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Designing Aisles for Working Facilities

Quarterman Lee, P.E.
Strategos, Inc.
Kansas City, Missouri USA
qlee@strategosinc.com

Abstract

While most plant layouts are drawn with CAD, the actual design remains a mostly human process. Aisle design is inherent in and concurrent with the macro-layout of a facility. While there is much discussion of macro-layout design in the literature, little is said about aisle design. There is even less discussion of the thinking process and design procedure that moves from a "layout primitive" or "space-relationship diagram" to a viable layout. This paper presents a general design procedure that integrates aisle design into the layout process and notes some general principles for an effective aisle system.

Keywords

Plant Layout, Lean, material handling, aisles, facility planning, spaceplan

1. Introduction

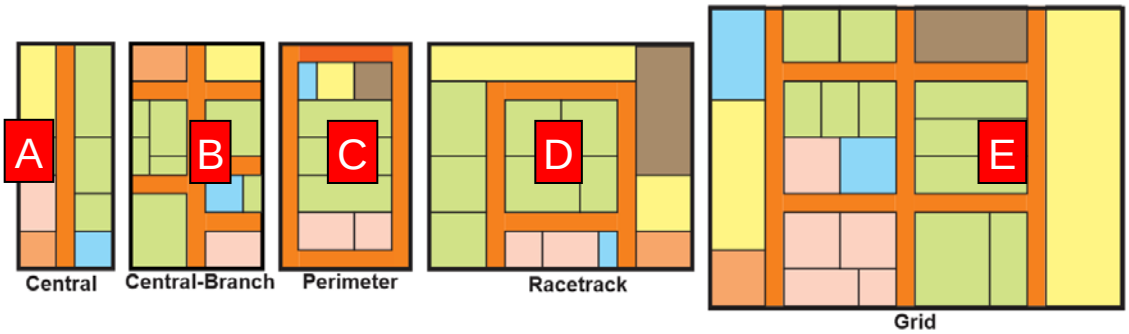
A rationalized aisle system is essential for the movement of people and product. It improves flexibility for the inevitable future changes and rearrangements. It improves communication by making the process and people visible and clear. Aisle system design is inherent to and concurrent with the design of a macro layout. This concurrency adds additional complexity and "black magic" to an already "creative" process. The procedure of section 5 can assist with this design task.

Almost all attempts to rationalize, systematize or computerize space planning are variations of Muther's Systematic Layout Planning (SLP)[4] procedure. The particular step in SLP that has been most resistant to further efforts is the generation of a macro (block) layout based on the layout primitive (space-relationship diagram) and constraints (modifying factors). There is little guidance in SLP or its variants on how to do this. Most attempts to computerize this step produce crude outputs that require considerable manual manipulation and the author is unaware of any that can adequately place and size aisles.

2. Aisle System Concepts

In many facilities there is little order or pattern to the aisle system. Indeed, the aisle layout would suggest a bovine origin rather than an engineered design. Figure 1 offers five conceptual designs for aisle systems. One, another or a combination will usually fit most spaceplans.

Figure 1 Aisle System Concepts



Central aisle systems work well with long narrow buildings. These are often seen in mill-type buildings with overhead cranes. When the building has a bit more width, aisles may branch out from the central aisle as in Figure 1B. The C***entral-Branch*** concept is often seen in warehousing. ***Perimeter*** aisles (Figure 1C) waste space, as noted previously. However a perimeter system may be appropriate where there are long processing lines such as with bolt-makers, assembly lines and bottling lines.

Racetrack systems work well in medium-size buildings as in Figure 1D. They are probably the most versatile of aisle configurations. Large and, especially very large factories will generally use a grid system similar to Figure 1E. Very large facilities might also use different configurations in different parts of the plant.

3. Guidelines for Aisles

Below are several general guidelines for aisles. These are not absolute rules and they are often compromised by other factors. Moreover, while such guidelines are helpful they give no insight for a design procedure or the mental processes required.

