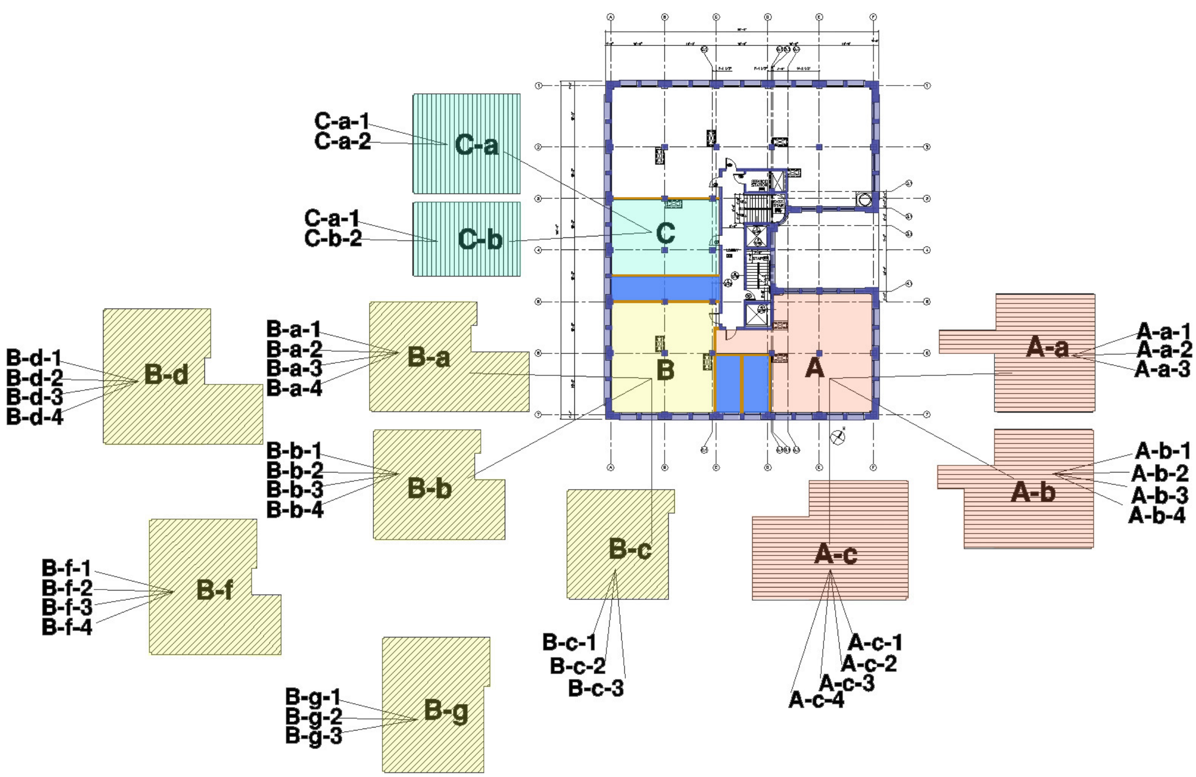
CAPACITY ANALYSIS

A STEP-BY-STEP METHOD TO LOCATE MEP STACKS FOR OPTIMUM DWELLING UNIT VARIETY IN AN APARTMENT BUILDING

Stephen Kendall



Introduction

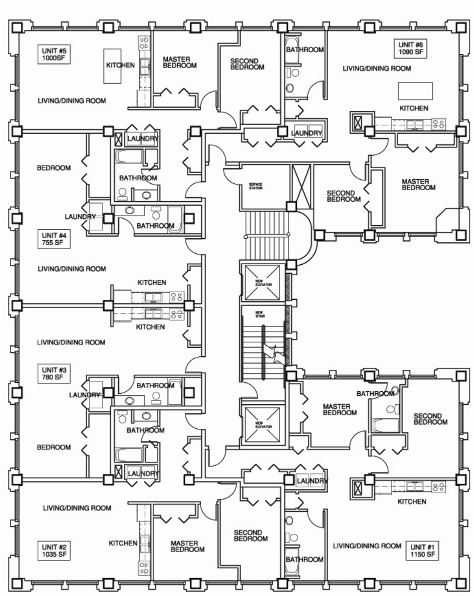
Open building requires careful positioning of the vertical mechanical, electrical and plumbing "stacks" of the base building, to enable variable unit size and layouts on a given floor plate of a multi-story building. Usually, the process is reversed. In conventional practice, the floor plans are decided first. A developer makes certain assumptions about the number of unit types and floor plans, and asks the architect to design the building accordingly. An example is shown here. The floor plan on the right is a conventional design. It results in floor penetrations (shown in red) as the left diagram shows – floor penetrations that correspond to the specific units and layouts as shown. In conventional designs, the relationship between the floor plan and the "base building" is "one to one". Variations in unit sizes and layouts - and decision flexibility for the investor - either during the design phase or during the life of the real estate asset, are poor.

