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A New approach to Optimizing the Facility Siting and Layout for Fire and Explosion Scenarios

Seungho Jung[a], Dedy Ng[a], Christian Diaz-Ovalle[b], Richart Vazquez-Roman[b] and
M. Sam Mannan[a,*]

[a] Mary Kay O'Connor Process Safety Center, Artie McFerrin Department of Chemical
Engineering, Texas A&M University, College Station, Texas, 77843-3122, USA
E-mail address: mannan@tamu.edu.

[b]Instituto Tecnológico de Celaya, Depto. de Ingeniería Química, Av. Tecnológico s/n, Celaya,
Gto., CP 38010, México

Abstract

Effective facility siting and layout should address plant operation and maintenance as well as safety performance. In order to obtain a safer plant layout, some possible consequence scenarios resulting from accidental chemical releases and their likelihood are often addressed at the initial stage of layout development. In this work, a new approach to optimizing facility siting and layout for flammable gas release scenarios and their resulting consequences such as fire and explosion are presented. This new approach focuses on integrating quantitative risk analysis in the optimization formulation to obtain the optimal allocation of new facilities based on particular risk criteria derived from accident scenarios. Three different approaches to configure the optimal location of new facilities are presented: fixed distance (recommended separation distance) approach, optimized layout by considering the structural damage due to blast overpressures, and finally, the integration of first two approaches with weighting factors to account for building occupancy and domino effect. The objective function was to minimize the total cost of land, interconnection, and financial risk. The overall problem was modeled as a disjunctive program to achieve a layout of rectangular-shaped facilities and the convex hull approach was used to reformulate the problem as a Mixed Integer Non-Linear Program (MINLP) to identify potential layouts. Furthermore, the proposed methodology was evaluated using Flame Acceleration Simulator (FLACS) to consider the congestion and confinement effects in the plant in order to provide substantial guidance for deciding the final layout.

Keywords: flammable gas release, facility layout, facility siting, MINLP, PHAST, FLACS

1. Introduction

High-profile incidents such as Buncefield (2005) and Texas City (2005) have prompted the urgency to assess the risks associated with process plant buildings and the protection they offer to building occupants [1]. To date, facility siting and layout have become one of the most scrutinized subjects when designing new plant layout or integrating new facilities into the existing plant. The needs for facility siting assessment also arise from a number of escalated incidents due to inadequate analysis of blast impact on the process plant buildings. The Texas City refinery explosion on March 2005 has highlighted concerns for facility siting of temporary buildings. Inadequate separation distances between trailers and the isomerization process unit was identified as the contributing causes of fatalities [2]. Similar accidents due to improper siting of occupied buildings and adjacent process units have been observed in the Flixborough accident (1974), which resulted in 28 fatalities, and in Pasadena, Texas (1989), which led to 24 fatalities [3].

The aftermath of industrial disasters has pointed out that facility siting is an important element in process safety and has been addressed in the Occupational Safety and Health Administration (OSHA)'s Process Safety Management regulation. To enforce this regulation, OSHA has issued approximately 93 citations from 1992 to 2004 to process industries for the following reasons: (1) no record of facility siting had been performed; (2) facility siting study had not been carried out; (3) inadequate analysis of facility siting study; and (4) the existing layout and spacing of buildings do not meet the current standards/recommended practices [4]. Based on these findings, OSHA identified that facility siting study should assess the following major subjects [4]: (1) location of buildings with high occupant density such as control room and administrative building; (2) location of other less occupant density units (including utility and maintenance buildings); (3) layout of process units such as reactors, reaction vessels, large inventories, or potential ignition sources; (4) installation of monitoring/warning devices; and (5) development of emergency response plans.

The current guidance and recommended practices, such as the Dow Fire and Explosion Index (Dow F&EI), Industrial Risk Insurance (IRI)'s General Recommendations for Spacing, American Petroleum Institute (API) Recommended Practice (RP) 752 and 753, has been adopted as guidelines for facility siting studies and evaluations in the process industries [5, 6]' [7]. Dow F&EI is the leading hazard index recognized by the process industry to quantitatively measure the safe separation distance from the hazardous unit by considering the potential risk from a process and the properties of the process materials under study [7]. This index has also been incorporated in a risk analysis tool for evaluating the layout of new and existing facilities [8]. Additionally, API RP 752 and 753 provides some guidelines to manage hazards associated with the siting of both permanent and temporary occupied buildings, however both RPs only provides conceptual guidelines to address facility siting without specific recommendations for layout and spacing of occupied buildings. Generally, it is often difficult to deduce a common separation distance and spacing criteria for particular process units without a proper risk assessment. Thus there is a need to develop new methodologies for facility siting and layout assessment.

