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PRD: ATF - Circulation fitting

Document Log

Contributor	Date	Status
Mahmoud	Jan 1, 2023	Documentation, logic, usecase scenarios In progress

Contents

Overview

Performing an automated testfit for a floor plan typically begins with calculating and determining the right circulation area and locations. This document provides a calculating guideline and logic of circulation design in office buildings.

Problem statement

The first step to start the auto Testfit is to calculate the circulation requirements and layout in the floor plan.

- The circulation layout is done manually by domain expertise (designers, space planners) through experience, regulations (fire exit), and constraints (points of interest, columns, walls, core). Although there are many research attempts to define step-by-step algorithms (or workflow) for circulation layout planning, there is no universally accepted guideline for that.
- Circulation layout planning is a first step in the testfit process. However, it keeps evolving with every design stage.

Definitions

Table 1.

Term	Definition	Example
Building design efficiency	The effectiveness and efficiency of the layout, design, and use of spaces on the floor	Factors such as circulation multiplier, circulation factor, and the relationship between net area, circulation area, and usable area.
Circulation area (CA)	Primary and secondary circulation areas on the floor, such as elevators, stairwells, and hallways	Total square footage of all elevators, stairwells, and hallways on the floor

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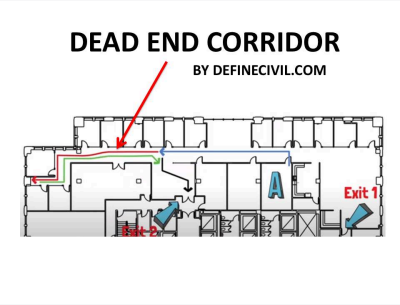
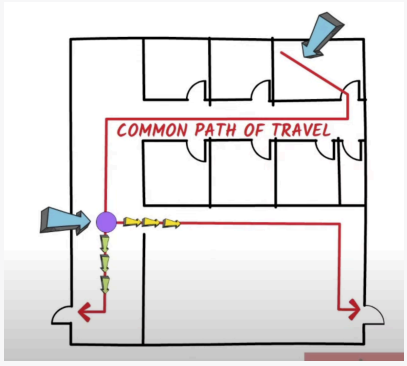
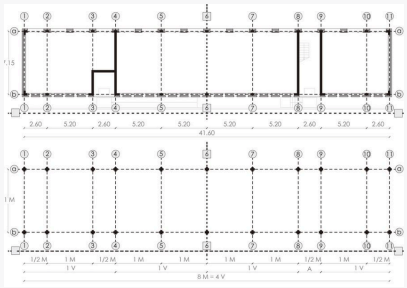
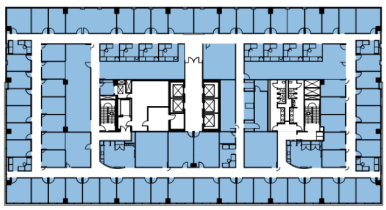
Term	Definition	Example
Circulation Factor	The ratio of circulation area to usable area, used to measure the proportion of the floor's area that is dedicated to circulation = Circulation area / Usable area	Circulation Area / Usable Area
Circulation Multiplier	The ratio of net area to circulation area, used to measure the efficiency of the layout and design of the floor = Net area / Circulation area	Net Area / Circulation Area
Gross area (GA)	All areas on the floor, including vertical circulation areas	Total square footage of all the offices, elevators, stairwells, and hallways on the floor
Net Floor Area (NFA)	Area of spaces on the floor that exclude circulation and core areas	Total square footage of all the offices on the floor
Primary circulation	The main route connecting the core areas of the floor, such as elevators, exit stairs, and restrooms	Elevator lobby and exit stairwell
Rentable Square Feet (RSF)	All areas on the floor that can be rented to tenants, excluding vertical circulation areas	Total square footage of all the offices and common areas that can be rented to tenants, excluding elevators and stairwells
Secondary circulation	The aisles between individual spaces on the floor, such as offices or classrooms	Hallway connecting individual offices to a conference room
Usable Square Feet (USF)	Sum of the net area and circulation area on the floor, the total area available for use by occupants or tenants = Net area + Circulation area	Total square footage of all the offices, elevators, stairwells, and hallways on the floor
Dead-end length	Where more than one exit or exit access doorway is required, the exit access shall be arranged such that dead-end corridors do not exceed 20 feet (6096 mm) in length. Video illustration	

Term	Definition	Example
Common path fo travel	A common path of travel exists in the initial portion of the exit access where a space is arranged so that occupants within that space can travel in only one direction to reach any of the exits or to reach the point at which they have the choice of two paths of travel to two different remote exits. When an occupant is provided only one direction before reaching a point at which he travels in an independent direction, all that travel is considered a common path.	
structural module	The structural module is a standard unit of measurement used in architectural design and construction to determine the size and spacing of structural elements such as columns, beams, and walls. It is used to create a consistent and harmonious composition and to ensure that the building is stable, safe, and efficient to construct. The structural module is based on the structural logic of the building and the design criteria. It can be based on different criteria such as human scale, structural logic, or aesthetic considerations. The structural module can be used to establish the dimensions of key elements of the building such as room sizes, window sizes, and the spacing of structural elements. It can also be used to establish the proportions of the building, such as the ratio of the width to the height of the building.	
Passing place	A passing place in corridor design refers to an area within a corridor that is specifically designated for people to pass each other. It's usually wider than the rest of the corridor to allow for more space for people to move around. It is often used in areas where the corridor is too narrow for two people to pass each other comfortably, and it is used to overcome this problem by giving people space to pass each other.	
Turning point	A turning point in corridor design refers to an area within a corridor that is specifically designated for people to change direction. It is often used in areas where the corridor is too narrow to make a 180-degree turn and it is used to overcome this problem by giving people space to change direction. The turning point may also be used to create a visual interest, to break up a long corridor or to lead people to a specific area. It is also called a turning radius or a turning area.	
Double loaded	A double-loaded corridor is a type of corridor design	

Term	Definition	Example
and single loaded corridors	where rooms or offices are located on both sides of the corridor. This means that there are rooms or offices facing each other across the corridor. A single-loaded corridor, on the other hand, is a type of corridor design where rooms or offices are located on one side of the corridor. This means that there is only one row of rooms or offices along the length of the corridor.	

