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The Impact of Plant Layout Dimensions on Fire Load Density in the Rice Milling Industry in Lambayeque-Peru

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ABSTRACT

Fire incidents represent a substantial threat to the sustainability of companies, with their impact predominantly influenced by fire load density. This study aimed to examine the impact of plant layout dimensions on the overall fire load density within the rice milling industry of Lambayeque, Peru. To this end, the study characterized the sizing of four plants, determined the unit fire load of each work area, and employed simulation to analyze the relationship between area size and total fire load density in a rice plant layout. The findings indicated that (i) by increasing the size of the maneuvering yard areas by 4% to 10%, the fire load was reduced by 2% to 3%; and (ii) by increasing the size of the husk rice warehouses (by 10% to 21%), finished product (by 13% to 19%), and empty sacks (by 14% to 22%), the fire load increased by 3% to 8%, 2% to 4%, and 1% to 3% respectively.

1. INTRODUCTION

An environmental problem is characterized by a disruption in the natural equilibrium of various environmental components, including atmospheric air, hydrospheric water, and lithospheric soil. Such disruptions may result from accidents or disasters. Specifically, in the event of a fire, atmospheric air is negatively impacted by the release of toxic emissions [1], as well as by the generation of debris and non-recoverable solid waste [2].

When a building is impacted by fire, sustainability—defined as the comprehensive consideration of economic, social, and environmental dimensions of all activities—is compromised [3]. This results in environmental impacts, such as pollution and the generation of non-recyclable materials, social impacts, including job losses and service interruptions, and economic impacts related to remediation costs. Therefore, fire risk in buildings must be anticipated in the pursuit of sustainable societal development [4, 5]. Additionally, assessing the level of fire risk in properties necessitates adherence to mandatory protection and prevention requirements to mitigate such risks [6].

The predominant threat to human life during a fire incident is smoke inhalation, which is responsible for approximately 75% of fire-related fatalities, while the remaining 25% result from burns due to thermal exposure [7]. The building environment must be designed to ensure the availability of sufficient water sources, such as hydrants, sprinkler systems, wells, water tanks, or other fire-extinguishing agents, to facilitate firefighting operations, contingent upon the assessed level of risk [4-7]. Fire risk is contingent upon the various areas within an industrial facility and their respective degrees of flammability, which are determined by two principal factors: (i) the use or function of the space, and (ii) the type of material stored in storage areas [8].

Peruvian fire safety regulations are delineated in Standard A.130 of the Ministry of Housing, Construction, and Sanitation [9]. This regulation mandates the installation of fire water systems, including hoses and automatic sprinklers, in non-industrial buildings—such as multifamily housing, commercial facilities, healthcare buildings [10], and offices—based on their floor area and height. For industrial buildings, Standard A.060 [9] requires a fire risk assessment as a compulsory regulatory measure, considering the diverse range of industrial processes, products, and inputs with varying levels of combustibility [11].

In the context of calculating fire load density within industrial settings, Standard A.060 is supplemented by the Technical Prevention Standard (NTP) 831, as promulgated by the Spanish National Institute for Safety and Health at Work [12]. The operationalization of NTP 831 is achieved through the Technical Guide to the Regulation on Fire Safety in Industrial Establishments (RSCIEI), which is issued by the Spanish Ministry of Industry, Trade, and Tourism [13]. This guide delineates specific fire load density values and hazard coefficients applicable to diverse productive and support areas, as well as storage sections, contingent upon the type of materials stored.

The literature identifies four studies pertinent to fire risk assessment in industrial activities: the application of the analytic hierarchy process to fire risk evaluation in industry [14]; the utilization of the Gretener method for determining a fire safety coefficient [15]; the examination of fire safety requirements in the food industry [16]; and the implementation of fire protection systems in the plastics industry [17]. These studies do not assess the influence of the environment on the fire load.

In the industrial sector, the fire load, which significantly impacts the fire risk level of a facility, primarily originates from processing and storage areas [18]. Rice milling companies in the Lambayeque region contribute the largest portion of the national milled rice production, accounting for 38% of the national total [19]. The rice milling plants in Lambayeque contribute the majority of the national production of milled rice, representing 38% of the national total, and have 98 active milling plants [19, 20]. Within these companies, the distribution of areas and, consequently, the level of fire risk are comparable; thus, it is imperative to implement measures to protect operations from such risks [21].