Several studies have been performed to solve the complex plant layout problem using heuristic methods and focused only on the economic viability of the plant, however little work has addressed safety issues directly into their formulations. In recent years, the use of optimization methods has gained increasing attention in facility siting study as it determines the optimal location of a facility. Such method has been demonstrated in the layout configuration of pipeless batch plants [9]. Subsequently, Penteado et al. developed a Mixed Integer Non-Linear Programming (MINLP) model to account for a financial risk and a protection device into their layout formulation, and configured the new facilities with circular footprints [10]. This model was further evaluated using a MILP model by adopting rectangular-shaped footprints and rectilinear distances [11]. Both works used the equivalent TNT model to obtain the risk costs due to particular accidents with a simple risk assessment approach.

For the purpose of incorporating safety concept into the facility layout, it is essential to combine a detailed risk analysis called Quantitative Risk Analysis (QRA) and optimization. In this work, risk analysis was utilized in site selection and location relative to other plants or facilities. Three approaches to configure facility layout based on optimization methodology have been proposed in order to guide the development of optimal facility siting and layout for fire and explosion scenarios. In the first approach, facility layout using fixed distances (recommended separation distances) was configured to minimize the objective function, *i.e.,* the sum of land cost and interconnection cost between facilities. In the second approach, the layout was formulated without the recommended separation distances; however it includes the risk cost derived from the probability of structural damage caused by blast overpressures. Finally, the above two approaches were integrated to form a layout whose objective function minimizes the land, interconnection and risk costs along with weighting factors. The weighting factor is introduced to account for the building occupancy and the likelihood of domino effect. In these three approaches, the overall problem was modeled as a disjunctive program to achieve the layout of rectangular-shaped facilities, then, the convex hull approach was used to reformulate the problem as a Mixed Integer Non-Linear Program (MINLP) model to identify potential layouts. Consequence modeling program, PHAST (ver. 6.53.1), was used to measure the overpressure around the process plant unit and the result was further studied to obtain the risk cost. The applicability of the proposed approaches was further demonstrated in the illustrated case study of hexane leak incident. Results generated from each approach were compared and evaluated using 3D explosion simulator program, Flame Acceleration Simulator (FLACS) for evaluating the congestion and confinement effects in the plant in order to provide substantial guidance for deciding the final layout. The proposed methodology can aid in decision making process for facility siting and layout in early design stage as well as provide assessment of the existing layout against fire and explosion scenarios.

2. Problem Statement

There are two types of layout formulation, grid based and continuous plane. Some of the disadvantages associated with the grid-based approach have been identified by previous researchers, such as the configured grid locations tend to be larger than the facilities, leading to a coarse grid and require the use of sub-optimal solution; or the units may cover multiple grid locations thereby generating a more complex formulation and requiring excessive computer time [12]. Another drawback of grid-based approach is that sizes of facility are often difficult to be accommodated in the formulation because the units must be allocated in predetermined discrete grids or locations [13]. In order to overcome the limitations of grid-based approach, the continuous-plane formulation has been adopted and highlighted in various studies [14-16].

In this study, the site occupied by the facilities was assumed to be a rectangular footprint, with dimensions Lx (length) and Ly (depth) in a continuous plane. Similarly, a rectangular shape was also used to represent a design of each facility. All new facilities ($n \in N$) are to be allocated on a given site, on an x-y plane, including hazardous units ($r \in N$). It was assumed that a flammable gas release occurs from one of the hazardous facilities. Another consideration in the layout design is the minimum separation distances ($D_{i,j}$, *st*) between facilities to allow access for maintenance and emergency response. Other considerations include parameters to calculate the probability of structural damage due to flammable gas release. Prior to the optimization step, these parameters were obtained from Quantitative Risk Analysis (QRA) by estimating the consequences of a flammable gas release. Given a set of facilities and their building costs and dimensions, unit land cost, cost of interconnection between facilities, and minimum separation distance of facilities from the property boundary along with the conditions mentioned above, the overall problem was then solved with the optimization program GAMS (General Algebraic Modeling System) to determine optimal locations of facilities (x and y) and the lowest total cost associated with optimized plant layout.