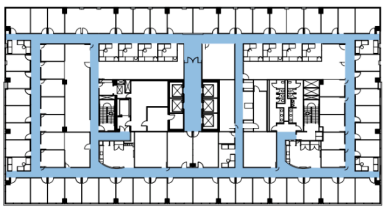
DEFINING

A common language about office space.



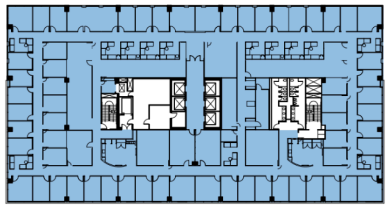
NET AREA (NET SQUARE FEET - NSF)

The area of each identified program space. For example, the Net Area of an 8' x 8' workstation is 64 NSF. It includes individual workspaces, dedicated and shared support spaces, and special mission-critical spaces.



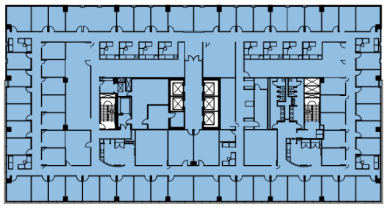
CIRCULATION AREA (PRIMARY & SECONDARY)

Primary circulation is the main circulation route connecting to the building core and common spaces, such as elevators and exit stairs. Secondary circulation includes the aisles between individual spaces, such as offices and cubicles, and support spaces.



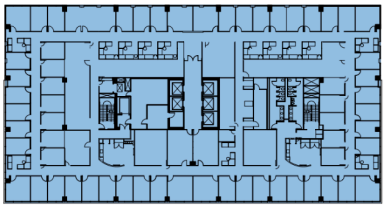
USABLE AREA (USABLE SQUARE FEET - USF)*

Area of a floor occupiable by a tenant where personnel or furniture are normally housed.



RENTABLE AREA (RENTABLE SQUARE FEET - RSF)*

Total Usable Area plus a prorated allocation of the floor and building common areas within a building.



GROSS AREA (GROSS SQUARE FEET - GSF)*

Total area of a building enclosed by the exterior face of the perimeter walls, calculated on a floor-by-floor basis.

* Definitions per ANSI/BOMA Z65.1 - 1996, "*Standard Method for Measuring Floor Area in Office Buildings*"

~~Proposed Solution~~

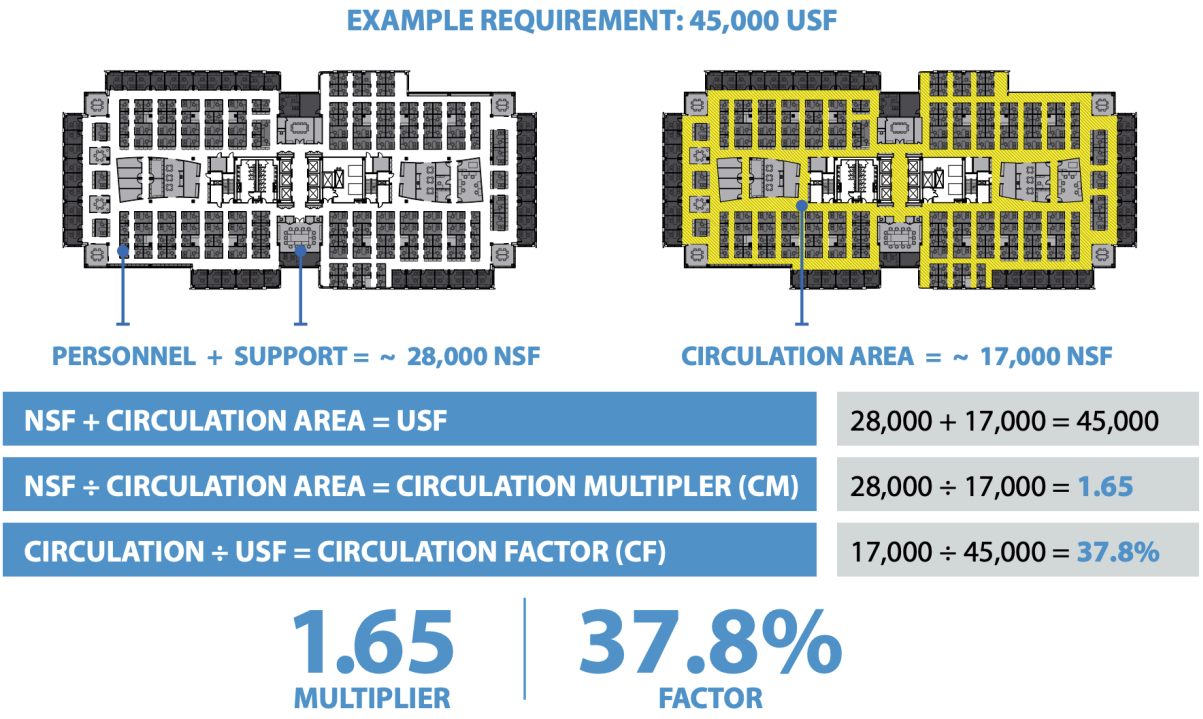
~~In this document, we propose a step-by-step workflow for circulation calculations and layout planning for a single floor plan.~~

1. ~~Basic calculations: to determine the minimum required circulation area.~~
2. ~~Constraints: driven from different standards, such as the maximum travel distance, the minimum and maximum corridor width.~~
3.