3.1 General

- Every SPU (Space Planning Unit, Activity Area, department) should be adjacent on at least one side to a main aisle.
- Aisles adjacent to building walls waste space because they serve SPUs on only one of their sides.
- Perimeter aisles provide flexibility and good traffic flow similar to perimeter highways around a city. However, they waste space since an aisle against a wall requires the same width as an aisle between SPUs but only serves SPUs on one of its two sides.
- Racetrack or Semi-perimeter aisles have the advantages of perimeter aisles but use space more efficiently.
- Aisles should be as straight as practical with the fewest turns and intersections.
- Avoid placing columns within an aisle, particularly if there is heavy equipment traffic such as fork trucks.
- Aisles adjacent to columns are desirable since they minimize the number of columns within an SPU. This offers greater flexibility for layout within the SPU.
- Dead-end aisles are suitable only for occasional traffic and unsuitable for trailers.
- One-Way aisles are narrower than two-way aisles but should be spaced close enough to avoid long detours.
- Chamfered aisles at intersections make turning easier, increase visibility and may allow smaller aisle width.

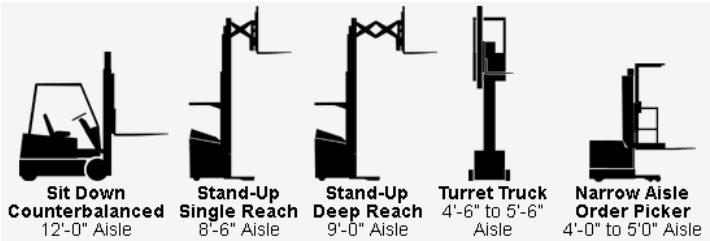
3.2 Space

- Main aisles for manufacturing *usually* occupy 20%-35% of total space but this is highly variable.
- In a warehouse the size and space for aisles is even more variable than for manufacturing. It depends mostly on the storage and handling equipment.
- Functional layouts are likely to require more internal aisle space then cellular layouts.

3.3 Aisle Width

- Industrial material handling aisles should be at least 4 feet wide and at least 3 feet wider than the largest equipment that has to pass through them.
- One-way transit-only aisles should be *at least* one foot wider than the widest ***load*** and two-way aisles should be three feet wider than the widest normal combined passing loads. These are minimums for occasional traffic and short distances only.
- Aisles accessing storage locations may need additional width for fork truck maneuvering.
- In the absence of load and equipment information, Figure 2 is a general guide for forklift aisles.
- Pedestrian-only aisles should be at least 28” wide for occasional traffic. For heavier traffic, 4-6 feet is preferred. Refer to local building code for evacuation requirements.

Figure 2 Fork Truck Aisle Widths



4. Elements of a Spaceplan (Layout)

Since Muther's [4] original publication of Systematic Layout Planning (SLP) in 1973, the concepts of SLP have dominated the facilities planning literature although terminology and methodological details may change. Figure 3, adapted from Lee [3] illustrate the most important concepts for our discussion here.

Almost all attempts to rationalize, systematize or computerize space planning are variations of Muther's Systematic Layout Planning (SLP)[4] procedure. The particular step of this procedure that has been most resistant to further efforts is the generation of a macro (block) layout based on the layout primitive (space-relationship diagram) and constraints (modifying factors). Inherent to and concurrent with the design of a macro layout is the design of an aisle system for material and personnel traffic. This concurrent design adds additional complexity and "black magic" to what is already a "creative" process.

When designing the Macro spaceplan, allocate space for main aisles only. This space has no affinities attached. Allocate the space for departmental aisles that serve traffic within an SPU to each SPU. These aisles will be defined in the Micro stage.

