Spatial Configuration of Factory Buildings

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Abstract: ***In factories, spatial configuration plays an important role in order to improve workers' comfort which will result in maximising the productivity and at last will contribute to economy generation. With the goal of identifying the major variables influencing shoe factories' spatial layout choices, this study explores the spatial arrangement and organization of shoe factories. By analyzing a cluster of shoe manufacturing plants located in Agra in India through site visit and international case studies in Bangladesh, this study examines how factors such as workflow process, machinery placement, storage areas and logistical considerations impact the spatial arrangement of factories. With the help of workers and factory officials interviews in shoe factories, site visits, and spatial analysis techniques this research provides insights into the actual indoor environment of the factories in terms of spatial arrangement. This actual indoor environment is further comparatively analysed by existing standards for industrial buildings which helped to find out the potential areas for improvement. The findings of this research work aim at identifying the potential areas and best practices for improvement in spatial configuration of shoe factories which will contribute to workers' comfort.***

Keywords: Spatial configuration, spatial layout, standards

1. Introduction

Industrial architecture refers to the style of architecture which is used for the construction of industrial structures and the purpose of job creation, boosting national economy coercion to secondary and tertiary sector, transforming the India to a self-sustaining country and to give the India economy global acknowledgment is fulfilled by industrial development(Kumar, 2022).

Steel began to be used majorly in the field of architecture. Bigger working spaces can into existence due to longer spans.(Shuble, 2022).

Numerous industrial factories followed these structures. The laborers found these factories to be unwelcoming most of the time. Working conditions were hazardous and subpar as a consequence of the factories. Factories have no ventilation systems, fire alarm systems and poor spatial arrangement which resulted in workers' discomfort and at last decreased productivity which is directly proportional to economy of India.

With introduction of standards with respect to spatial configuration for industrial buildings the past situation started improving over decades. But the potential areas in the working environment of factories which has a direct impact on workers' comfort are still more in number which needs to be improved. This dissertation aims to understand the drawbacks in the existing spatial configuration of factories.

Dense factory conditions in past times

Factory conditions in present times
Case showcasing operable window designs in Fagus Factory designed by Walter Gropius

Figure 1: Difference between past and present times
Source:(Shuble, 2022)

1.1 Introduction to Spatial Configuration

The spatial configuration of space refers to the arrangement and layout of the given space. Placement of anything in that given space can be studied under spatial configuration of that space. It encompasses factors such as arrangement and distribution of elements, orientation of those elements which are responsible in space-making, and the overall composition of space as a whole.

Understanding spatial configuration is crucial for designing functional indoor working environment, optimizing resource utilization, and facilitating efficient movement and interaction among people and elements of space-making.

1.2 Vision Inside Factories' Situation

Steel started to appear in more and more architectural designs. Larger mills and working areas were made possible by longer spans.(Shuble, 2022).

These structures were followed by several industrial firms. The laborers found these factories to be unwelcoming most of the time. (Shuble, 2022). When constructing industrial facilities, the product being produced should take precedence over the people who will be occupying the space.(Shuble, 2022).

2. Aim and Objectives

This research paper aims at critical analysis of spatial configuration of factories for workers' comfort.

The objective suggests:

- To analyse the existing standards for the industrial buildings related to spatial configuration.
- To explore the spatial configuration in existing shoe factories through primary study/survey and literature studies.
- To comparatively analyse the existing spatial configuration of the factories and standards for finding the loopholes
- To analyse those loopholes and find a solution within that space

3. Scope and Limitation

- This research work will analyse the spatial configuration for the workers' comfort in factories
- The study will analyse the spatial configuration of shoe factories
- Live cases of Agra cluster shoe factories are taken into consideration for the same
- National building code, Neuferts , Factories Act 1948 and some Industrial building guidelines are taken into consideration for analysis of industrial building standards
- It will conclude finding out solutions for the existing shoe factories drawbacks in their spatial configuration.

4. Methodology

This study's methodology is outlined in the flowchart. The main methods of gathering data include study articles, books, and site visits to a number of shoe factories. The analysis of the selected case studies based on the identified parameters from literature review is done to generate the inferences and conclusion.