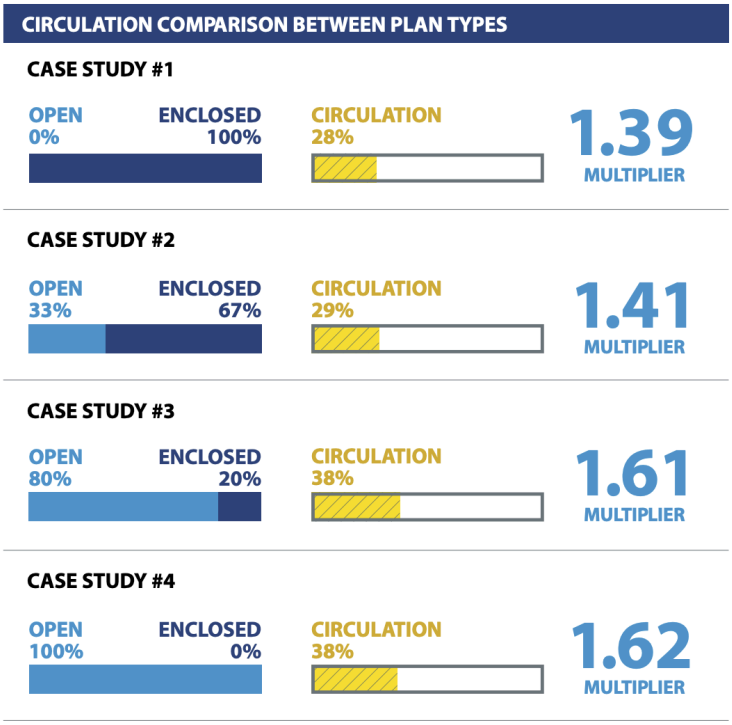
Basic calculations

Net Square Footage (NSF) = Usable Square Footage (USF) - Circulation Area (CA).
Circulation Multiplier (CM) = NSF/CA
Circulation Factor = CA/USF
Closed to Open space ratio = Closed space Area : Open spaces Area

Example :



Recommended Circulation factor and Circulation Multiplier values based on the closed to open space ratios:



Standards and guidelines

Example of existing standards and guidelines:

1. The International Organization for Standardization (ISO)
2. Occupational Safety and Health Administration (OSHA)
3. The National Fire Protection Association (NFPA)
4. International Building Code (IBC)
5. Society of Facility Engineers (SFE)
6. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
7. Building Owners and Managers Association International (BOMA)
8. The National Electrical Code (NEC)
9. The American Institute of Architects (AIA)
10. Americans with Disabilities Act (ADA)
11. Leadership in Energy and Environmental Design (LEED)
12. The National Institute of Building Sciences (NIBS)
13. The American Society of Testing and Materials (ASTM)
14. Uniform Building Code (UBC)
15. The Universal Building Code (UBC)

Circulation constraints from IBC standard.

Table 2.

item	value	variables	scope
Circulation area	Basic calculations		
Maximum walking distance for employees to reach key areas	15m	key_areas, point_of_interest	
Minimum corridor width	1.2m	corridor_width	
Maximum corridor width	2.5m	corridor_width	
Minimum corridor length	25m	corridor_length	
Maximum corridor length	80m	corridor_length	
Minimum width for doors	0.9m		out of scope
Maximum width for doors	1.2m		out of scope
Maximum length of escape route to nearest stairs/fire exit	30m	travel_distance	
Minimum width for escape routes to staircase or fire exit	1.2m	corridor_width	
Number of evacuation stairs needed as per building height and occupancy load: 1 Evacuation Staircase/1000 occupants or 40 meters whichever is lower	1: 1000 occupants Or 1: 40 building height		out of scope
Minimum width at turns and intersections	1.5m	corridor_width	
Maximum egress route travel distance to exit door/opening	30m	travel_distnace	
Maximum walking distance to elevator or stairs	40m	travel_distance	
Maximum dead-end length: 7.5m	7.5m	travel_distance	
Maximum common path of travel	30m	travel_distance	
Corridors and routes longer than 15 m must have a passing place for two wheelchair users of at least 1.80 m width and depth.	1.8m * 1.8 m /15m	travel_distnace	

Double loaded and single loaded circulation guidelines

The choice between a single-loaded corridor and a double-loaded corridor depends on the specific needs of the building and its occupants. For example, if the building requires a large number of rooms or offices to be located in a smaller area, a double-loaded corridor may be more appropriate. In addition, some factors such as fire safety, noise control, and privacy should also be considered.

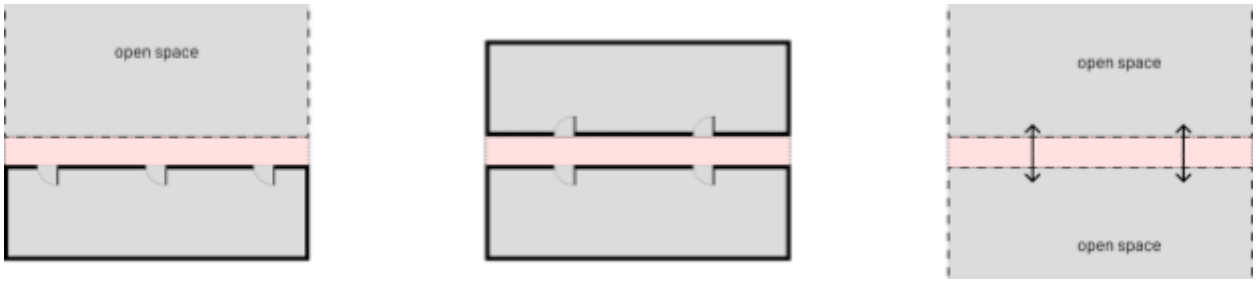
Circulation loading choice criteria:

- Minimize the circulation area.