The layout of rice plants in Lambayeque generally consists of a covered area and an open-air area. The covered area includes the processing environments such as: (i) pre-cleaning; (ii) destoning; (iii) second cleaning sifting; (iv) dehusking; (v) separation via Paddy table; (vi) polishing; (vii) brightening; (viii) separation; (ix) color sorting; and (x) bagging, as well as support environments such as: (xi) offices; (xii) laboratories, among others. Within the covered area there are also storage areas such as: (i) finished product warehouse; (ii) bran warehouse; (iii) empty sack warehouse; (iv) general warehouse, among others. The open-air area consists of the maneuvering yard and the natural drying area for paddy rice.

In this study, the objective was to analyze the impact of plant layout dimensions on fire load density in the rice milling industry of Lambayeque, Peru. The remainder of this article is structured as follows: Section 2 outlines the research methodology, Section 3 presents the findings, and Section 4 discusses the conclusions.

2. METHOD

Fire load calculations were performed using wood-equivalent mass per unit area (kg/m²) as the reference standard [22]. The quantitative fire load (or fire load density) model expressed in Eq. (1) was applied, which estimates the rate of heat or thermal energy release per unit area that would result from a building fire [13, 23]. Specifically, Eq. (1) allows the calculation of the total fire load density of a building sector, Q_s, in which productive, support, and storage activities coexist:

$$Q_s = \frac{(Q_{ac}+Q_{al})}{(A_{ac}+A_{al})} \times R_a [Mcal/m^2] \tag{1}$$

where,

Q_{ac} is the fire load per unit area in productive and support areas (hereinafter referred to as functional areas);

Q_{al} is the fire load per unit area in storage areas;

A_{ac} is the total area of functional areas;

A_{al} is the total area of storage areas;

R_a is a dimensionless hazard correction coefficient.

To calculate Q_{ac}, Eq. (2) was used [16]:

$$Q_{ac} = \left(\frac{\Sigma_i (q_i s_i c_i)}{A_{ac}}\right) \times R_a \tag{2}$$

where, q_I is the fire load density of each functional area (MJ/m² or Mcal/m²), s_i is the area of each functional space (m²), and c_i is the dimensionless combustibility hazard coefficient of each functional area.

Similarly, to calculate Q_{al}, Eq. (3) was applied [16]:

$$Q_{al} = \left(\frac{\Sigma_j (q_j h_j s_j c_j)}{A_{al}}\right) \times R_a \tag{3}$$

where, q_j is the fire load of each storage area according to the type of stored material (MJ/m³ or Mcal/m³), c_j is the dimensionless combustibility hazard coefficient of each stored material, h_j is the stacking height of the stored materials, and s_j is the stacking area of the stored materials.

The study began with the characterization of four rice milling plants (RMPs) located in the Lambayeque region, considering the size of all existing areas—both functional and storage—during the period 2021–2023. For this purpose, data corresponding to functional areas were collected, including fire load density (q_i), area of each functional space (s_i), and the respective hazard coefficient (c_i), as defined in Formula (2). Likewise, data for storage areas included stacking height (h_j), stacking area (s_j), fire load density (q_j), and the hazard coefficient associated with each stored material (c_j), in accordance with Eq. (3).

Based on these data, the heat load of each functional area (c_f) was calculated as the product of fire load density, area, and hazard coefficient ($q_i \times s_i \times c_i$), as presented in Appendix 1. Similarly, the heat load of each storage area (c_a) was determined as the product of fire load, hazard coefficient, stacking height, and stacking area ($q_j \times c_j \times h_j \times s_j$), as shown in Appendix 2. Using the calculated values of c_f and c_a, the most significant functional and storage areas were identified based on their highest contributions.

By combining Eqs. (2) and (3) and considering all functional and storage areas, the total fire load of the building is obtained using Eq. (4):

$$Q_e = \frac{(Q_{ac} * A_{ac} + Q_{al} * A_{al})}{(A_{ac}+A_{al})} \tag{4}$$

Subsequently, the total fire load density model Q_e, given by Eq. (1), was applied using the area (m²) of the most influential functional and storage areas.

3. RESULTS

In this section, the characterization of the functional and storage areas is presented, along with the calculation method used and the results obtained. Moreover, for this study, information from four rice milling plants (IP1, IP2, IP3 and IP4) in the Lambayeque region was considered, to which the established calculation process for the total fire load was applied.

3.1 Characterization of functional and storage areas

The first task was to perform the calculations for the heat load values of the functional areas (Cf) of the four plants (IP1, IP2, IP3, and IP4), determining the average and then calculating the thermal load (See Appendix 1). Similarly, carry out the calculations for the load values of the warehouse areas (See Appendix 2). The analysis showed that, among the functional areas, the maneuvering yard is the most influential, accounting for 54% of the total heat load (Appendix 1). With respect to storage areas, three zones were identified as having the greatest contribution to the total heat load: the rice husk warehouse (53%), the finished product warehouse (18%), and the empty sack warehouse (11%). The remaining functional and storage areas exhibit lower levels of contribution to the total heat load and are therefore considered less significant. Consequently, these areas were not included in the scenario analysis. The most relevant areas, according to Appendix 1 and 2, were:

AC1: Maneuvering yard,

AL1: Rice husk warehouse,

AL2: Finished product warehouse, and

AL3: Empty sack warehouse.