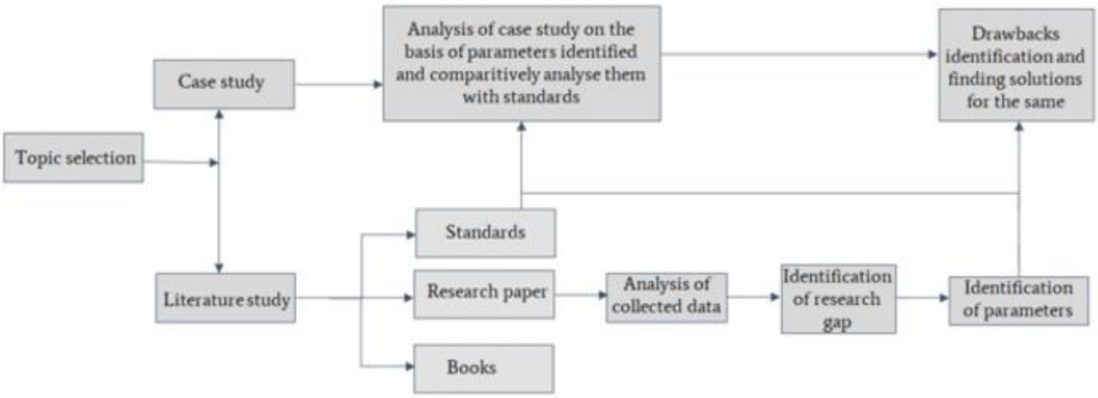


Table 1: Flowchart for methodology

5. Parameters

The following parameters have been determined from literature reviews.

5.1 Site and Internal Planning

Site and internal planning refers to the organisation and arrangement of spaces around the built up the following aspects which are kept into consideration for this research are

- Open spaces around the built up area within the building(setback)
- Size of the plot
- Orientation

5.2 Spatial Layout

Spatial layout refers to the organized arrangement of different areas within a space. It is a critical aspect which influences the functionality , aesthetics, and usability of the space. The spatial layout encompasses several key components. The components which are kept into consideration for our research are:

- Column layout
- Zoning and alignment of workflow to measure qualitative efficiency
- Different zones of activities

5.3 Natural Light and Ventilation

Natural light and ventilation refers to optimization of the building's orientation to maximize exposure to natural light, Position the building to take advantage of prevailing winds for natural ventilation and Placement work areas and communal spaces along the perimeter of the building to allow for access to natural light and ventilation,etc. . The components which are kept into consideration for our research are:

- Placement of windows
- Window area to floor area
- Workspace per worker

5.4 Safety, Security and Accessibility

The following aspects which are kept into consideration for this research are:

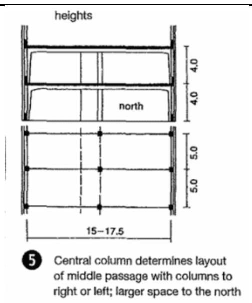
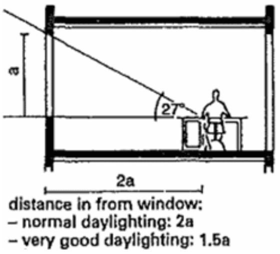
- Occupant load factor
- Fire norms
- Exit widths
- Staircase and ramps
- Accessibility to disables

6. Existing Standards for Industrial Architecture

Guidelines, principles, and rules that control different facets of architectural design, construction, and building practices are referred to as Standards in field of architecture. These standards ensure sustainability, safety, functionality, and adherence to legal and regulatory requirements, among other things.

Taking into consideration Neuferts, Factories act 1948, National building code-2016(Volume 1 &2) and IS code 3103-Industrial ventilation standards this research work has been analysed further.