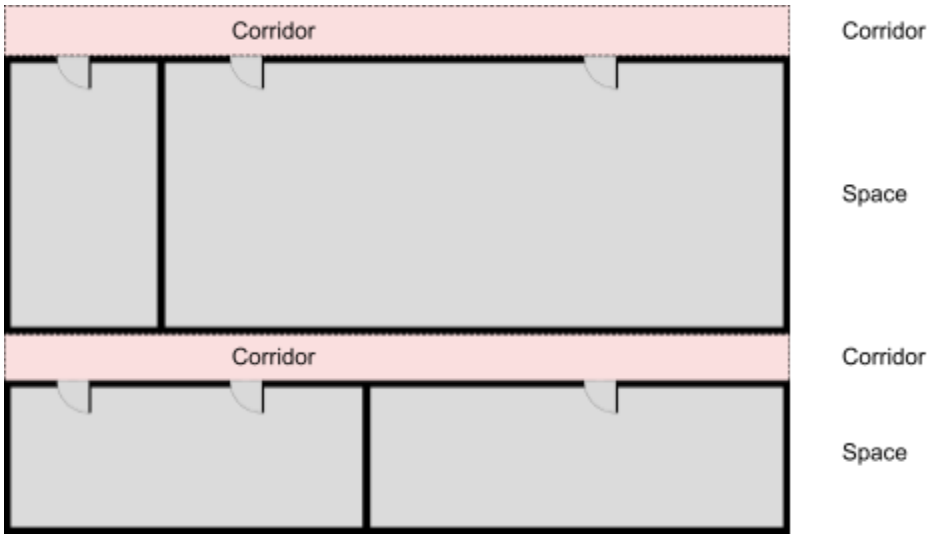
- Single-loaded circulation is generally considered more efficient than double-loaded circulation in office buildings.
- Each space should have easy access to it.

Note: The above points are general rules of thumb, and the efficiency of circulation design depends on the specific needs of the building and its occupants. Factors such as natural light, views, fire safety, noise control, and privacy should also be considered.

Double loaded corridor



Single loaded corridor (less efficient)

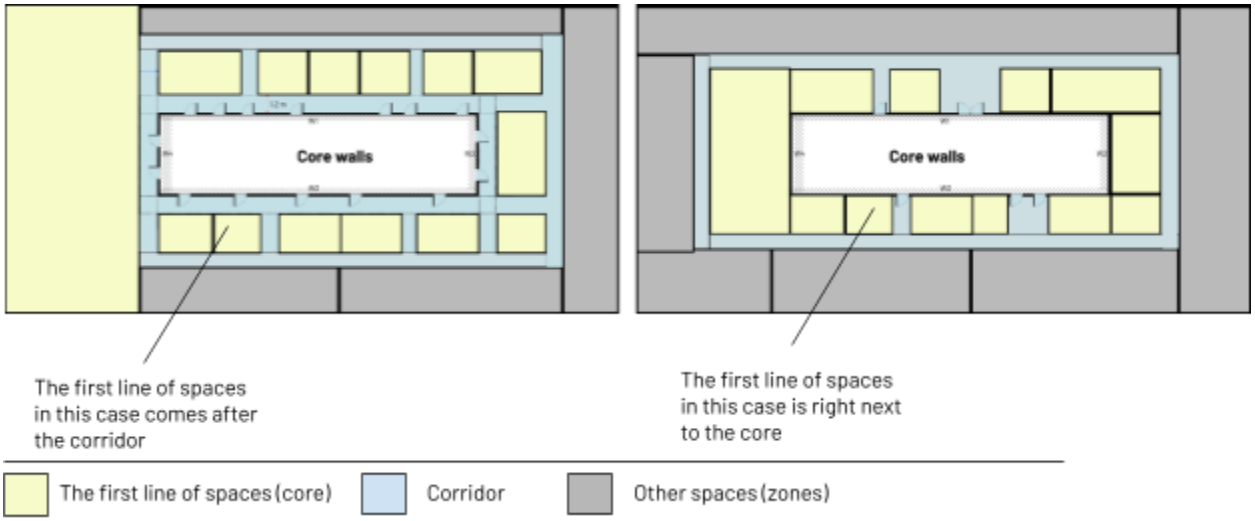


The first line of spaces

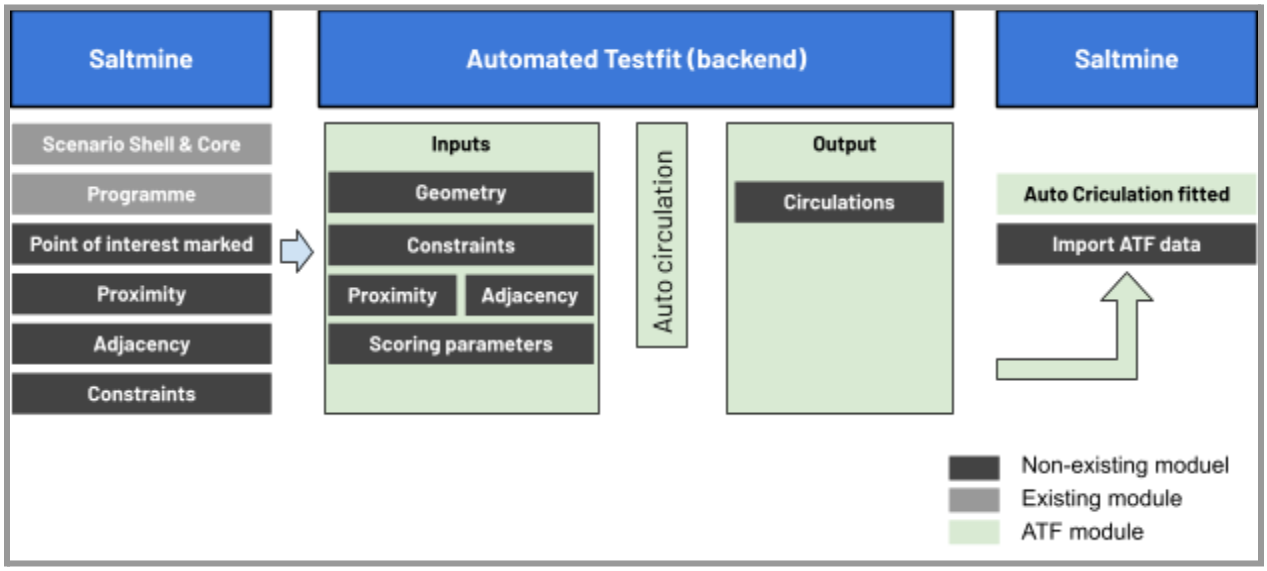
The **"first line of spaces**" refers to the spaces that are closest to the "points of interest" of the building core and shell, such as the main entrance, elevators, staircases, windows, and other frequently used areas. These spaces can either be located directly next to the walls that contain these "points of interest" (called "core" and "shell walls") or they can be located after a short corridor that is next to these walls.