Figure 3 Fundamental Elements of a Spaceplan

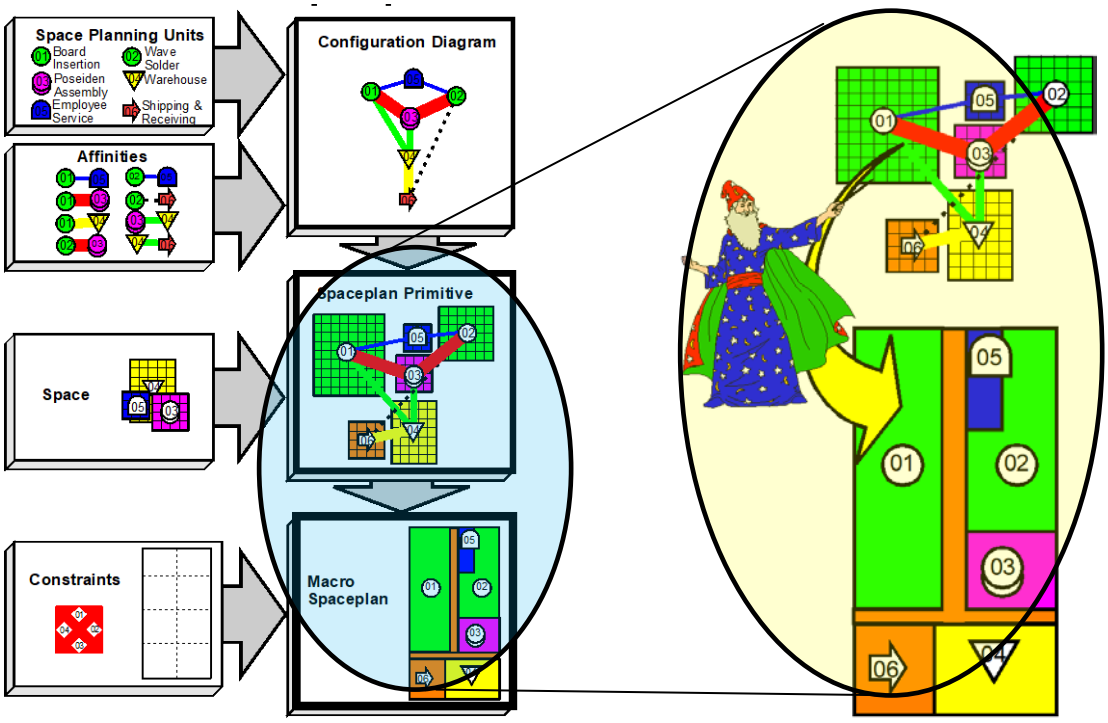


Figure 3 illustrates how Space Planning Units (SPUs), the blocks or departments, combine with Affinities (need for proximity) to form a configuration diagram. Then, space is added and distorts the configuration diagram into a spaceplan primitive, a sort of idealized layout. Finally, constraints (factors that limit aspects of the design) are applied and result in an actual, viable facility spaceplan.

It is this last step, the transition from primitive to layout where the main aisles for transport and communication enter the design. This is also the step where magic is invoked; where human creativity and experience are necessary; where algorithms and computation are inadequate. Those of us who write about spaceplanning procedures usually dance around this step with phrases such as "apply constraints" (my term) or "modifying considerations" (Muther's term). Competence with this step seems to come primarily from experience combined with trial-&-error and the less experience the more trial-&-error.

5. Macro Spaceplan/Aisle Design Procedure

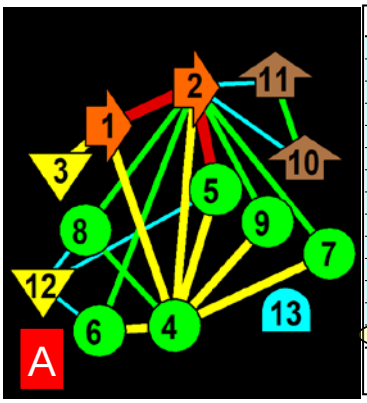
With all this in mind, the author suggests the following as an initial approach to aisle and macro spaceplan design:

1. Draw scaled blocks for each SPU that are initially square and superimpose them on the affinity diagram to create a “spaceplan primitive” aka space-relationship diagram (Figure 4).
2. If necessary, rearrange the primitive to reflect the fixed locations relative to other SPU blocks (Figure 5A)
3. Draw in any fixed SPUs maintaining the approximate space but varying the heights, widths and shapes to accommodate the building. (Figure 5B)
4. Visual a possible aisle system, keeping in mind the previous guidelines (Figure 6A).
5. Adjust dimensions of the SPU blocks to match building walls and aisle boundaries, maintaining the original square footage within +/- 10% or so.
6. Place interior SPU blocks and adjust these dimensions.
7. Place remaining aisles and then adjust both aisles and SPU blocks.

6. An Example

The following figures show how this usually works. This plant produces a wide variety of hardware items with stamping and assembly as the primary processes. Figure 4A is the affinity diagram. It has been adjusted somewhat to fit the shape and fixed features of the building. Figure 4B is the space estimate. Note the 25% allowance for main aisles. Figure 4C combines affinities with space for a spaceplan primitive, aka space-relationship diagram. Notice how the addition of space distorts the affinity diagram.