Table 2: Standards in relation to parameters

Parameters	Standards
Site and internal planning Source:(National building code, 2017)	For height upto 16m,4.5m wide open spaces around building
	Plan depth : room height(2:1)
	Size of plot not less than 300 sq.m Width not less than 15m
	Habitable room Ceiling height =3.6m Conditioned = 3m
Spatial Layout Source:(Neuferts, 1967)	 Figure 3 Column layout Source:(National building code, 2017)
Spatial zoning Source:(The Factories act, 1948)	Point of drinking water should be 6m away from washing place, urinal
	Washroom and work room should have intervening open space or ventilated passage.
	Canteen & rest rooms should be provided(150 or more workers)
Natural light and ventilation Source:(IS 3103:1975 Code of practice for industrial Ventilation)	Windows on one side should face north east & windows on both sides face north south
	1)If height is 4.25m or more no account of space taken 2)If height is less than 4.25m=For each worker 3.5sq.m of floor space
	Width is more than 30m,roof ventilation should be incorporated
	Window height =1.6m(1.1m above floor) Window width =2/3rd of wall width
	Inlet openings not more than 3 to 4.5m above floor level
	Window area = 1/10th of floor area for rooms upto 600m2 For fine work =1/5th of floor area
	 Figure 4 Daylighting Source:(National building code, 2017)
Safety ,security and accessibility	Occupancy load factor=10(m2/person)
	Stairways=10

Source:(National building code, 2017)	Level components and ramps=6.5 (Width per person)(mm)
	Staircase ,lobby , passage=1.2 m or more

(Source: Author)

7. Live Case Studies

7.1 KAPS Overseas Shoe Factory

Located in the famous ancient city of Agra, which boasts of the Great Taj Mahal, this factory is in the middle of one of the biggest footwear markets in the world. this industrial building with a site area of 1000m2 and built up area of 96125m2 gives employment to 600-650 workers

It has a rectangular plan of 33m by 15m with full fledged equipments for shoe production.At every 6 months of time period, survey is conducted by BSI(Business improvement partner) to analyse the working environment of the factory and workers' comfort in that working environment.This factory comes under S.A.8000:2014 which is a voluntary standard for auditable third-party verification, setting out the requirements to be met by organisations, including the establishment or improvement of workers' rights, workplace conditions and an effective management system. After every 6 months then business improvement partner (BIS) conducts the survey under S.A.8000:2014.

7.2 Modern Tech Shoe Industry

Located in the Khasra No. 123, opp site- C, Mohammadpur, Sikandra, Agra-282007, with a site area of 450m2 gives employment to 150-180 workers this factory is also in the middle of one of the biggest footwear markets in the world.

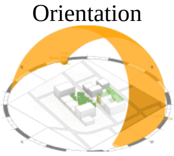
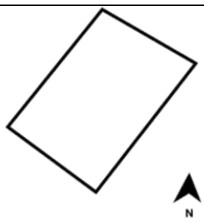
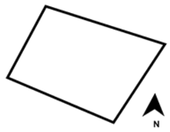
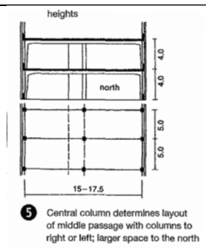
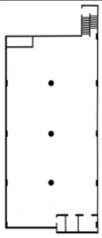
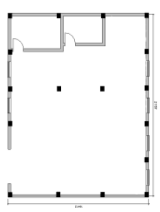
It has a rectangular plan of 22m by 17m with full fledged equipments for shoe production.

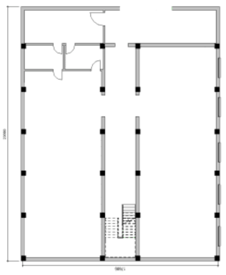
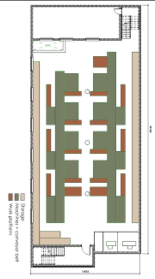
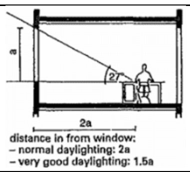
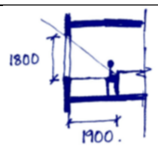
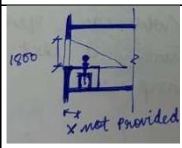
7.3 Neoron Shoe Factory

Located in Plot No.:D-3, Part of Khasra No. 84, Mauja Lakhanpur, Agra-282007, which boasts of the Great Taj Mahal, this factory consists of 400m2 site area with 200-220 workers working in the factory

It is a small scale factory which consists of a rectangular plan of 21m by 16m with full fledged equipments for shoe production.