The criteria for deciding whether the first line of spaces should be directly adjacent to the core/shell walls depend on various factors such as the number of openings in the core walls, the depth of the spaces, and the distance to the nearest structural element (See Algorithm 1).

The following figure shows the first line of spaces next to the core walls.



Circulation ATF solution architecture



Inputs

This section consists of the following input items.

1. Core
2. Shell

3. Constraints
    a. Structural system.
    b. Guidelines and regulations.
4. Scoring system

Core

There may be one or more cores in the floor. The core here refers to a central part of a building or structure. It typically includes functional spaces such as elevators, stairwells, and bathrooms, and is often designed to be the structural backbone of the building.

Core points of interest

List of points of interest on the core walls:

1. Entry/Exit points
    a. Main entry:
    The main level entry/ies
    b. Fire exit.
    Opening that is used for fire escape.
    c. Secondary entries.
    Any opening on the core other than main entries and fire exits (example: electrical room, shafts, storage openings...).
2. Others
    Such as plumbing, shafts, HVAC ..

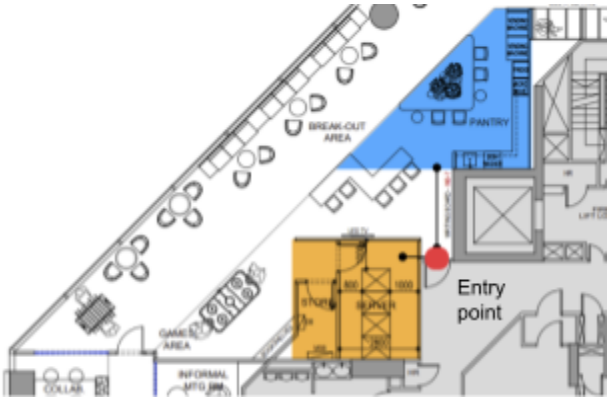
Zone/Block proximity.

The proximity matrix between the core points of interest and zones should be inputted to decide which zones/blocks will be connected to the core.

Example:
In the following example, the proximity between the entry point (red) and the pantry and the server room is indicated:

Proximity matrix

	Entry point 1
Pantry	[1, 10]
Server	[0,5]
Storage	[0,10]



Shell

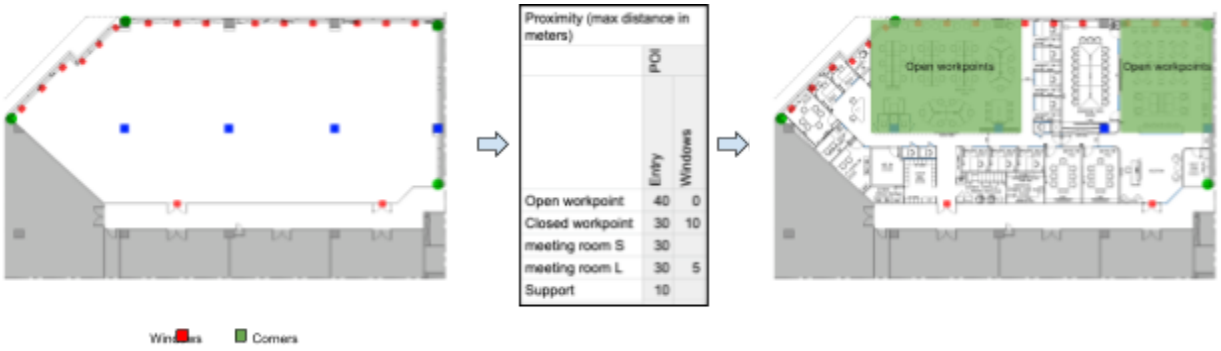
Shell point of interest

A list of shell points of interest:

1. Windows
2. Corners

Shell-zone proximity

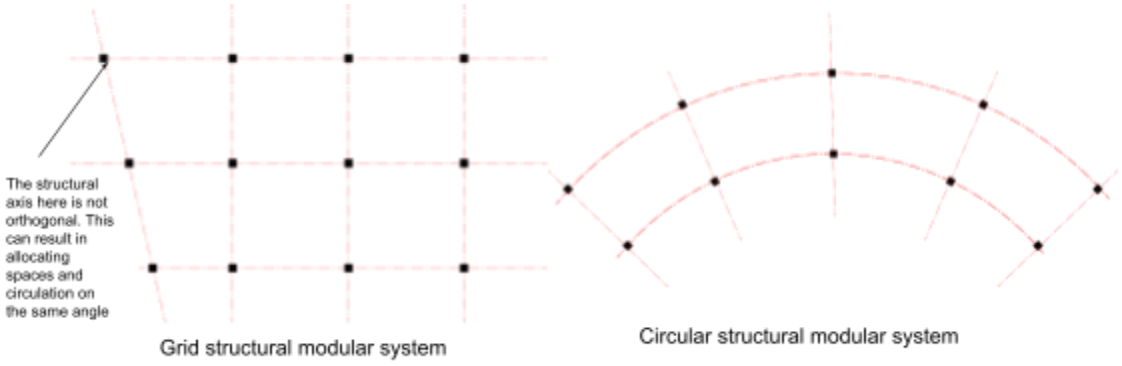
Example: Open workpoints are closest to the windows in the following proximity matrix. Thus, the auto testfit should allocate them in conjunction with the windows since the distance is 0.



Structural system

The structural design of a building plays a crucial role in determining the location, direction, and orientation of circulation routes. Specifically, the placement of columns within the structural system greatly influences the layout of these pathways.