Conventional multi-floor condominium building with multiple, randomly placed floor penetrations (in **RED** on the left diagram) fixed per floor plan (shown in the right diagram)

Capacity Analysis
To demonstrate how an open building process corrects this problem, I use a building – a 20-story office building planned for conversion to residential occupancy – in which to show how a base building can be prepared for variable fit-out. The method is called **capacity analysis**. The same method is useful in new building design.

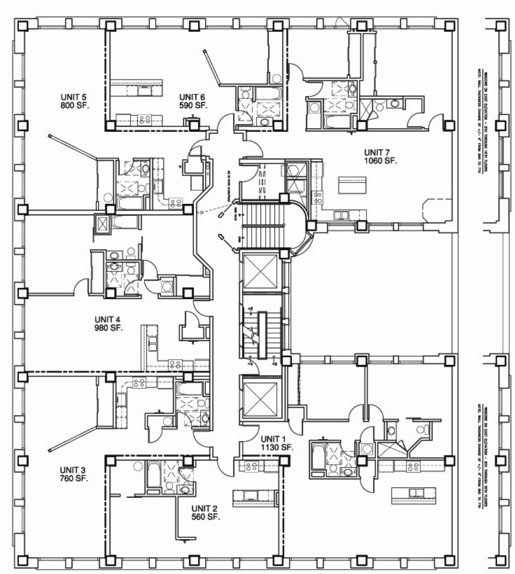
CAPACITY ANALYSIS is a method for evaluating a base building design for variable fit-out. It involves a trial and error, step-by-step process. First, I fix base building elements, and then assess what variable fit-out decisions are enabled. If the result is not suitable, I adjust the base building elements and again evaluate the capacity of the base building to accommodate variable fit-out decisions. This process is repeated until all parties involved agree that the base building has “good” or “sufficient” capacity. The criteria for evaluation used by the different parties can differ. Once agreement is reached, the base building can be constructed.

The 20-story existing office building being prepared for residential occupancy was in fact planned using conventional decision-making processes. The developer’s initial market analysis led to a decision to have six units per floor, of almost equal size. The architect designed the building accordingly and the mechanical engineer designed the piping system to match the floor plans. Cost estimates were obtained, and financing sought. After some months, the developer decided that seven units per floor made more sense with two of them being quite small. The architect redesigned the building accordingly and the mechanical engineer re-engineered the MEP systems. This happened one more time before the drawings were given to the contractor. The two drawings show two of the three layouts mentioned.



KALES- SIX UNIT FLOOR PLAN

UNIT	BR	BA	SF.
UNIT #1	2	2	1150
UNIT #2	2	2	1035
UNIT #3	1	1	780
UNIT #4	1	1	755
UNIT #5	2	1	1000
UNIT #6	2	1	1090



KALES - TYPICAL FLOOR PLAN (3-18)

UNIT	BR	BA	SF.
UNIT #1	2	2	1130
UNIT #2	1	1	560
UNIT #3	1	1	760
UNIT #4	2	2	980
UNIT #5	1	1	800
UNIT #6	1	1	590
UNIT #7	2	2	1060