As mentioned above, three approaches in layout formulation were proposed in this study. For the distance-based and integrated approaches, the distance matrix was used as a constraint for determining the minimum separation distance. Subsequently, a list of potential incidents caused by a hazardous process unit was employed for risk cost estimation in the overpressure-based and integrated approaches.

3. **Methodology**

Figure 1 shows the overall scheme of proposed methodology for optimizing the layout formulation. The proposed methodology can be classified into three folds: QRA, optimization and layout validation using FLACS. For the QRA stage, we assumed the worst case scenario for flammable gas release, *i.e.*, fire and explosion in process plant buildings. The resulting consequences were estimated using PHAST (ver. 6.53.1).

One of the main challenges before the optimization stage is to obtain accurate estimates of risk cost for realistic and reliable risk assessment. The risk cost was calculated from the probability of structural damage due to blast overpressures. Furthermore, a 3D explosion simulator based on CFD (computational fluid dynamics) code, FLACS, was used to simulate the explosion scenario in the optimized layouts for selecting the final layout.

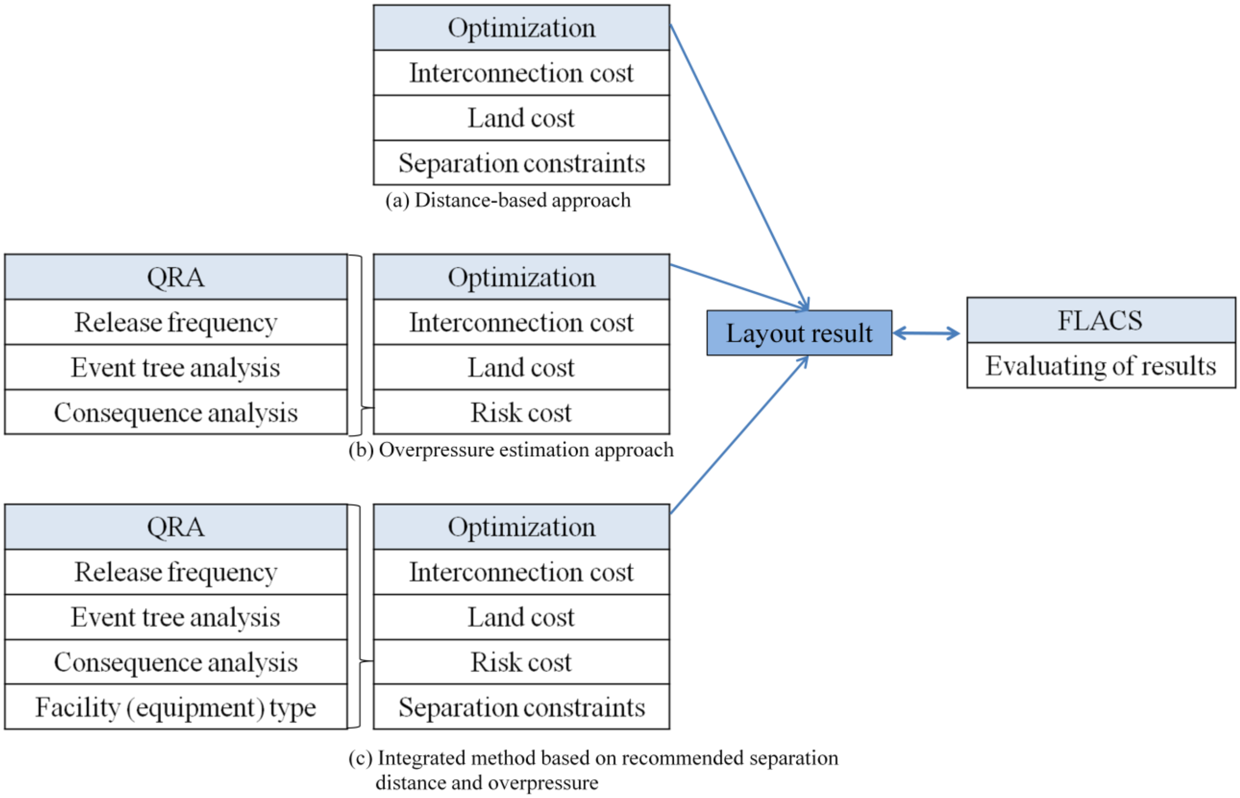

Fig 1. Scheme of the proposed methodology

4. Case Study

The case study used to demonstrate the proposed methodology is a hexane distillation unit, which consists of an overhead condenser, reboiler, accumulator and several pumps and valves [17]. In addition to this process unit, several new facilities are to be configured in the layout formulation. For the worst-case scenario of flammable gas release, BLEVE (Boiling Liquid Expanding Vapor Explosion) and VCE (Vapor Cloud Explosion) are identified as potential accidents in the hexane distillation unit. Table 1 shows the dimension of each facility along with its recommended distances from the property boundary and the building cost. Based on the distance from property boundary, several occupied buildings such as the control room, administrative building and warehouse tend to be located closer to the process unit.

Table 1. Dimension, distance from the property boundary and building cost for each facility

Facility (i)	Type of Facility	Length (m-m)	Distance from property boundary (m)	Facility cost, FC_i (\$)
1	Control room (non-pressurized)	10-10	30	1,000,000
2	Administrative building	20-15	8	300,000
3	Warehouse	5-10	8	200,000