In architectural design and construction, it is common to use a standard unit of measurement called the **structural module**. This module is used to determine the distance between columns in a building. The structural module can also be used to define the distance between other structural elements such as beams and walls.
It's worth mentioning that in some designs, the horizontal and vertical distances between the columns may differ, but the most important is that each column must be defined by at least two structural axes.

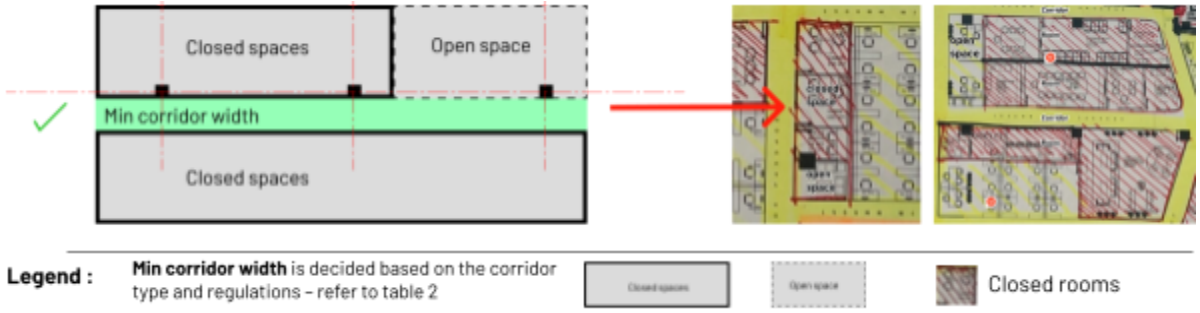


Understanding Structural System Constraints

It is crucial to keep in mind that the corridor must be completely clear of any obstructions, including structural elements. The following use cases show the correct and incorrect ways of allocating structural elements within columns.

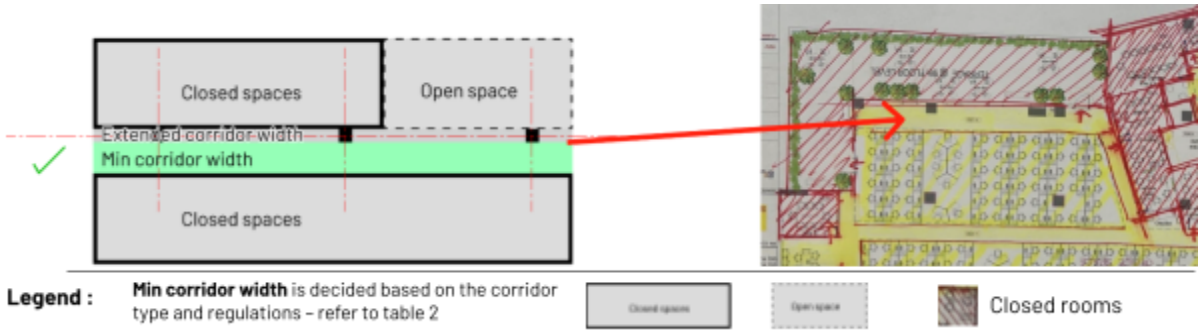
Case1.

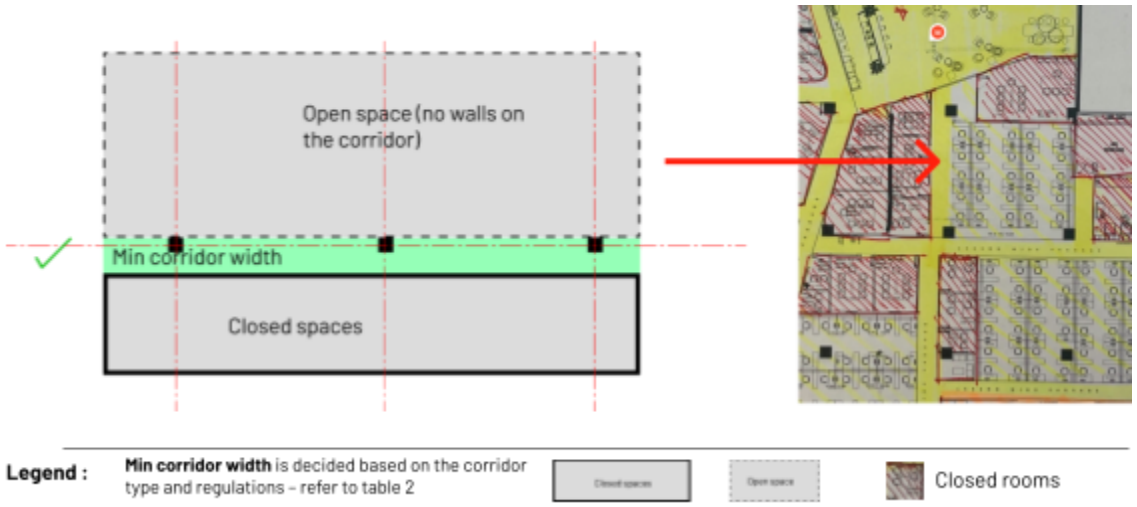
The corridor has closed rooms (fully or partially) on both sides, The columns should not distract the corridor at any point. They should be placed inside the rooms (preferred towards the side with open space.



Case2.

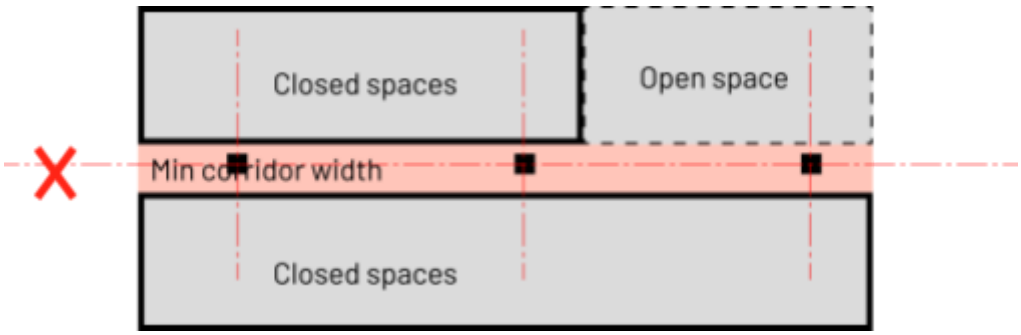
There are columns inside the corridor, but the corridor doesn't have any closed spaces on one of its sides (all open spaces without walls or any fencing)





Case3.