Exploring Constraints

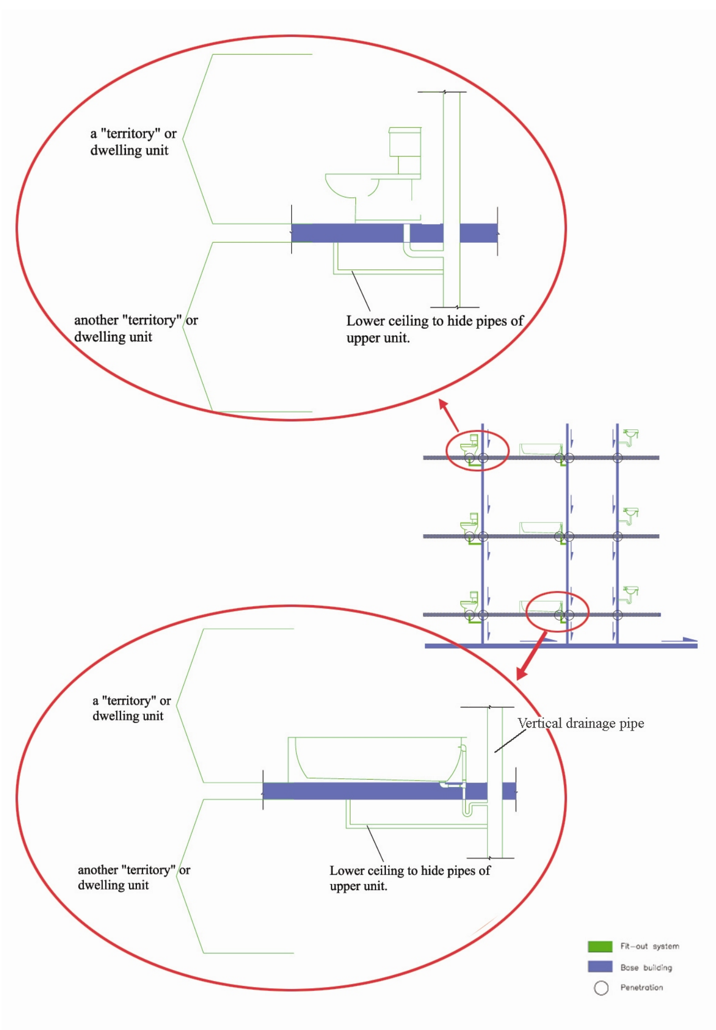
Capacity analysis is essentially an exploration of constraints – both explicit and implicit.

"Firstly, there are always, in a design situation, a large number of implicit constraints that are so obvious to us that we do not bother to formulate them. No one would propose to place the bed in front of the door. This indicates that we always operate in an implicit solution space that is already much smaller than the one bounded by the explicit constraints…

Secondly, the forms subsequently generated will reveal, to those involved in the design process, additional constraints that must be made explicit. Constraints can only come from the consideration of possible – desirable or undesirable – alternatives. Without such alternatives there is nothing to approve of or to reject, and we cannot learn about our values and preferences. (Habraken, 1988)

Control of Territory

The first and probably most important constraint in an open building design process has to do with control of territory. The goal is autonomy of the individual dwelling unit. That means that decisions concerning a dwelling unit should not intrude upon decisions concerning another dwelling unit. Once a dwelling unit's position and size in the base building are determined (and demising or separating walls constructed), all decisions about the dwelling unit should be free of decisions by or about other units of occupancy.



The most important of these constraints concerns drainage piping. In conventional buildings, the drainage piping serving one unit's sanitary fixtures enter the territorial space of the dwelling unit below before joining the common (base building) vertical drain stack. This is a basic violation of the principle of the autonomy of the dwelling unit. The diagrams explain the problem.

This entanglement between piping and the building construction causes trouble in at least four ways - from pre-construction to post-construction use.

First of all, for architects, this entanglement causes multiple redesigns before construction begins and the likelihood of change orders later. The problem is that layout decisions are interdependent among floors. Once a floor layout is determined (or changed) especially in regard to drainage plumbing, the other floor layouts have to correspond. Without confirming the architectural plan, other consultants such as mechanical and electrical design and even structural engineering cannot work efficiently.

Secondly, these plumbing entanglement problems produce high-rise residential building designs that can offer only a very few unit plans or mix variations from floor to floor. When a high-rise residential building is built, occupants must adjust their preferences, lifestyles and budgets to the same "uniform" units. Therefore, conventional high rise residential buildings cannot offer variation corresponding to real variation in the market population, without excessive costs. Of course developers can produce highly varied floor plans but they inevitably cost more and it is never certain that the extra costs can be passed to the renters or buyers who were not consulted.