4	High pressure storage sphere	10-10	30	150,000
5	Atmospheric flammable liquid storage tank 1	4-4	30	100,000
6	Atmospheric flammable liquid storage tank 2	4-4	30	100,000
7	Cooling tower	20-10	30	500,000
8	Process unit	30-40	30	.

4.1. Distance-based approach

In the distance-based approach, the objective function is to minimize the total cost of land and interconnection, and can be written as follows.

$$Total\ cost = Land\ Cost + \sum Interconnection\ cost_{i,j} \tag{1}$$

$$Land\ cost = UL \times Max(x_i + 0.5Lx_i) \times Max(y_i + 0.5Ly_i) \tag{2}$$

$$Interconnection\ cost = UIC_{i,j} \times d_{i,j} \tag{3}$$

$$\boldsymbol{d_{i,j}^2 = (x_i - x_j)^2 + (y_i - y_j)^2} \tag{4}$$

st . Non-overlapping constraint

where UL is a unit land cost and $UIC_{i,j}$ is a unit interconnection cost between facilities i and j.

The interconnection cost includes costs for maintenance or physical connection such as piping or cabling. It was assumed that the interconnection cost between occupied facilities is 0.1 $ / m and a similar amount was also assumed for the storage units. Additionally, preliminary areas and spacing for site layout from Mecklenburgh [18] were used to define a minimum separation distance between facilities. Table 2 shows the interconnection cost and separation distances for each facility. The distance between tanks (#5 and #6) is assumed to be equal to its diameter.

Table 2. Unit interconnection costs and minimum separation distances between facilities

Facility (i)	Unit interconnection cost, $UIC_{i,j}$ (\$ / m)							
Minimum separation distance between facilities (m)	1	0.1	0.1	10	10	10	10	10
	5	2	0.1	0	0	0	0	0
	5	5	3	0.1	0.1	0.1	0.1	0.1
	30	60	60	4	0.1	0.1	100	0
	60	60	60	10	5	0.1	100	0
	60	60	60	10	4	6	100	0
	30	30	30	30	30	30	7	100
	30	60	60	15	5	5	30	8

To avoid overlapping problems in the layout configuration, we had previously proposed a disjunctive model by considering two facilities, *i* and *j*. As shown in Fig. 2, a new facility *j* with respect to facility *i* can be accommodated by expanding the footprint of facility *i* by the street size. Then, facility *j* could be placed anywhere on region “*L*” (left hand side); or anywhere on region “*R*” (right hand side); or at the center in which case it would lay either in region “*A*” (above) or “*D*” (downward). Details of this work can be found elsewhere [19].

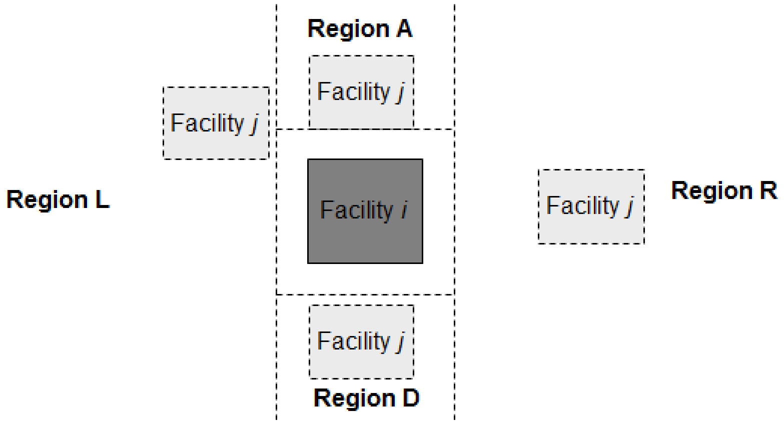

Fig. 2 Schematic drawing of new facility placement in the layout design

The above disjunction model can be formulated as follows:

$$\begin{bmatrix} "Left" \\ x_j \le x_i - D_{i,j}^{NO,x} \end{bmatrix} \vee \begin{bmatrix} "Right" \\ x_j \ge x_i + D_{i,j}^{NO,x} \end{bmatrix} \vee \begin{bmatrix} "Above","Down" \\ x_j \ge x_i - D_{i,j}^{NO,x} \\ x_j \le x_i + D_{i,j}^{NO,x} \\ \begin{bmatrix} "Above" \\ y_j \ge y_i + D_{i,j}^{NO,y} \end{bmatrix} \vee \begin{bmatrix} "Down" \\ x_j \le y_i - D_{i,j}^{NO,y} \end{bmatrix} \end{bmatrix} \qquad (5)$$

where:

$$D_{i,j}^{NO,x} = \frac{Lx_i + Ly_j}{2} + D_{i,j} \qquad (6)$$

$$D_{i,j}^{NO,y} = \frac{Ly_i + Ly_j}{2} + D_{i,j} \qquad (7)$$

Table 3 and Fig. 3 show the optimized result using the DICOPT solver. As seen in the layout result, facilities #4, #5, #6, and #7 are allocated closely to the process unit. Among the occupied buildings, facility #1, control room, has been closely located to the process unit because of the high interconnection cost.

Table 3. Optimized cost from the distance-based approach

Type of Cost	**Cost ($)**	**Remarks**
Interconnection	3840.232	Between all facilities
Land	52275	$5 / m^2
Total	56115.232	

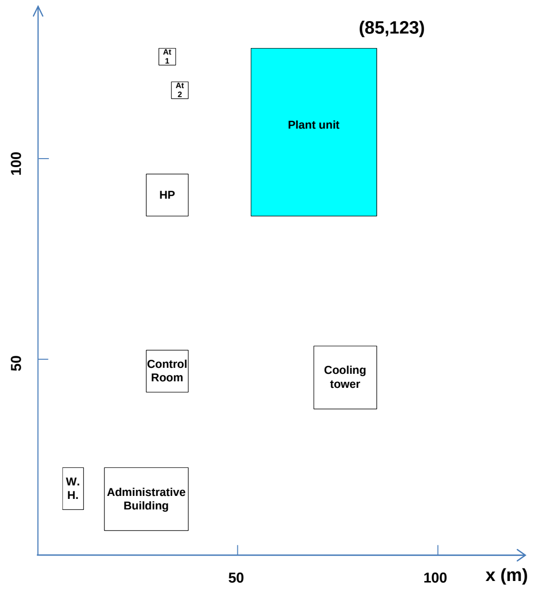

Fig. 3 Layout result for distance-based optimization model

4.2. Overpressure estimation approach

According to the CPQRA (Chemical Process Quantitative Risk Analysis) book, BLEVE (Boiling Liquid Expanding Vapor Explosion) and VCE (Vapor Cloud Explosion) are identified as potential accidents in the hexane distillation unit [17]. To assess the likelihood and consequence of BLEVE, PHAST ver. 6.53.1 was used to estimate the distance to certain overpressures following ignition of a flammable vapor cloud. In this work, the term BLEVE is reserved for only the explosive rupture of a pressure vessel and the flash evaporation of liquefied gas. The resulting fireball formation will not be taken into account. The mass of released gas was assumed to be 28,000 kg of hexane and later used as an input for predicting blast overpressures of BLEVE and VCE. There are three models for analyzing the VCE in PHAST: TNT-equivalency model, multi-energy explosion model, and Baker-Strehlow-Tang (BST) model. We used the BST model to account for the congestion and confinement effects in layout formulation. Parameters such as medium material reactivity, flame expansion 1, high obstacle density and 2 ground reflection factor were also selected when using this model. In addition, a wind speed of 1.5 m/s and F-class stability were also assumed to obtain an overpressure profile from the explosion center.