The columns are located inside the corridor and the corridor has closed doors on both sides.



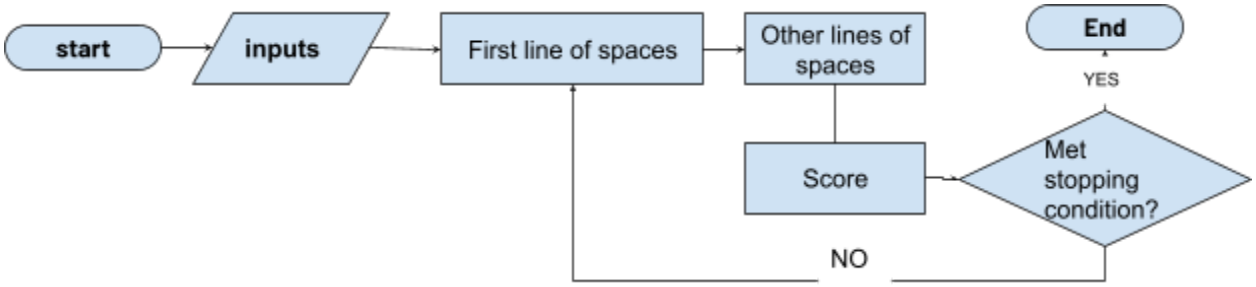
Scoring system

The scoring system for corridors shall comply with the standards and regulations mentioned in table 2. There are some variables that need to be considered to score circulation:

1. **Corridor width** from both sides and this is defined by the narrowest point on the corridor.
2. **Walking distance**. Between any two points.

Proposed circulation design logic

General overview



First line of spaces algorithm

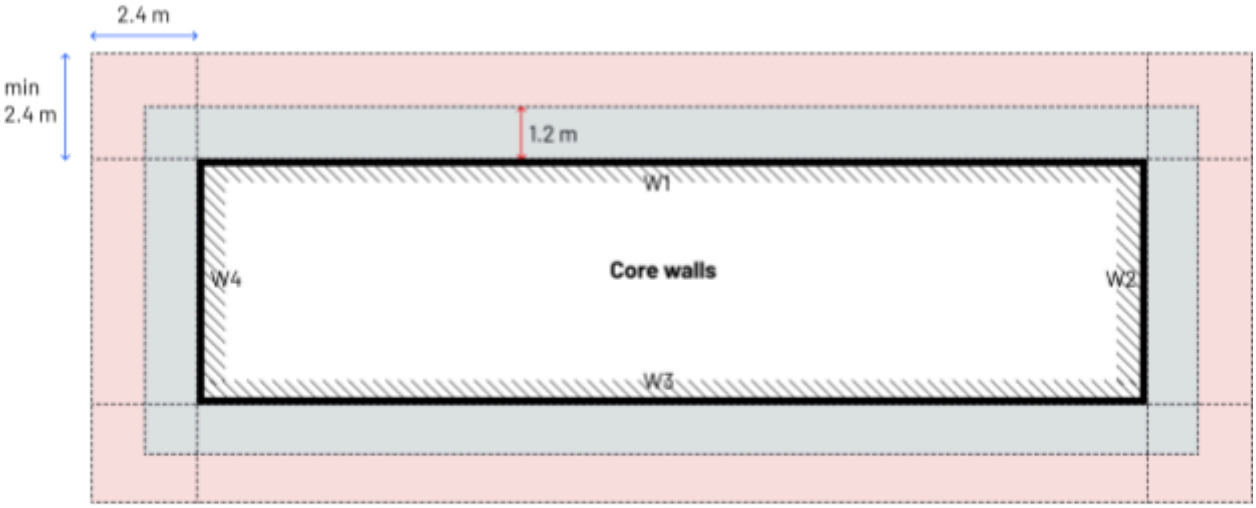
[Flowchart link]

Problem definition

Should we place corridors or rooms on the core walls ?

Generally, we try to minimize the corridor areas by:

- reducing redundant circulation areas.
- Try to make each circulation double loaded as possible

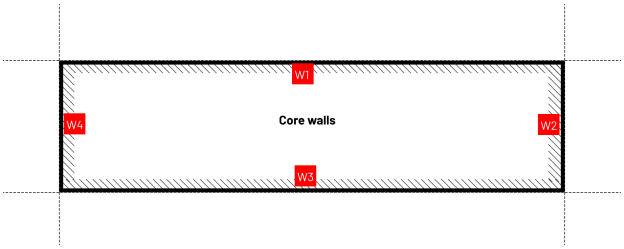
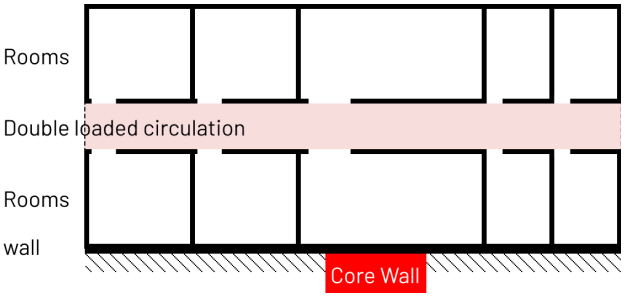
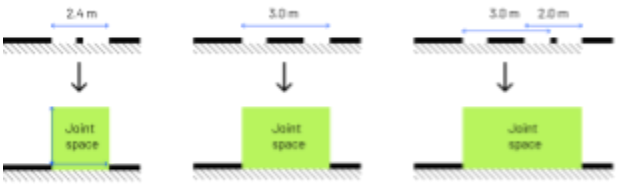
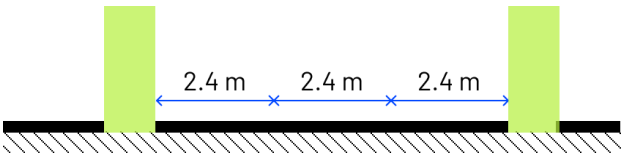