Table 3: Study of case study showing comparative analysis between their existing situation and standards

Parameters	Standards	Existing Situation			Drawbacks
		Kaps Overseas	Modern Tech	Neoron Shoes	
Site and internal planning	For height upto 16m,4.5m wide open spaces around building	4.2m on all four sides	Only front setback of 3m is available	Only front setback of 3m is available	Open spaces around the building is not provided: 1)Does not allow fresh air to come in
	Plan depth : room height(2:1)	Plan depth= 28m Room height = 3.45m Ratio = 8:1	Plan depth= 23m Room height = 3.15m Ratio = 7:1	Plan depth=16m Room height=3.15m Ratio= 5:1	1)Difficult to naturally ventilate 2)A building with greater depth will require artificial lighting in the center of the building.
	Size of plot not less than 300 sq.m Width not less than 15m	Size of plot = 1000 sq.m Width=21m	Size of plot = 450 sq.m Width=18 m	Size of plot = 400 sq.m Width=16 m	-
	Orientation 	 	 	 	It is important to determine the direction of the sun and the direction of the wind in that environment which as a result regulates daylighting and ventilation.
	Habitable room Ceiling height =3.6m Conditioned = 3m	Non conditioned factory Ceiling Height = 3.45	Non conditioned factory Ceiling Height = 3.15	Non conditioned factory Ceiling Height = 3.15	Low ceilings hinder the circulation of air in a room, which leads to poor ventilation
Spatial layout	 		Whole plan is divided into rooms so that columns do not come in b/w workspaces which as a result will enhance the circulation pattern		Columns in between the workspace creating problems: 1)workspace arrangement 2)workers' work Circulation pattern is not defined which results in less efficiency for the space

					
					Storage zones are not segregated which results in storing things in front of windows which as a result blocks daylight.
	Point of drinking water should be 6m away from washing place, urinal	Point of drinking water is made 3m away from urinal	Point of drinking water is made 1m away from urinal	Point of drinking water is made 1m away from urinal	This results in smell , health issues for workers'
	Canteen & rest rooms should be provided(150 or more workers)	Not provided	Not provided	Not provided	Workers eat at the same place where they work which results in health issues.
Natural light and ventilation	Windows on one side should face north east & windows on both sides face north south	Windows on adjacent walls are facing south east and south west	3 windows at sill height of 2.1m in south east	Windows on both sides facing north and south	
	1)If height is 4.25m or more no account of space taken 2)If height is less than 4.25m=For each worker 3.5sq.m of floor space	In total=510m^2 Workspace= 390 m^2 Work platforms= 190.5m^2 **3.9m^2 of floor space for each worker**	In total=450m^2 Workspace=250 m^2 Work platforms=97m^2 3.4 **3 m^2 of floor space for each worker**	In total=400m^2 Workspace=288 m^2 Work platforms= 62m^2 5.65 **4 m^2 of floor space for each worker**	workspace is less for each worker which effects the workers' comfort due to bad ventilation
	Window height =1.6m(1.1m above floor) Window width =2/3rd of wall width. Inlet openings not more than 3 to 4.5m above floor level	Window height =1.8m(0.9m above floor)	Window height =0.6m(2.1m above floor)	Window height =1.8m(0.9m above floor)	Accidental injuries
	Window area = 1/10th of floor area for rooms upto 600m2 For fine work =1/5th of floor area	Window area = 1/11th of floor area	Window area = 1/26th of floor area	Window area = 1/14th of floor area	Bad ventilation and daylighting
					Distance between work platform and window is less which result in bad daylighting. direct exposure to natural light and potential glare
Safety, security and accessibility	Occupancy load factor=10 (m2/person)	510/10=51 persons allowed 150 persons at present	450/10=45 persons allowed 75 persons at present	400/10=40 persons allowed 100 persons at present	No. of persons working are more than no. of persons allowed in a space.
	Stairways=10 Level components + ramps=6.5 (Width per person) (mm)	Min exit width (staircase)= 510mm. Min exit width (ramp)=332mm	Min exit width (staircase)=450mm Min exit width(ramp)=300mm	Min exit width (staircase)= 400mm Min exit width (ramp)= 260mm	No ramp is provided in any of the 3 factories which makes it inaccessible to disables.
	Staircase, lobby, passage=1.2m or more	2 staircase of width 1.2m is provided	1 staircase of width 0.9 m is provided	1 staircase of width 0.9 m is provided	Fire norms are not followed which risks workers' life.