The probit value was calculated from the data of overpressure using the following equation (AICHE/CCPS, 1999).

$$\mathrm{Pr} = k_1 + k_2 \ln(p) \tag{8}$$

where k_1 and k_2 are probit parameters used for estimating structural damage and values are -23.8 and 2.92, respectively [[20]]. The probability of structural damage can be converted from the probit function. The resulting probability of structural damage fitted well with the sigmoid function, and is given by:

$$y = \frac{a}{1 + \exp\{-(\frac{x - x_0}{b})\}} \tag{9}$$

where y is the probability of structural damage, x is the distance from the explosion center, and a, b, and x_0 are the sigmoid function parameters. Both BLEVE and VCE follow the sigmoid function profile agreeably, and these parameters are presented in Table 4.

Table 4. Correlated sigmoid function parameters for BLEVE and VCE

	a	b	x_0
BLEVE	1.000	-8.009	64.694
VCE	1.006	-64.887	513.220

Potential Structural Damage Cost (PSDC) for i-th facility is defined as follows.

$PSDC_i$ = Plant lifetime × Incident outcome frequency × probability of structural damage × FC_i (10)

$$Total\ cost = Land\ Cost + \sum Interconnection\ cost_{i,j} + \sum PSDC_i\ ,\ r \nexists i \tag{11}$$

where: FC_i is i-th facility cost assumed in Table 1.

For overpressure-based approach, non-overlapping constraints in eqns. (6) and (7) have been changed to eqns. (12) and (13) in order to have fixed separation distance between facilities, st.

$$D_{i,j}^{NO,x} = \frac{Lx_i + Ly_j}{2} + st \tag{12}$$

$$D_{i,j}^{NO,y} = \frac{Ly_i + Ly_j}{2} + st \tag{13}$$

where st is assumed to be 5 meters.

The plant lifetime was assumed to be 50 years. Other assumptions include incident outcome frequencies of 5.7 x 10^{-6} / year for BLEVE and 7.8 x 10^{-6} / year for VCE in the distillation unit [17]. In the overpressure estimation approach, the total cost is also a function of PSDC as seen in eqn. (11). This overpressure approach does not consider the recommended separation distance, but it includes the property boundary line for each facility.

In order to enable access for emergency response and maintenance, each facility is separated by a street of 5 meters and this is simply formulated by changing $D_{i,j}$ to st (5 meters). After running the optimization program, the total cost was obtained and showed in Table 5. The land cost has been decreased as compared to the result obtained from the distance-based approach due to no separation distance constraints. The PSDC is very low because incident outcome frequencies are very small. The layout result is shown in Fig. 4.

Table 5. Optimized cost from the overpressure-based approach

Type of Cost	**Cost ($)**	**Remarks**
Interconnection	1921.319	Between all facilities
Land	30000	\$5 / m^2
Risk	1174.978	
Total	33096.297	

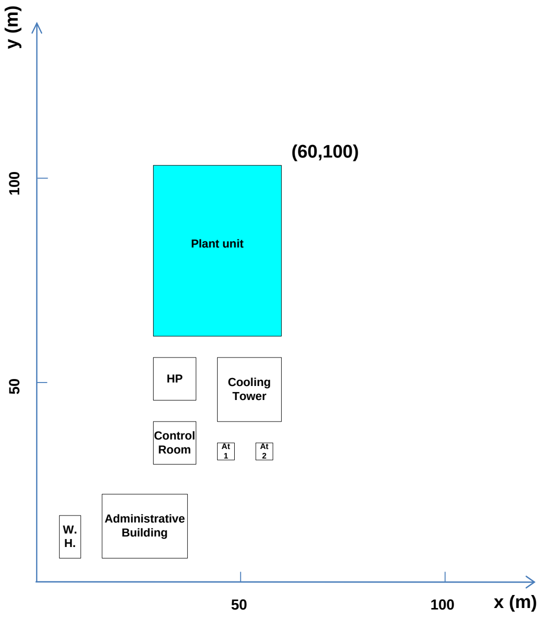

Fig. 4 Layout result for overpressure-based optimization model

4.3. Integrated method based on recommended separation distance and overpressure

In this approach, the recommended separation distance and PSDC are considered in the layout formulation. In addition to equations and constraints used in the first two approaches, here weighting factors and different probit parameters are taken into account to solve the complex optimization problem. Weighting factors shown in Table 6 were derived from population data of occupied buildings and potential domino effects caused by a pressurized vessel and atmospheric tanks containing flammable liquid.