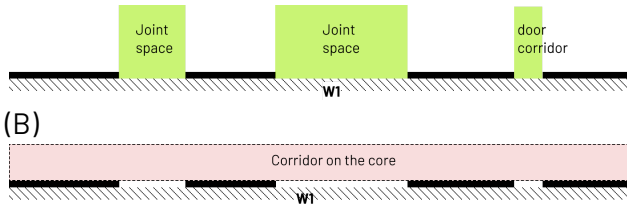
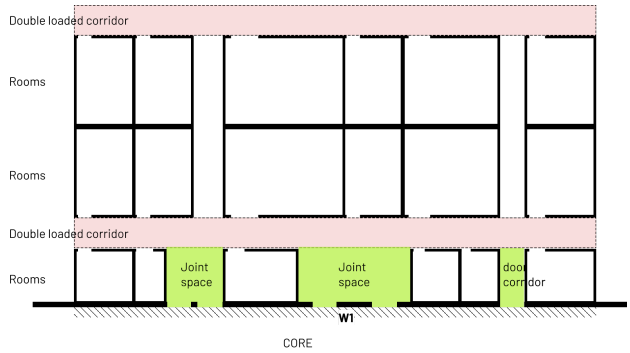
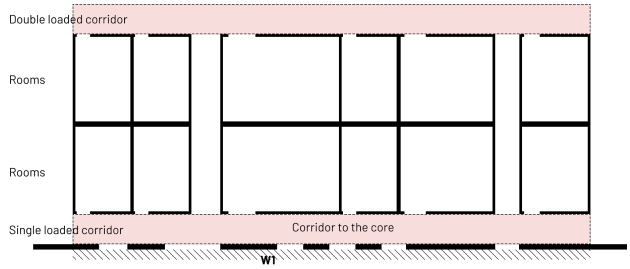
Possible room location

Possible circulation location

In this problem, we are making trade-off between the circulation and the room location on the core walls.

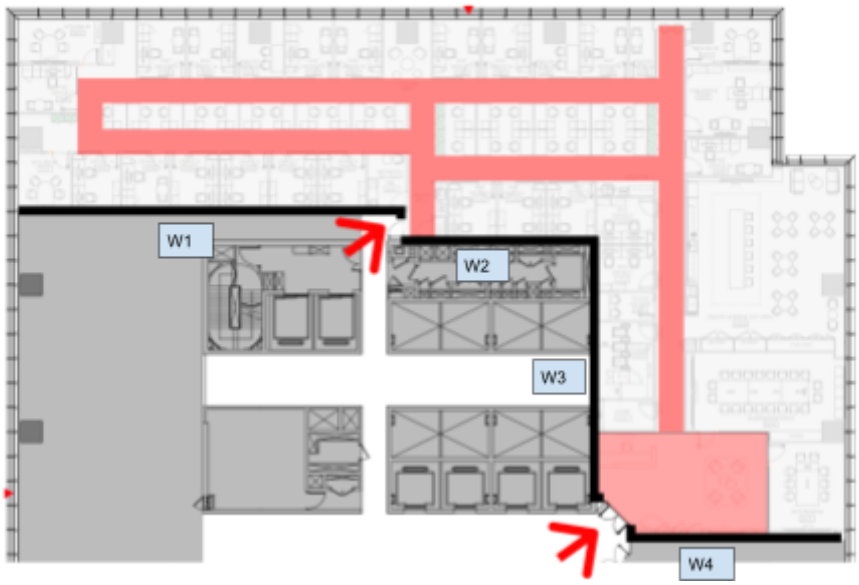
Solution

Step	illustration
1. Collect the proximity matrix to get spaces that should be nearest to the core points of interest.	
2. Divide the core walls into segments (Example, rectangular core W1, W2, W3, and W4)	
3. Iterate through core walls	
- If the wall is solid without openings, add spaces then corridor.	
- Else if the wall has openings, **calculate the outer distance** between each adjacent openings.	
- If the outer distance between two adjacent openings **<= 2.4 (the minimum module length)** , merge them and create a joint space (joint_space)	
- Else add a vertical corridor (vertical_corridor) at each opening.	
- Calculate the total corridors area (the vertical_corridors + joint_spaces) → (A)	(A)

Step	illustration
- Calculate the total area of corridor adjacent to the core wall → (B)	
Compare area(A) and area(B)	
- If area(A) < area(B), the first line of spaces will be adjacent to the core walls	
- Else, add a corridor next to the core wall then add spaces.	

Examples and use cases:

Use case scenario	image
Use case 1: W1 is solid, so, the first line of spaces id directly adjacent to it. W2 has two openings and the distance between them is greater than the minimum modular unit. So, vertical corridors have been created from each opening.	
Use case 2 W1 has one opening, so a vertical corridor from the opening is created. W2 and W3 each one has one opening, however, the reception space has been allocated in front of the door at W3 and then merged with the corridor next to it.	

Use case scenario	image
Use case 3 W1 and W2 share only one opening at the corner. So a corridor created vertical to the door wall W3 and W4 share one opening at the corner, however, the reception has a high proximity to the door, thus, the reception is located next to the door and the first line of spaces are also located next to the core wall (W3).	
More use case scenarios can be found here	

Key User Requirement

Target User Profiles

The following user profiles will be referred to as user

- Designers.
- Workplace planners.

User stories

S.N	User Story	Priority

saltmine

Key Dates/Timelines

	Sprint2 Jan 30, 2023	Sprint3 Feb 13, 2023	Sprint4 Feb 27, 2023	Sprint5 Mar 13, 2023	Sprint6 Mar 27, 2023
Circulation Fitting (Jira)					
Logic and algorithm					
Backend					
Frontend					
QA and UAT					
Deploy to SIT					
Documentation					