Based on relevant area, four analytical scenarios were stablished (see Table 1).

Table 1. Scenarios considered for calculating the total fire load density (Q_e)

Scenario	Description
1	Maneuvering yard size (AC1) and resulting total fire load density (Q_e), assuming AC1 increases while AL1, AL2, and AL3 remain constant.
2	Rice husk warehouse size (AL1) and resulting total fire load density (Q_e), assuming AL1 increases while AC1, AL2, and AL3 remain constant.
3	Finished product warehouse size (AL2) and resulting total fire load density (Q_e) assuming AL2 increases while AC1, AL1, and AL3 remain constant.
4	Empty sack warehouse size (AL3) and resulting total fire load density (Q_e), assuming AL3 increases while AC1, AL1, and AL2 remain constant.

Note: S means scenarios.

3.2 Application of the total fire load calculation model for the rice milling industry

The second task was to generate reasonable data to allow building graphs to facilitate analysis. For each of the relevant areas AC1, AL1, AL2, and AL3, the associated size was considered and designated as R1 as the first data point to be graphed. Taking into account the reality of the rice milling industry in Lambayeque, possible maximum values (P10) were established according to that context. The intermediate values P1 to P9 were determined randomly. Using Eq. (4), the influence of the area (m²) of the following spaces—the maneuvering yard (AC1), rice husk warehouse (AL1), finished product warehouse (AL2), and empty sack warehouse (AL3)—on the total fire load density of the building (Q_e) was plotted, considering the four scenarios defined in Table 1.

As an example, based on the first scenario, by applying Eq. (4) with the results from Tables 2 and 3, the total fire load (Q_e) of the rice milling plant IP1 is obtained:

Q_{ac} = 138.08 Mcal/m^2

A_{ac} = 8057.64 m^2

Q_{al} = 1497.82 Mcal/m^2

A_{al} = 7455.21 m^2

Q_e = 791.55 Mcal/m^2

AC1 = 6,424 m^2 (R1) is used along with its respective fire load Q_e = 791.55; then, 10 increasing random data points (P1 to P10) are generated within a range from 6,424 m^2 up to 12,000 m^2, which is approximately twice the actual size in this case. From the knowledge available about the rice milling industry in Lambayeque, the largest maneuvering yard is less than 15,000 m^2.

Table 2. Areas of functional environments and resulting fire load (Q_{ac}), case IP1

Area	q[1]	c	R_a	A_{ac} [2]	q*s*c*
Process	144	1	1.5	528.66	76127
Bagging	96	2	1	183.21	28141
Homogenized	144	1	1.5	398.57	57394
By-products bagging	144	2	1.5	25	5760
Workshops	119	2	1.5	51.9	9881
Lab and QC[3]	48	1	1	35	2184
Administrative[4]	144	1	1	329.78	61734
Dining[5] and kitchen	72	1	1	51.53	4823
Maneuvering yard	48	2	1	6424	493362
Work crew[5]	48	2	1	30	2304
		Total		8057.6	741712
		max Ra			1.5
		Q_{ac} (Formula 2)			138

Note: 1. q is expressed in Mcal/m^2. 2. A_{ac} is expressed in m^2. 3. Laboratory and Quality Control. 4. Offices. 5. Area or zone.

Table 3. Storage areas and resulting quantity (Q_{al}), case IP1

Area	q[1]	c	R_a	A_{al}[2]	h[3]	q*c*h*s
Rice husk[4]	192	1	1.5	4037.4	3.5	3527029
Finished product[4]	192	1	1.5	926.25	3.6	832291
Rice dust[4]	192	1	1.5	361.28	3.5	315614
Wooden pallets	313	1	2	594	0.14	26029
Empty sack[4]	6058	1	2	1287.5	0.01	101398
Harvest sack[4]	6058	1	2	245	0.4	771789
Transport[4]	601	1	2	1.3	0.3	304
Workshop[5]	601	2	2	1.5	0.3	432
LPG[6]	10505	2	2	1	0.5	8404
		Total		7455.2		5583292
		max Ra				2
		Q_{al} (Formula 3)				1497

Note: 1. q is expressed in Mcal/m^2. 2. A_{al} is expressed in m^2. 3. h is height expressed in m. 4. Warehouse. 5. Workshop warehouse (solvents). 6. Liquefied Petroleum Gas.

