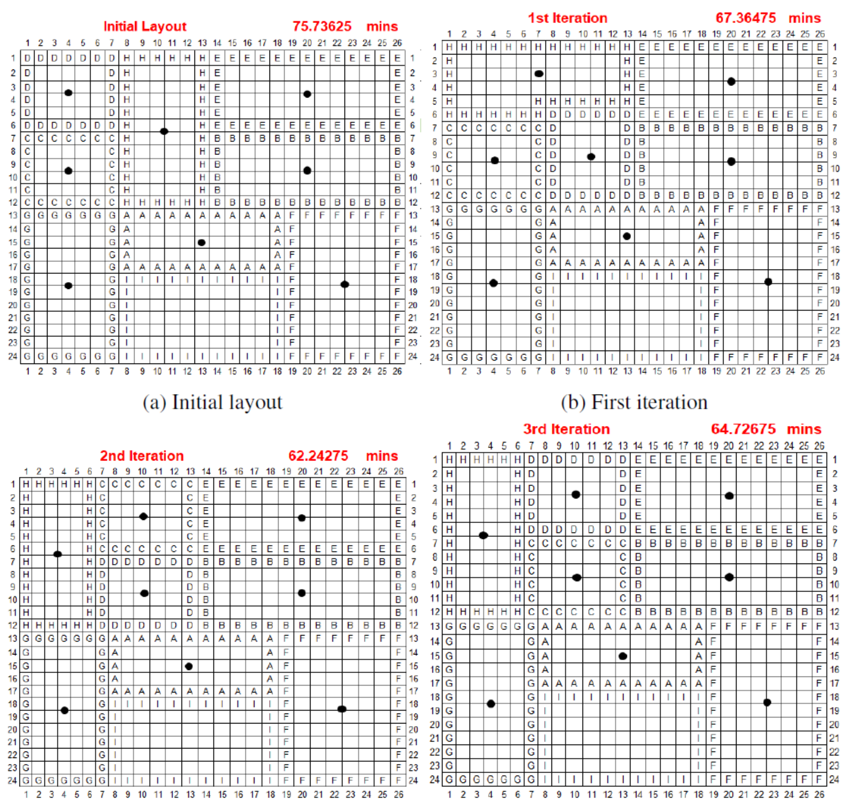
Table 5. Department's data and From-To Chart (meters)

Department Name	Area (m^2)	No. of Grids	From-To (meters) d_{ij} or f_{ij}							
			A	B	C	D	E	F	G	H
A: Covid-19 Check	55	55	0	12.5	14.5	20.5	18.5	-	-	11
B: Check-in Counters *	72	72	-	0	16	22	6	-	-	12.5
C: Customs Check	36	36	-	-	0	6	22	-	-	9.5
D: Boarding	36	36	-	-	-	0	16	-	-	9.5
E: Flight Gates *	50	50	-	-	-	-	0	-	-	-
F: Waiting Hall 1	77	77	13	-	-	-	-	0	-	-
G: Waiting Hall 2	77	77	12.5	-	-	-	-	-	0	-
H: Waiting Hall 3	66	66	-	-	-	-	12.5	-	-	0

*fixed departments

Table 6. Time matrix (minutes)