Figure 4 An Example of Affinities, Space & the Primitive



ID	SPU Name	Space (sf)
1	Load Docks	200
2	Ship & Receive	700
3	Pallet Storage	2,000
4	Flat Handle & Blanking	800
5	Corner & Clamp	250
6	Claw Bolt	325
7	Post Handle	225
8	Catch/Sq Lock	250
9	Sewn Handles	820
10	Main Office	1,250
11	Plant Office	200
12	Die Storage	250
13	Utilities	125
	Main Aisles (25%)	1,850
	Totals	9,245
	Available:	9,700

B

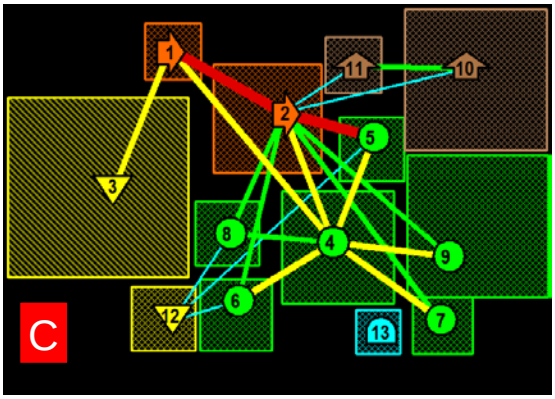


Figure 5A superimposes the primitive on the building drawing and further adjusts the primitive to reflect fixed locations. Figure 5B defines the exact location of three fixed SPUs. SPU#1 includes the truck docs and a staging area. SPU#13 are the building’s main utility panels and air compressor. SPU#10 is the main office area. All three are determined by the design of the existing building.

From an examination of Figure 5B, we attempt to visualize the aisle system. SPUs 2 &4 will be at the center of the spaceplan. They also have the heaviest traffic and the largest number of affinities with other SPUs. A racetrack aisle surrounding SPUs 2 &4 looks very promising but it may require a few branch aisles. Figure 6A shows what such a system might look like and Figure 6B begins the development of a spaceplan based on that aisle system.

In Figure 6B we have located the main office (SPU#10) in the existing office space. This was an initial design constraint based on the management decision not to spend funds on relocating it. SPU#11 is the plant manager’s office and it is located in an existing space. It might be relocated but the existing space was central and would serve the purpose reasonably well.

The next space to be defined was SPU#3. This is storage space for another enterprise belonging to the owners. It will be long-term, simple floor storage of pallets. Its only affinity is to the loading dock. The left wall of the building becomes the left boundary for this space and the right-hand boundary is set by the square footage.

The initial concept for a racetrack aisle would place the left-hand aisle against the right-hand boundary for SPU#3 as shown. In Figure 6B we made the aisle eight feet wide because the company had only a single walkie fork truck and nearly all such fork truck traffic would occur along this aisle. This also determines the right boundary for this aisle.