Table 4. Rate of change of AC1 and Q_e for IP1 in Scenario 1

	AC1[1] (m^2)	Q_e (Mcal/m^2)	AC1 Growth Rate	Q_e Growth Rate
R1	6424	791.55	-	-
P1	6582	784.73	2%	-1%
P2	6890	771.82	5%	-2%
P3	7750	738.29	12%	-4%
P4	8286	719.07	7%	-3%
P5	9198	688.95	11%	-4%
P6	9199	688.92	0%	0%
P7	9356	684.03	2%	-1%
P8	9538	678.48	2%	-1%
P9	10655	646.61	12%	-5%
P10	11812	617.19	11%	-5%
Average growth rate			6%	-2%

Note: Values from P1 to P10 were generated randomly between. 6423.99 a 12000.

Subsequently, the average rate of variation for the generated value pairs (P1 to P10) was calculated; this allowed for the determination of the relationship between both variables. Continuing with the previous example, for IP1, an average variation in the maneuvering yard size of 6% results in a decrease of -2% in the total fire load, which means that the larger the maneuvering yard, the lower the fire risk in the rice plant (see Table 4). Similarly, the calculation was performed with the maneuvering yard areas and fire load of the other rice plants (IP2, IP3, and IP4), in the other three scenarios (see Appendix 3). The results for each of the four scenarios are presented in Figures 1-4, respectively.

In Scenario 1, an inverse relationship is observed between AC1 and Q_e; as AC1 increases, Q_e decreases. This behavior is explained by the relatively low fire load density (q) of AC1 [11], since this area is open and uncovered, and by its low hazard correction coefficient (R_a). This trend is illustrated in Figure 1. In contrast, in Scenarios 2, 3, and 4, increasing the areas of AL1, AL2, and AL3 leads to an increase in Q_e. This behavior is attributed to the high fire load densities (q) associated with these storage areas compared to AC1 [11], as shown in Figures 2-4.

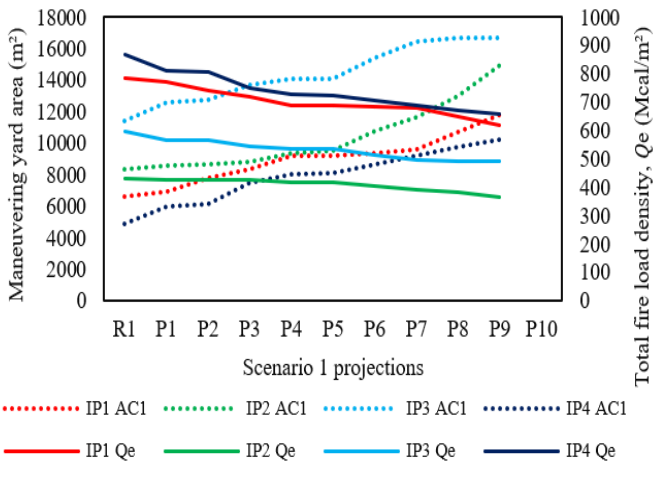

Figure 1. Scenario 1: Total fire load density as a function of the maneuvering yard area

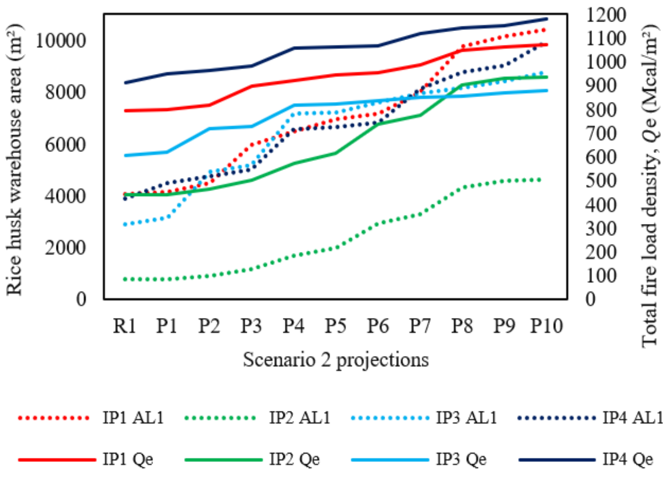

Figure 2. Scenario 2: Total fire load density as a function of the rice husk warehouse area