(Source: Author,2024)

8. Case Studies

8.1 Shoe Factory Ashulia

Located in Bangladesh and constructed in 2023 this industrial building has a site area of 7000m^2 (production part built up area 1070m^2 gives employment to 1100-1200 workers this factory is also in the middle of one of the biggest footwear markets in the world.

8.2 Design Intent

Prime consideration of this factory design was on workers well-being and safety which coordinates with our research aim. 446 m^2 semi-intensive green roof with 724 m^2 site landscaping was incorporated for thermal and environmental benefit. For the best indoor air quality and illumination, natural ventilation and daylighting are been allowed through various methods of treatments on the windows. Electricity for utilities, service areas, and the surrounding site, including emergency lighting and alarm systems are provided by solar panels. Energy-efficient lighting, drip irrigation for landscaping, and low-flow water fixtures were also installed.

8.3 Parameters Study

Table 4: Parameter analysis for shoe factory at ashulia

Parameters	Analysed Condition
Site and internal layout	724 m^2 Site landscaping is done around the built up area which acts as a buffer zone and enhances the indoor air quality
	Plan depth: building height =4:1
	Ceiling height = 4.2 m
Spatial layout • Open plan or divided into rooms • Circulation pattern for efficiency	Steel structure with bricks infill wall construction allows: • Strength and Durability • Design flexibility • Fire resistance • Thermal performance
Spatial zones	• Zones such as warehouse, washrooms, canteens and rest rooms are well segregated according to functional use of each zone in a proper order • Integration of landscaping with indoor environment.
Natural light and ventilation	• Full height window of 4.2m with width of 2m is provided in east and west direction which allows proper day lighting and cross ventilation • Eliminates the dark zone in the mid zone of the factory due to full height window of 4.2m
Safety, security and accessibility	• At every 30m staircase is provided following proper fire norms • These staircase should be open to landscape area. • Lift is provided beside the staircase making the building accessible to disables.

(Source: Author, 2024)

9. Conclusions and Recommendations

The aim of this research was to find a gap between intentions of design and the way it is being experienced.

Table 5: Conclusions and recommendations

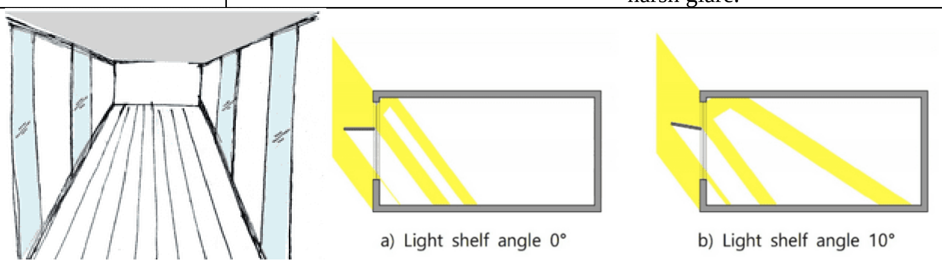
<table>
<tr><th>DRAWBACKS</th><th>SOLUTIONS</th></tr>
<tr><td>Windows placement</td><td>Full height windows should be placed to provide ample day lighting on opposite walls at regular intervals so that dark zones are not created inside the space
• Select window treatments with light-filtering or glare-reducing properties
Installing daylight redirecting devices such as light shelves, prismatic film, or reflective louvers on windows . These devices can help direct natural light deeper into the factory space.
Select glass with frosted or textured surfaces that diffuse light more evenly and minimize harsh glare.</td></tr>
<tr><td colspan="2">