Thirdly, the entanglement of pipes causes boundary conflicts and even legal disputes between dwelling units. For example, when a toilet pipe of the upper floor is leaking, it causes inconvenience for the lower floor unit and violates the principle of territorial autonomy. Individual fixture penetrations of the floor plate can increase the potential of leaks. In the US, condominiums are well known to be the most legally troubled building type, due in part to this problem. (Butt, Thomas "The Condo Conundrum" The Construction Specifier, May 1993, pp. 132-141; http://community.lawyers.com/forums/t/118234.aspx (from 2012), etc.)

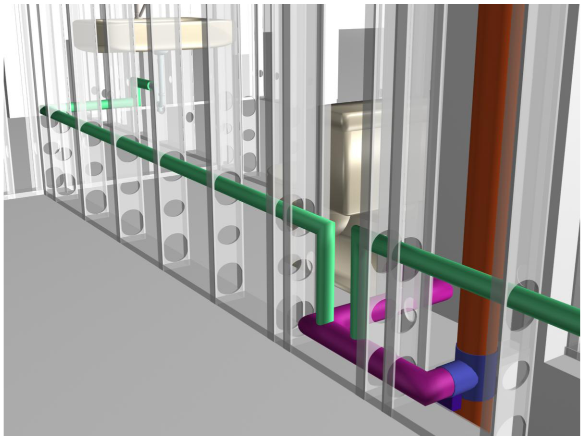
Last but not least, these entanglements cause difficulties for future adaptations, often needed to maintain a real property asset with continuing positive return-on-investment. Once a conventional building is built, it is almost impossible to have a bathroom or kitchen on one floor move to another location or even be enlarged in the same location with additional or upgraded fixtures and layouts. There are two reasons contributing to this impossibility. Firstly, drainage pipes are fixed into sleeves in the floors (concrete slabs or wood – framed floors are the same in this regard), and the vertical pipe shaft must remain in a fixed position because it is not only draining one floor but also the upper and lower floors; secondly, there are no vertical plumbing pipes that can carry waste water from sanitary fixtures in the new locations. Adding a penetration would affect all the units above and below the unit in question.