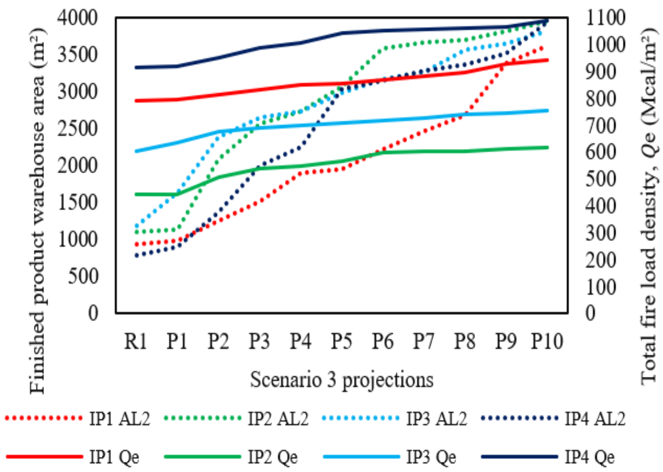

Figure 3. Scenario 3: Total fire load density as a function of the finished product warehouse area

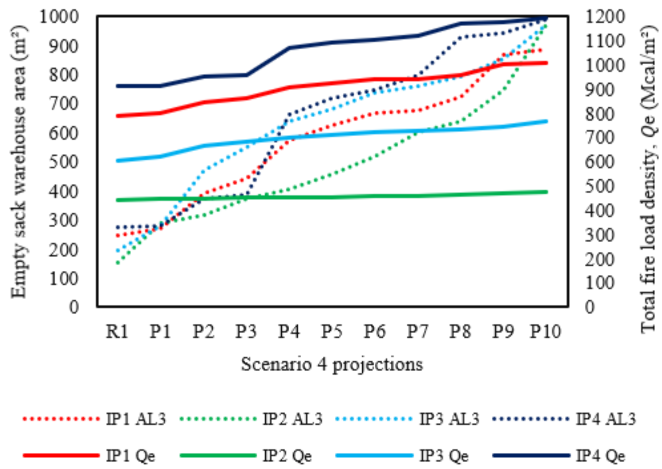

Figure 4. Scenario 4: Total fire load density as a function of the empty sack warehouse area

4. DISCUSSION

In analyzing the four scenarios, the simulation reveals that an increase in the maneuvering yard's size (AC1) is associated with a reduction in the total fire load (Q_e), as depicted in Figure 1. In contrast, for the remaining three scenarios, an enlargement of the warehouse area is associated with a rise in the total fire load (Q_e). This pattern is due to the maneuvering yard's relatively low unit fire load (q_i) of 48 Mcal/m^2 and a hazard coefficient of R_a=1. Conversely, the unit fire load (q_j) in the warehouses is considerably higher, measuring 192 Mcal/m^3 for both the rice husk and finished product warehouse, and 6058 Mcal/m^3 for the empty sack warehouse. Additionally, the dimensionless hazard coefficient for these warehouses ranges between 1.5 and 2.

On the other hand, few studies have been found in the literature related to fire load in the rice milling industry. In particular, a study by Willis and Llaja [11] was found for the metal-mechanical industry, which analyzes the fire risk for a facility, determining a total fire load of 140.08 Mcal/m². This fire load is lower than in the case of the rice milling industry, which averages 800 Mcal/m² in Lambayeque. This highlights that the rice milling industry presents higher fire-related risks. Despite this, an evaluation in the study by Hahnemann et al. [15] concludes that, in the facilities of said metal-mechanical industry, fire protection is insufficient. This makes it clear that, in addition to design, operation also presents factors that can cause a fire.

Also, Tascón [16] examines fire safety requirements within the agri-food sector, concluding that the dimensions of warehouses and the selected fire compartmentalization are of significant importance; similar to the arguments presented in the conclusions of this study. Additionally, Andrade [3] emphasizes that the appropriate selection of a building's shape and configuration is a crucial factor in controlling fire spread. These findings substantiate the analysis of dimensions conducted in this study concerning the rice milling industry [24].

The practical implication of this article is the recommendation to examine the design from the project's inception, particularly in industrial applications, such as the rice milling industry, as similarly discussed in the study by Seong and Leman [25].

5. CONCLUSIONS

This study examines the impact of spatial dimensions in both functional and storage areas on the overall fire load density in rice milling industry facilities situated in Lambayeque. A detailed assessment of the spatial configurations of four rice milling plants in the region was undertaken. The findings indicate that the maneuvering yard is a significant factor in determining the heat load of functional areas, accounting for 54% of the total heat load. Regarding storage areas, the paddy rice warehouse (53%), the finished product warehouse (18%), and the empty sacks warehouse (11%) were identified as the primary contributors to the total heat load.

The total fire load calculation model was applied to the four evaluated plants, facilitating an analysis of the impact of the spatial dimensions. This analysis involved four scenarios, structured in pairs, which considered both the dimensions of each space and the building's overall thermal fire load.