Table 6. Population data and weighting factor for each facility

Facility (i)	Type of Facility	Population	Weighting Factor, WF_i
1	Control room (non-pressurized)	10	100
2	Administrative building	15	150
3	Warehouse	2.5	25
4	High pressure storage sphere	0	20
5	Atmospheric flammable liquid storage tank 1	0	10
6	Atmospheric flammable liquid storage tank 2	0	10
7	Cooling tower	0	1

A number of probit models have been developed for different types of process equipment for the prediction of probability of equipment damage caused by blast overpressures [21]. In this approach, it was assumed that all units can be grouped into 3 types of facilities or equipment, such as a general building, a pressurized vessel, and an atmospheric vessel. Specific probit functions were used to calculate the damage cost for different types of facilities [21]. Subsequently, different types of facilities may have different impacts from the resulting overpressure, thus, the probability of structural damage represented by the sigmoid equation may have different parameters. These parameters were calculated for different types of explosion as shown in Table 7.

Table 7. Probit function and sigmoid equation parameters for different types of facility

Facility (i)	Type of Facility	Probit function	Type of Explosion	Sigmoid parameters		
				a	b	x_0
1 2 3	General Building	$-23.8+2.92\ln(p^0)$	BLEVE	1.000	-8.009	64.694
			VCE	1.006	-64.890	513.220
4	Pressurized vessel	$-42.44+4.33\ln(p^0)$	BLEVE	1.005	-2.558	33.838
			VCE	1.014	-23.220	208.780
5 6 7	Atmospheric Vessel	$-18.96+2.44\ln(p^0)$	BLEVE	1.019	-10.050	66.186
			VCE	1.002	-74.530	524.120

$$PSDCW_i = \text{Plant lifetime} \times \text{Incident outcome frequency} \times \text{probability of structural damage} \times FC_i \times WF_i \qquad (14)$$

$$Total\ cost = Land\ Cost + \sum Interconnection\ cost_{i,j} + \sum PSDCW_i\ , \quad r \nexists i \qquad (15)$$

As seen in eqns. (14) and (15), PSDCW (Probability of Structural Damage Cost with Weighting factors) has been multiplied with the weighting factor for each facility. After including the same separation constraints used in the distance-based approach, the optimized total cost and final layout are shown in Table 8 and Fig. 5, respectively. The land size has slightly increased as compared to the result obtained in Fig. 3, similarly, the distance between the process unit and the control room is also increased. The main difference in the result of the integrated approach is the location of administrative building, which has been moved to the furthest location from the process unit due to high occupancy. Therefore, the integrated approach offers the best solution for creating a safer plant layout. Table 9 summarizes each layout coordinate based on the proposed formulations.

Table 8. Optimized cost from the integrated approach

Type of Cost	Cost ($)	Remarks
Interconnection	4009.319	Between all facilities
Land	52700	5 $ / m^2
Risk	44285.798	
Total	100995	

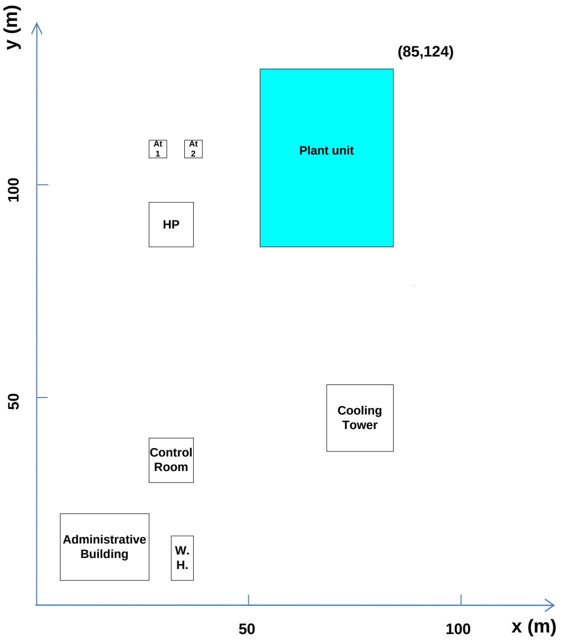

Fig. 5 Layout result for the integrated optimization model

Table 9. Coordinates of all facilities based on the proposed approaches

Facility (i)	Type of Facility	Distance-based approach		Overpressure-based approach		Integrated approach	
		x (m)	y (m)	x (m)	y (m)	x (m)	y (m)
1	Control room (non-pressurized)	35	46	35	35	35	35
2	Administrative building	30	15.5	28	15.5	20	15.5
3	Warehouse	12.5	18	10.5	13	37.5	13
4	High pressure storage sphere	35	88	35	50	35	88
5	Atmospheric flammable liquid storage tank 1	35	121	47	33	32	105
6	Atmospheric flammable liquid storage tank 2	38	113	56	33	40	105
7	Cooling tower	77.5	45.5	52.5	47.5	77.5	46.5
8	Process unit	70	103	45	80	70	104