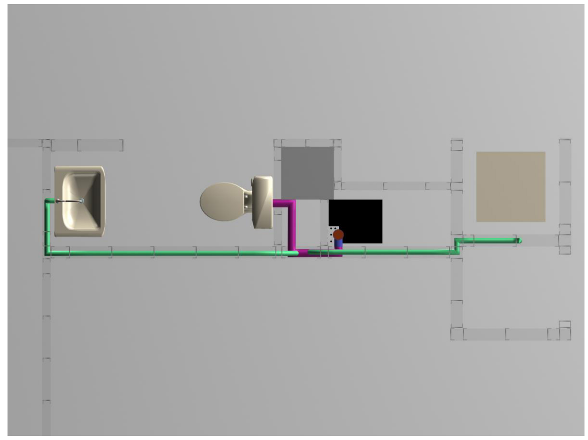
Criteria or Assumptions

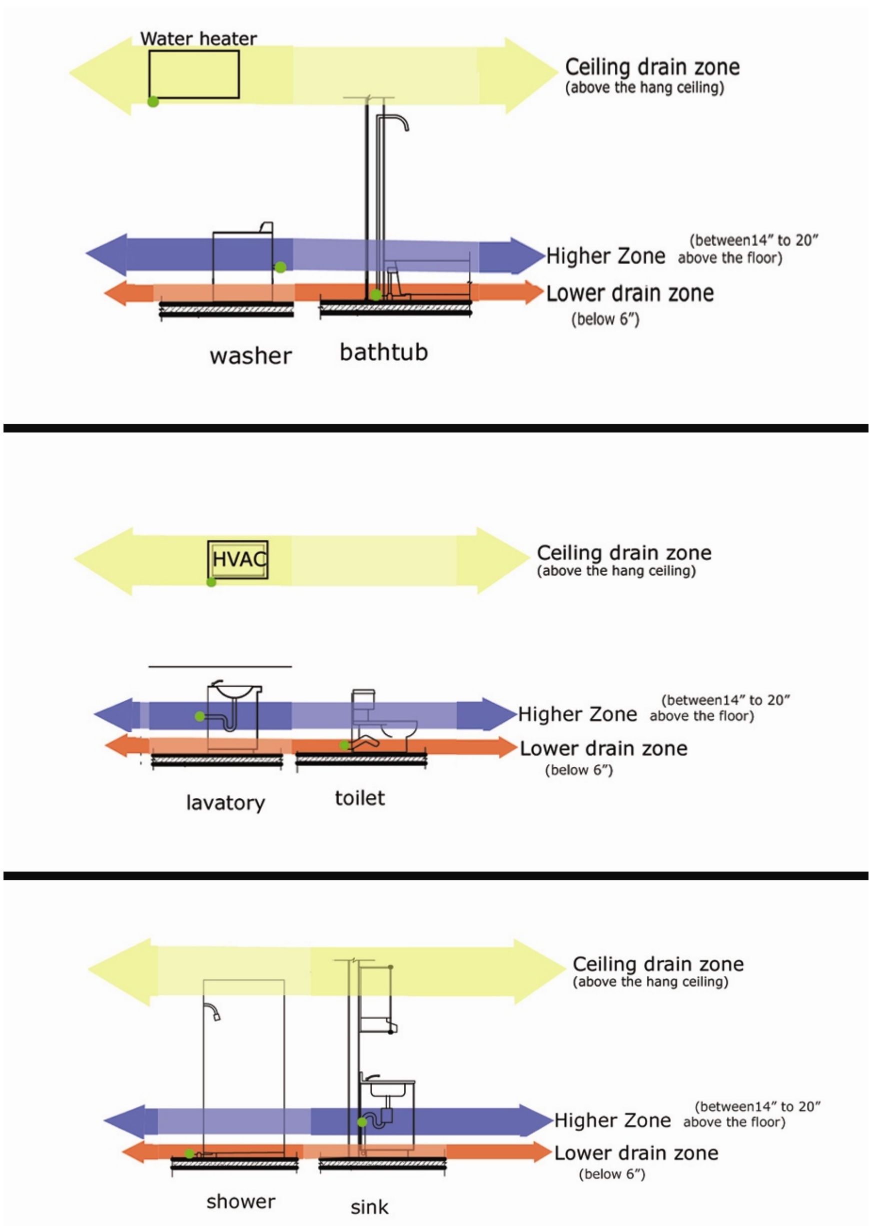
In the study using the conversion of an existing building to residential occupancy, we used a number of criteria, the first one being to avoid using a "raised floor" for horizontal pipe routing. In addition, we assumed:

1. Horizontal drainage pipes slope @ 1/8" per foot. (Standard US code requirement)
2. All sanitary fixtures are above floor rough-in (rear outlet).
3. All horizontal drainage pipes go into fit-out partition walls.
4. All waste water discharges into vertical MEP stacks inside the territorial unit
5. There are no other penetrations except MEP stack openings.
6. The use of code-approved "air-admittance valves" is assumed for all plumbing fixtures (except toilets)

Three horizontal "zones" are used for managing the "traffic" of the fit-out pipes and ducts serving an individual dwelling unit, as the diagrams below show.