The analysis reveals that expanding the maneuvering yard leads to a reduction in the building's overall thermal load (Q_e). This reduction is attributed to the environment's low fire load density and a decreased hazard coefficient (R_a). Conversely, in the other three scenarios, it was found that increasing the areas designated for paddy rice storage, finished products, and empty sacks results in a rise in Q_e. This rise is due to the higher fire load densities and Ra coefficient values in these areas, as opposed to those in the maneuvering yard.

From a quantitative standpoint, it has been estimated that (i) expanding the maneuvering yard by 4% to 10% results in a reduction of the fire load by 2% to 3%, and (ii) increasing the storage of paddy rice (by 10% to 21%), finished products (by 13% to 19%), and empty sacks (by 14% to 22%) results in corresponding increases in fire load by 3% to 8%, 2% to 4%, and 1% to 3%, respectively.

Through scenario analysis, the relationship between the size of the selected areas and the total thermal load of the building was evaluated. An inverse relationship was observed.

An inverse relationship was observed in the maneuvering yard, attributable to its low fuel load. Conversely, direct relationships were identified in the three storage facilities.

The findings suggest that, from the outset of architectural design, it is crucial to accurately estimate the dimensions of spaces within industrial facilities for rice milling, particularly those areas that significantly influence fire load, such as the maneuvering yard and the primary warehouses. The spatial design of the plant should aim to minimize the building's total weighted fire load, thereby reducing fire risk, enhancing safety, and decreasing the costs associated with the implementation of fire protection systems, as well as the likelihood of human casualties in the event of an emergency.

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APPENDIX

Appendix 1. Area and thermal load of functional areas

Functional Area	Parameter	Rice Milling Plants (IP)				C_f (Average)	Thermal Load (%)
		IP1	IP2	IP3	IP4		
Processing	q (Mcal/m^2)	144	144	144	144		
	C	1	1	1	1		
	R_a	1.5	1.5	1.5	1.5		
	s (m^2)	528.66	6288.68	519.56	772.86		
	Cf = q*s*c	76127.04	905569.92	74816.64	111291.84	291951.36	28%
Bagging	q (Mcal/m^2)	96	96		96		
	C	1.6	1.6		1.6		
	R_a	1	1		1		
	s (m^2)	183.21	79.37		173.71		
	Cf = q*s*c	28141.06	12191.23		26681.86	22338.05	2%
Homogenization	q (Mcal/m^2)	144	-	144	144		
	C	1	-	1	1		
	R_a	1.5	-	1.5	1.5		
	s (m^2)	398.57	-	301.7	378.57		
	Cf = q*s*c	57394.08	-	43444.80	54514.08	51784.32	5%
By-product Bagging	q (Mcal/m^2)	144	-	-	-		
	C	1.6	-	-	-		
	R_a	1.5	-	-	-		
	s (m^2)	25	-	-	-		
	Cf = q*s*c	5760.00	-	-	-	5760.00	1%
Workshops	q (Mcal/m^2)	119	119	119	119		
	C	1.6	1.6	1.6	1.6		
	R_a	1.5	1.5	1.5	1.5		
	s (m^2)	51.9	90.48	151.66	71.9		
	Cf = q*s*c	9881.76	17227.39	28876.06	13689.76	17418.74	2%
Laboratories and Quality Control	q (Mcal/m^2)	48	-	48	48		
	C	1.3	-	1.3	1.3		
	R_a	1	-	1	1		

	s (m^2)	35	-	30.08	47		
	Cf = q*s*c	2184.00	-	1876.99	2932.80	2331.26	0%
	q (Mcal/m^2)	144	144	144	144		
	C	1.3	1.3	1.3	1.3		
Administrative Offices	R_a	1	1	1	1		
	s (m^2)	329.78	283.19	75.36	270.78		
	Cf = q*s*c	61734.82	53013.17	14107.39	50690.02	44886.35	4%
	q (Mcal/m^2)	72	72	72	72		
	C	1.3	1.3	1.3	1.3		
Dining Area + Kitchen	R_a	1	1	1	1		
	s (m^2)	51.53	188.91	59.07	71.93		
	Cf = q*s*c	4823.21	17681.98	5528.95	6732.65	8691.70	1%
	q (Mcal/m^2)	48	48	48	48		
Maneuvering Yard (AC1)	C	1.6	1.6	1.6	1.6		
	R_a	1	1	1	1		
	s (m^2)	6423.99	7459.33	11044.67	4073.89	7250.47	
	Cf = q*s*c	493362.43	572876.54	848230.66	312874.75	556836.10	54%
	q (Mcal/m^2)	48	48	-	48		
	C	1.6	1.6	-	1.6		
Work Crews Area	R_a	1	1	-	1		
	s (m^2)	30	1260.17	-	41		
	Cf = q*s*c	2304.00	96781.06	-	3148.80	34077.95	3%
	q (Mcal/m^2)	-	72	72	72		
	C	-	1.3	1.3	1.3		
Electrical Substation	R_a	-	1.5	1.5	1.5		
	s (m^2)	-	31.45	34.76	27.8		
	Cf = q*s*c	-	2943.72	3253.54	2602.08	2933.11	0%
					Total	1039008.94	100%