Figure 5 Superimpose on Building & Locate Fixed SPUs

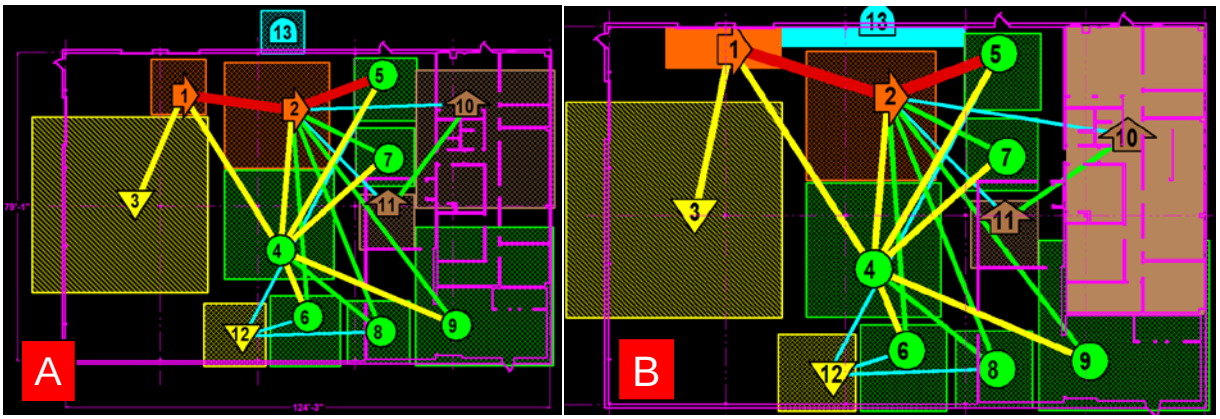
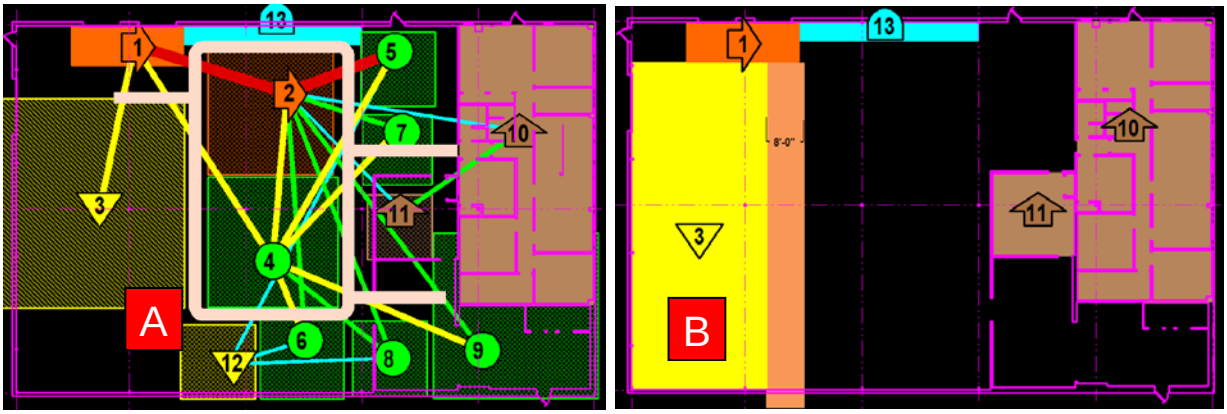


Figure 6 Visualize Aisle System & Locate Perimeter SPUs



Next, Figure 7A shows how several additional SPUs would fit. This leaves SPUs #12, #6 and #8. At this point, there is insufficient space at the bottom for all three SPUs. The space for pallet storage, SPU#3, is somewhat flexible. This space was reduced slightly, which moves the left aisle several feet to the left. The width of SPU#2 and #4 increases and the height shortens. This moves the lower aisle up and frees enough space for SPUs #12, #6 and #8. Several other minor adjustments were made that result in the spaceplan of Figure 7B. Figure 8 is the final micro (detailed) layout for this factory with the aisle system highlighted.