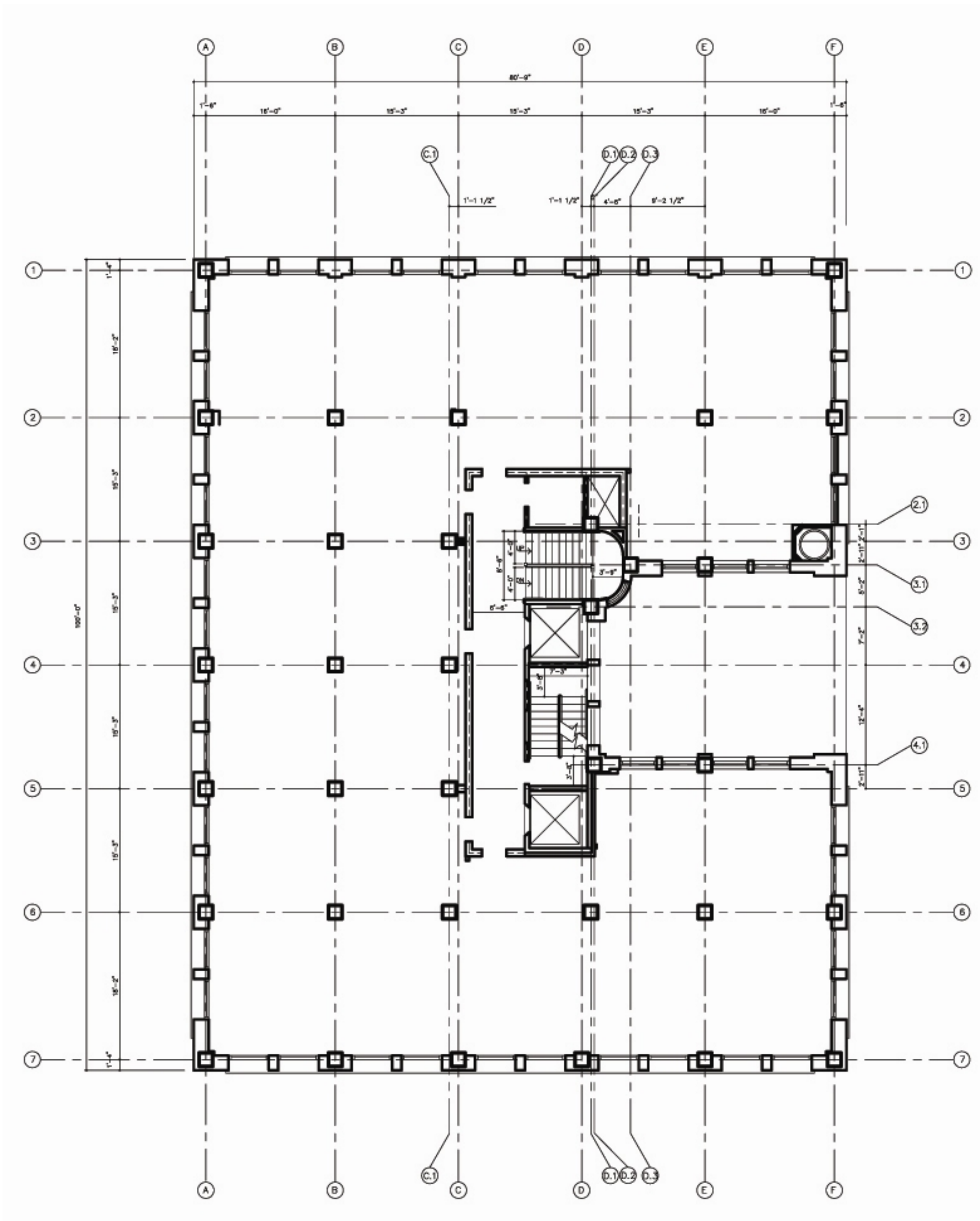


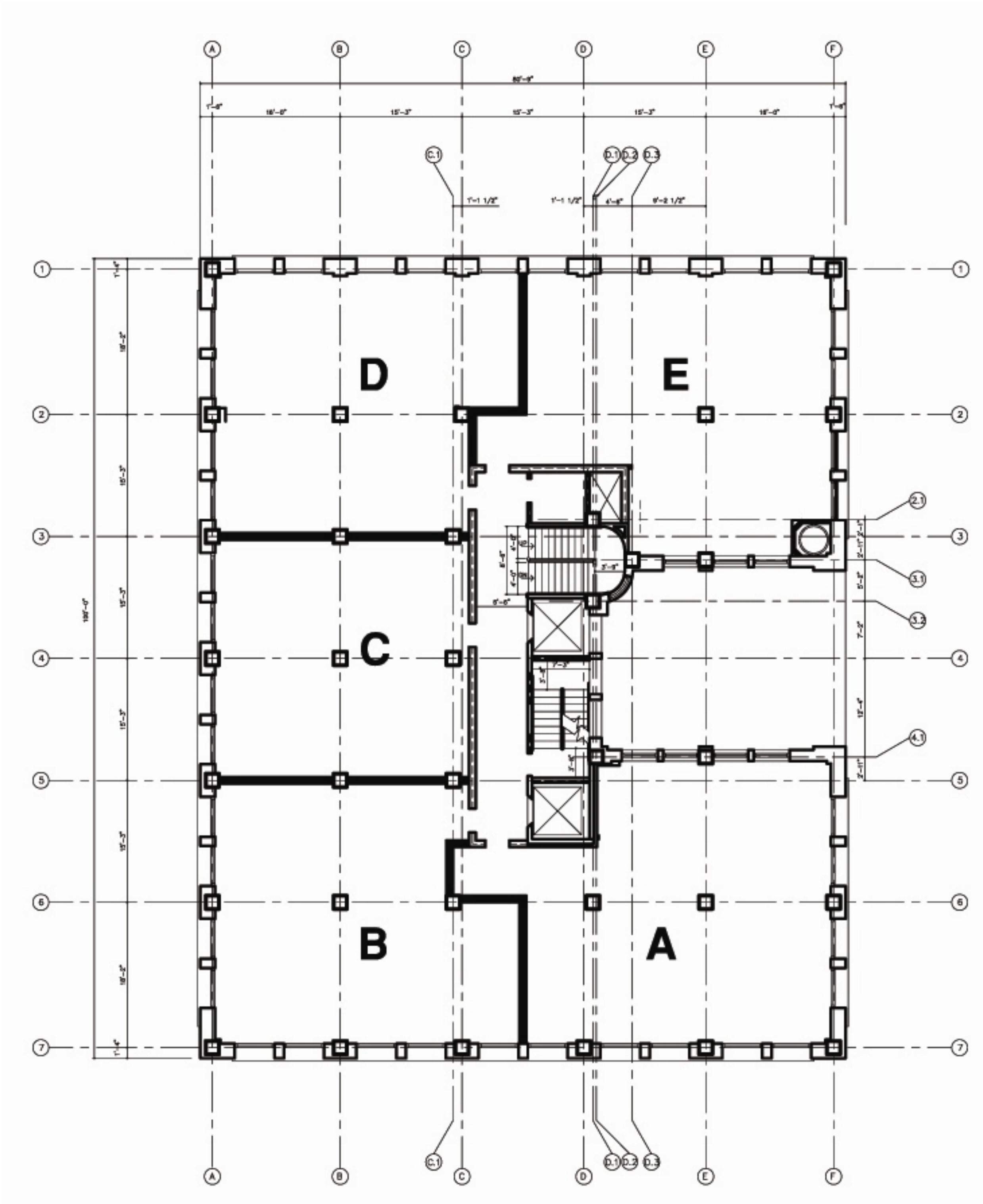


In these diagrams, standard openings in studs are created. Green pipes represent 1 1/2" or 2" diameter drainage pipes serving fixtures in the "high zone". They run through the higher opening. Purple pipes represent 3" diameter drainage pipes serving toilets and accepting waste from green pipes. Dark brown pipes are vertical drainage pipes that belong to the Base Building, gathering waste from each dwelling unit and transporting the waste to the city drainage system.