Appendix 2. Area and thermal load of storage areas

Storage Area	Parameters	Rice Milling Plants (IP)				C_a (Average)	Thermal Load of the Area (%)
		IP1	IP2	IP3	IP4		
	q (Mcal/$m^{3)}$)	192	192	192	192		
Rice husk warehouse (AL1)	C	1.3	1.3	1.3	1.3		
	R_a	1.5	1.5	1.5	1.5		
	s (m^2)	4037.35	757.83	2877.29	3877.35	2887.46	
	Height (m.)	3.5	8	3.5	3.5		
	Ca = q*c*h*s	3527028.96	1513234.94	2513600.54	3387252.96	2735279.35	53%
	q (Mcal/ m^3)	192	192	192	192		
Finished product warehouse (AL2)	C	1.3	1.3	1.3	1.3		
	R_a	1.5	1.5	1.5	1.5		
	s (m^2)	926.25	1090.58	1183.29	786.25	996.59	
	Height (m.)	3.6	4.2	3.6	3.6		
	Ca = q*c*h*s	832291.20	1143276.83	1063257.06	706492.80	936329.47	18%
	q (Mcal/$m^{3)}$)	-	192	192	-		
	C	-	1.3	1.3	-		
Straw bale storage area	R_a	-	1.5	1.5	-		
	s (m^2)	-	181.25	597.93	-		
	Height (m.)	-	4	2.4	-		
	Ca = q*c*h*s	-	180960.00	358183.99	-	269571.99	5%
	q (Mcal/$m^{3)}$)	300	300	-	300		
	C	1.3	1	-	1.3		
Rice dust storage area	R_a	1.5	1	-	1.5		
	s (m^2)	361.28	106.92	-	381.78		
	Height (m.)	3.5	4.2	-	3.5		
	Ca = q*c*h*s	493147.20	134719.20	-	521129.70	382998.70	7%
	q (Mcal/m3)	313	313	-	313		
	C	1	1	-	1		
Wooden pallets	R_a	2	2	-	2		
	s (m^2)	594	1306.8	-	484		
	Height (m.)	0.14	0.14	-	0.14		
	Ca = q*c*h*s	26029.08	57263.98	-	21208.88	34833.98	1%
	q (Mcal/$m^{3)}$)	6058	6058	6058	6058		
Empty sack warehouse (AL3)	C	1.3	1.3	1.3	1.3		
	R_a	2	2	2	2		
	s (m^2)	245	152	194	275	216.50	
	Height (m.)	0.4	0.1	0.3	0.4		
	Ca = q*c*h*s	771789.20	119706.08	458348.28	866294.00	554034.39	11%
Enamel paint,	q (Mcal/$m^{3)}$)	6058	601	601	601		

thinner, etc.	C	1.3	1.6	1.3	1.3		
	R_a	2	2	2	2		
	s (m^2)	245	0.1	6.8	1.3		
	Height (m.)	0.4	0.3	0.3	0.3		
	Ca = q*c*h*s	771789.20	28.85	1593.85	304.71	193429.15	4%
Liquefied Petroleum Gas (LPG)	q (Mcal/$m^{3)}$	10505	10505	-	10505		
	C	1.6	1.6	-	1.6		
	R_a	2	2	-	2		
	s (m^2)	1	1	-	5		
	Height (m.)	0.5	0.5	-	0.5		
	Ca = q*c*h*s	8404.00	8404.00	-	42020.00	19609.33	0%
					Total	5126086.37	100%

Appendix 3. Scenarios for calculating the total fire load

Scenario 1. Maneuvering yard size (AC1) and resulting fire load (Q_e), with AC1 increasing, AL1, AL2 and AL3 constant