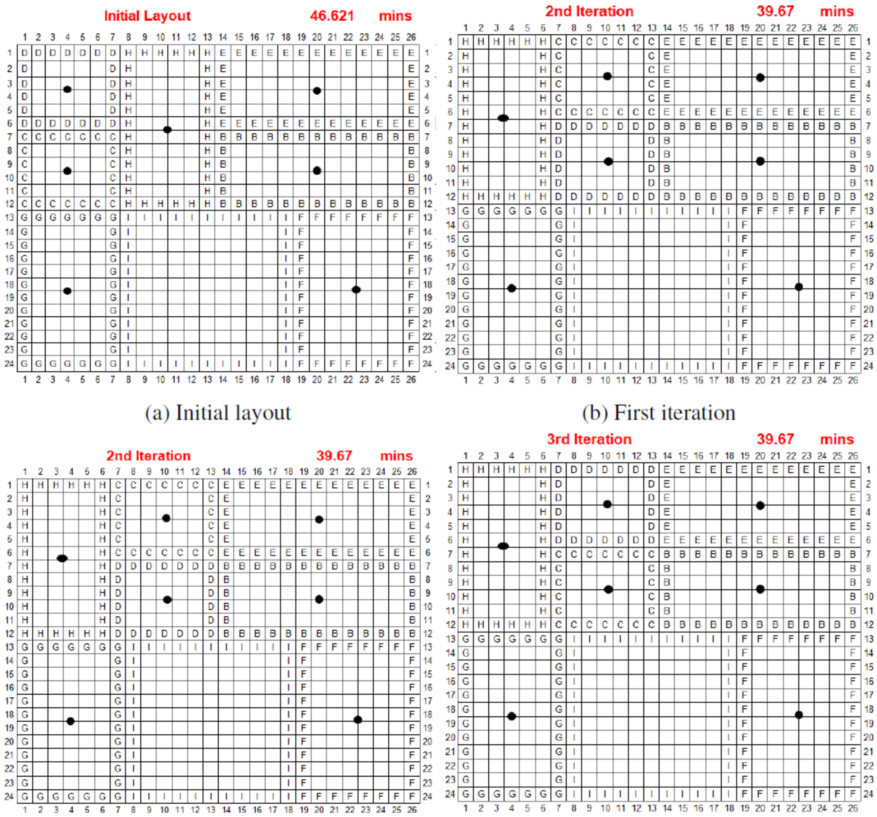
Department Name	From-To (Cost matrix, minutes) c_{ij}							
	A	B	C	D	E	F	G	H
A: Covid-19 Check	0.00	0.29	0.33	0.47	0.43	0.09	0.07	0.25
B: Check-in Counters *	0.14	0.00	0.37	0.51	0.14	0.16	0.21	0.29
C: Customs Check	0.12	0.16	0.00	0.14	0.51	0.23	0.12	0.22
D: Boarding	0.21	0.28	0.14	0.00	0.37	0.30	0.21	0.22
E: Flight Gates *	0.32	0.37	0.25	0.16	0.00	0.37	0.41	0.12
F: Waiting Hall 1	0.09	0.16	0.23	0.30	0.37	0.00	0.14	0.25
G: Waiting Hall 2	0.07	0.21	0.12	0.21	0.41	0.14	0.00	0.12
H: Waiting Hall 3	0.28	0.32	0.21	0.09	0.12	0.25	0.12	0.00



(a) Initial layout (b) First iteration

(c) Second iteration (d) Third iteration

Figure 2. First initial layout and its iterations.



(a) Initial layout (b) First iteration

(c) Second iteration (d) Third iteration

Figure 3. Second initial layout and its iterations.

5. Conclusion

The first main objective of this study was to reveal the most critical COVID-19 preventive measures in airports that effectively reduce potential risks. This was achieved through the collection of COVID-19 measures in airports based on which a questionnaire survey was designed targeting the opinions of experts in the fields of epidemiology and infectious diseases, as well as airport managers and operational staff. Using the VIKOR technique, results show that the most critical COVID-19 measures in airport facilities are glass barriers, floor posters, cart & facility disinfection, 2-hour prior arrival, and face masks. Results also show that the safety of employees and protection is key and that using glass or acrylic barriers can protect both employees and passengers. Moreover, floor posters and facility disinfection are considered important in ensuring safe social distancing between passengers in the facility and sanitizing every touchable surface. Furthermore, early arrival helps airport staff sufficient time to serve passengers and regulate their flow. Face protection is also considered an essential measure for both employees and passengers.

The second main objective of this study was to optimize the compliance of the revealed prioritized set of critical COVID-19 preventive measures in airport facilities' layout. A typical domestic medium-sized airport in Saudi Arabia was selected to capture the currently adopted internal facility layout and to collect input data related to the activities involved, the flow of passengers, activity relationships, space requirements, and the space available. The revealed prioritized set of critical COVID-19 preventive measures along with SLP procedure and the CRAFT technique were all used to generate airport facility internal layout design alternatives.

An optimal alternative was selected based on reduced passengers' cycle time and the level of its compliance with the revealed preventive measures and their priorities. Implications of this study include the proposed hybrid approach of the used methods and the revealed set of prioritized COVID-19 preventive measures in airports. Which can assist decision-makers and responsible authorities of airports in increasing the compliances with enforced measures through optimized internal layout designs of airports limiting the spread of viruses in pandemics.

Future research direction includes validating the revealed set of COVID-19 preventive measures and their priorities based on a larger number of experts' opinions. Moreover, conducting the study in other airports nationally and internationally with different internal layouts is a future research direction. Furthermore, including cost factors in the selection of alternative internal layout designs, and the use of simulation methods are also recommended. Finally, optimization studies can be conducted to include the uncertainties around the number of passengers, their changing routes, and uncertainty for the operations using discrete event simulation for models' development.

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