Figure 7 Full height windows and light shelf
(Source: Author,2024)
</td></tr>
<tr><td>When Plan depth: building height is more
• Difficult to naturally ventilate
A building with greater depth will require artificial lighting in the centre of the building.</td><td>• Segregation of space into smaller chunks or areas to disrupt the visual expanse which can be achieved with the help of partitions, screens, furniture arrangement or change in floor elevation. Juxtaposed areas can decrease the percentage of apparent depth and create a more dynamic indoor working environment
• Organize the layout
• Use Visual Tricks
• Maximize Natural Light</td></tr>
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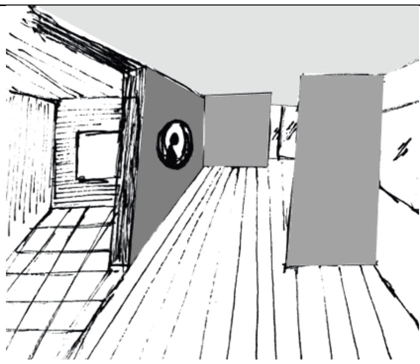
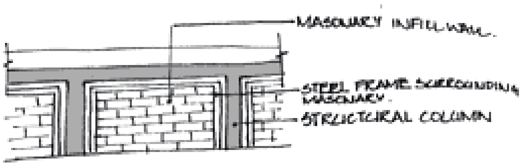
<tr><td></td><td></td></tr>
<tr><td colspan="2">
Figure 8 Division of spaces
(Source: Author,2024)</td></tr>
<tr><td>Columns in between the workspace creating problems:
1)workspace arrangement
2)workers' work</td><td>• Space Planning: Plan the layout of furniture and workstations strategically to minimize the impact of columns.
• Column Integration: Integration of columns should be such that it blends into the design narrative of the workspace by treating them as architectural features rather than obstacles.
• Columns can be transformed into functional elements such as seating. By repurposing columns, they become assets rather than obstacles within the workspace.
• Use of steel structure with Brick infill walls allows for greater span without hindrance of columns</td></tr>
<tr><td colspan="2">

Figure 9 Steel structure with brick infill walls
(Source: Author,2024)

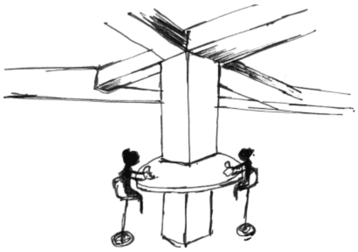
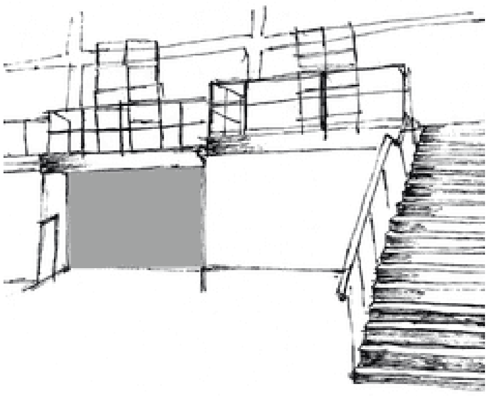



Figure 10 Workspaces around the columns
(Source: Author,2024)</td></tr>
<tr><td>Storage zones are not segregated which results in storing things in front of windows which as a result blocks daylight</td><td>• Workflow Optimization: To optimize efficiency and minimize material handling storage zones should be organized in alignment with workflow processes
• Physical Barriers: Use of physical barriers such as walls, fences, or partitions for separation of different storage zones.</td></tr>
<tr><td colspan="2">
Figure 11 Separate zones for storage
(Source: Author,2024)</td></tr>
<tr><td>Workers eat at the same place where they work which results in health issues.</td><td>• Spaces should be allocated for canteens and restrooms
• These spaces can came out from the landscaping around the building</td></tr>
</table>

Low ceilings hinder the circulation of air in a room, leading to poor ventilation	• **Install clerestory windows**: Bringing natural light into the room from above can make it feel more open and spacious. • Create vertical visual elements

(Source: Author, 2024)

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