Area and Fire Load	Rice Milling Plants (IP)							
	IP1		IP2		IP3		IP4	
	AC1	Q_e	AC1	Q_e	AC1	Q_e	AC1	Q_e
R1	6424	791.55	7459	440.12	11045	603.74	4074	911.96
P1	6582	784.73	8330	428.69	11362	595.55	4892	864.49
P2	6890	771.82	8525	426.24	12568	566.80	5989	809.06
P3	7750	738.29	8640	424.82	12685	564.20	6096	804.09
P4	8286	719.07	8761	423.33	13662	543.55	7441	747.18
P5	9198	688.95	9362	416.15	14088	535.13	7973	727.18
P6	9199	688.92	9459	415.03	14089	535.11	8086	723.10
P7	9356	684.03	10729	401.01	15361	511.83	8653	703.39
P8	9538	678.48	11633	391.81	16423	494.28	9202	685.49
P9	10655	646.61	12925	379.64	16624	491.13	9739	669.01
P10	11812	617.19	14937	362.68	16667	490.47	10188	655.94

Note: AC1: Maneuvering yard area in m^2; Q_e: Total fire load Q_e (Mcal/m^2).

Scenario 2. Rice husk warehouse size (AL1) and resulting fire load (Q_e), with AL1 increasing, AC1, AL2 and AL3 constant

Area and Fire Load	Rice Milling Plants (IP)							
	IP1		IP2		IP3		IP4	
	AL1	Q_e	AL1	Q_e	AL1	Q_e	AL1	Q_e
R1	4037.35	791.55	757.83	440.12	2877.29	603.74	3877.35	911.96
P1	4157	798.86	761	440.59	3163	621.01	4500	950.38
P2	4483	818.23	909	462.45	4928	717.14	4743	964.43
P3	5961	896.98	1176	501.23	5172	729.15	5009	979.26
P4	6489	921.97	1663	569.80	7144	816.85	6549	1055.14
P5	6937	942.05	1970	611.66	7205	819.32	6659	1059.99
P6	7154	951.42	2927	735.82	7577	834.12	6826	1067.23
P7	7967	984.70	3253	776.06	7950	848.49	8125	1118.70
P8	9745	1048.59	4302	899.06	8134	855.41	8751	1140.81
P9	10140	1061.35	4577	929.76	8429	866.29	9002	1149.25
P10	10416	1070.00	4627	935.28	8770	878.54	9925	1178.36

Note: AL1: Rice husk warehouse size in m^2; Q_e: Total fire load Q_e (Mcal/m^2).

Scenario 3. Finished product warehouse size (AL2) and resulting fire load (Qe), with AL2 increasing, AC1, AL1 and AL3 constant

Area and Fire Load	Rice Milling Plants (IP)							
	IP1		IP2		IP3		IP4	
	AL2	Q_e	AL2	Q_e	AL2	Q_e	AL2	Q_e
R1	926.25	791.55	1090.58	440.12	1183.29	603.74	786.25	911.96
P1	972	794.50	1128	442.71	1630	631.69	893	919.22
P2	1237	811.30	2071	505.40	2372	675.33	1369	950.18
P3	1512	828.14	2567	536.50	2639	690.24	1994	987.67
P4	1895	850.65	2735	546.76	2732	695.34	2249	1002.02
P5	1937	853.06	3067	566.65	2978	708.61	3028	1042.89
P6	2217	868.79	3571	595.89	3152	717.81	3150	1048.92
P7	2460	882.02	3667	601.33	3256	723.23	3284	1055.42
P8	2677	893.53	3698	603.08	3562	738.88	3361	1059.11
P9	3369	928.35	3817	609.75	3647	743.14	3503	1065.81
P10	3618	940.23	3941	616.65	3814	751.42	3924	1084.99

Note: AL2: Finished product storage area (m^2); Q_e: Total fire load (Mcal/m^2).

Scenario 4. Empty sack warehouse size (AL3) and resulting fire load (Q_e), with AL3 increasing, AC1, AL1 and AL2 constant

Area and Fire Load	Rice Milling Plants (IP)							
	IP1		IP2		IP3		IP4	
	AL3	Q_e	AL3	Q_e	AL3	Q_e	AL3	Q_e
R1	245.00	791.55	152.00	440.12	194.00	603.74	275.00	911.96
P1	268	799.70	288	446.54	279	622.46	280	914.05
P2	392	843.26	315	447.80	470	663.91	372	952.14
P3	444	861.32	373	450.52	552	681.46	385	957.47
P4	574	905.95	405	452.01	637	699.48	660	1067.96
P5	625	923.26	458	454.46	683	709.17	720	1091.46
P6	668	937.77	519	457.28	737	720.48	748	1102.35
P7	676	940.46	602	461.09	762	725.70	796	1120.93
P8	722	955.88	637	462.69	792	731.94	930	1172.08
P9	868	1004.24	745	467.60	854	744.78	944	1177.36
P10	887	1010.47	971	477.72	971	768.78	987	1193.53

Note: AL3: Empty sack storage area in m^2; Q_e: Total fire load ($Mcal/m^2$).