Figure 7 Locate Additional SPUs & Finalize Macro Layout

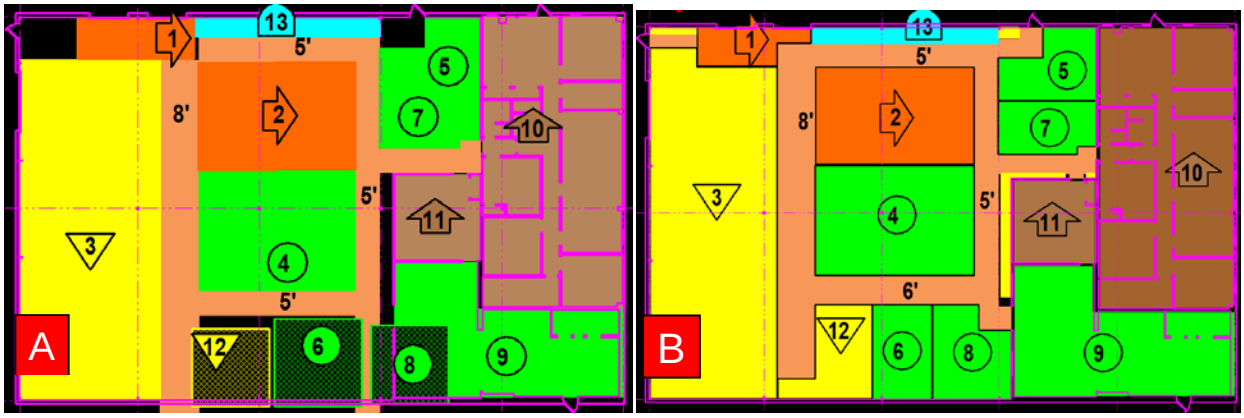
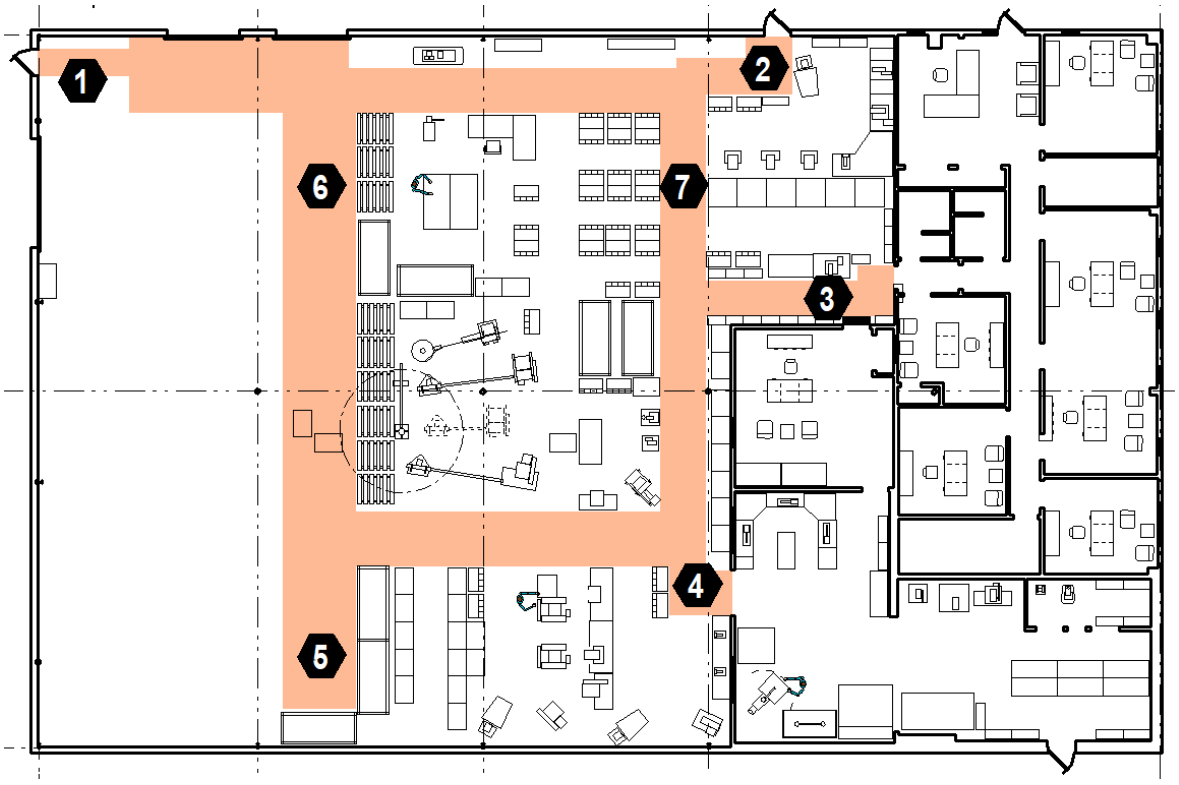


Figure 8 Final Detail Layout



Aisle design seems to be a mostly an exercise in compromise and few designs meet all the guidelines enumerated earlier. This particular spaceplan is no exception. The number flags on Figure 8 explain some of these compromises:

(1) This narrow aisle is for emergency evacuation only.

(2, 3) Pedestrian aisle only. Not worth relocating a door to keep this aisle straight.

(4) Not worth relocating a door to keep this aisle straight.

(5) This is a dead-end aisle but it is rarely used since SPU#12 is for long-term die storage.

(6) This main aisle is only eight feet wide but that is sufficient for the single walkie fork truck that is utilized.

(7) This aisle is only 5' wide because handling is with tote boxes on a stock cart.

7. Summary

This paper attempts to bring a degree of rationality and procedure to the subject of aisle and macro-layout design. However, it remains a somewhat messy business, highly dependent on experience and individual insight. There may be situations where the logic presented is inadequate or does not apply but from the author's experience of 40+ years designing layouts, this is a good way to start.

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