4.4. Evaluation of layout result using 3D explosion simulator program, FLACS

In order to evaluate the accuracy of optimized layouts in terms of congestion and confinement and its corresponding explosion overpressures, a CFD-based fire and explosion simulator, FLACS was employed in this study to provide more comprehensive risk analysis. In our first attempt to simulate the explosion scenario for the generated layouts, it was observed that some low overpressures in the FLACS results might be due to the low obstacle density, attributed by the simple geometry proposed from the case study. To avoid this simple geometry problem, we imported a real geometry obtained from the laser scanning, which is stored in the RealityLINx software. Using the RealityLINx software, the user can create a 3D object to accurately represent the existing or “as-built” plant conditions from laser scan data. In this paper, the geometry generated by the software was imported to FLACS and used to evaluate the optimized layout. The flame region was assumed to cover the process unit space, and the ignition source was assumed to be the center of the process plant. Overpressure of the locations having the center coordinates of each facility was monitored and its height was assumed to be 1 meter. According to the simulation results, the overpressure values around the process plant for all optimized layouts are between 0.086 barg and 0.355 barg, as shown in Table 10.

Table 10. Overpressure results from FLACS simulations

Facility #, i	Overpressure of the layout using distance-based approach (barg)	Overpressure of the layout using overpressure-based approach (barg)	Overpressure of the integrated layout (barg)
1	0.130	0.185	0.113
2	0.092	0.131	0.089
3	0.086	0.116	0.091
4	0.218	0.241	0.215
5	0.233	0.207	0.226
6	0.254	0.225	0.269
7	0.170	0.355	0.170

As seen in Table 10, the overpressure results generated from the distance-based and integrated layouts are relatively lower than that of the overpressure-based approach. In both distance-based and integrated approaches, lower overpressures are especially observed in the occupied buildings (facilities #1 - #3) as compared to the overpressure-based approach. Moreover, in the integrated approach, a slightly higher overpressure has been obtained for the warehouse (facility #3), which is attributed by the close proximity to the process unit and the low occupancy of facility #3. The high overpressures as indicated in facilities #5 and #6 in the integrated approach are due to the close proximity to the ignition source. The probit function of atmospheric vessel (facilities #5 and #6) was found to generate lower impact of overpressures as compared to the probit function for general buildings, and thus these facilities can be placed closer to the process unit.

The overpressure-based approach has a relatively higher overpressure results because of the close distances of facilities from the process unit as depicted in Fig. 4. Among the three approaches described in here, the integrated approach has more considerations about occupancy and domino effect thereby allow more important facilities to be allocated in a safer place. Therefore, the integrated approach is found to generate the safest layout among three optimized layouts.

5. Conclusions

The method proposed in this paper demonstrates a systematic technique to integrate QRA in the optimization of plant layout. The use of QRA allows better estimation of potential consequences under study. Three different approaches to allocate facilities for a flammable gas release scenario were developed: fixed distance (recommended separation distance) approach, overpressure-based approach, and the integration of first two approaches with weighting factors to account for building occupancy and domino effect. The optimized layouts from each approach were further evaluated by measuring overpressures in order to provide guidance to select the final layout. According to the prediction results obtained from FLACS, lowest overpressures were observed in the locations of occupied building of the integrated approach result, whereas a slight increase in overpressures and highest overpressures were observed in almost all facilities covered by the fixed distance and overpressure-based approaches, respectively.

The use of FLACS and real geometry from the RealityLINx software can enhance process safety in the conceptual design and layout stages of plant design. The computed value under this deterministic approach for the expected risk becomes useful information for siting consideration. The approaches suggested in this methodology can be used to aid decision makers in creating low-risk layout structures and determining whether the proposed plant could be safely and economically configured in a particular area.

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