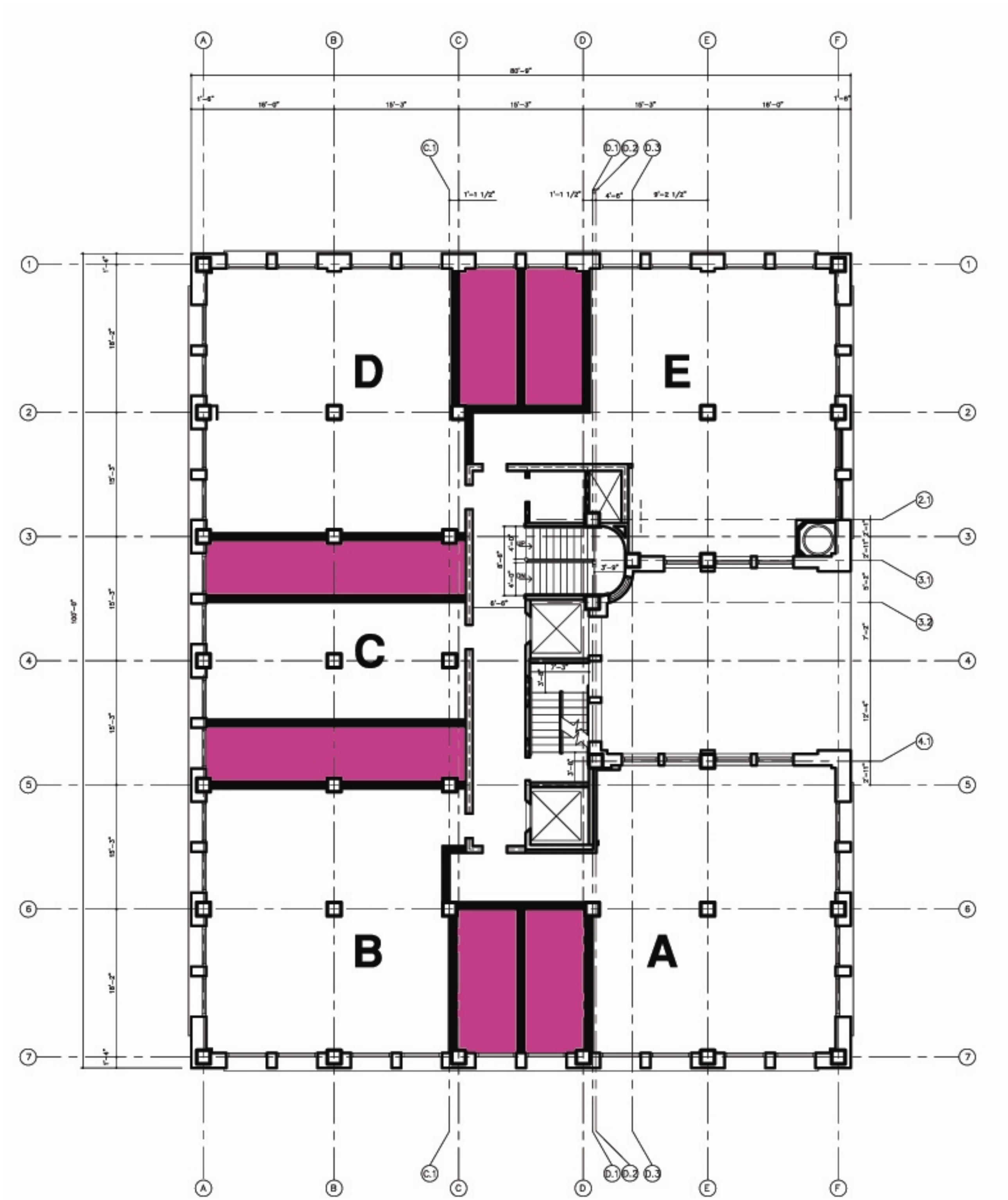
Establishing the Base Building elements

The diagram below shows the building with all non-structural interior walls removed. What remains are the building shell, the structure, the main public circulation (corridors + elevators + fire stairs) and the main vertical MEP shafts.

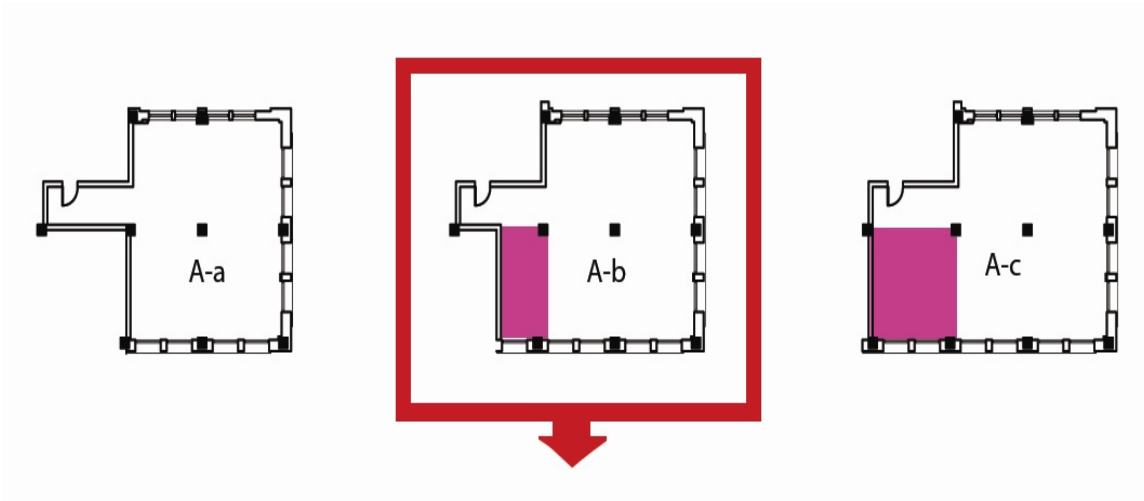




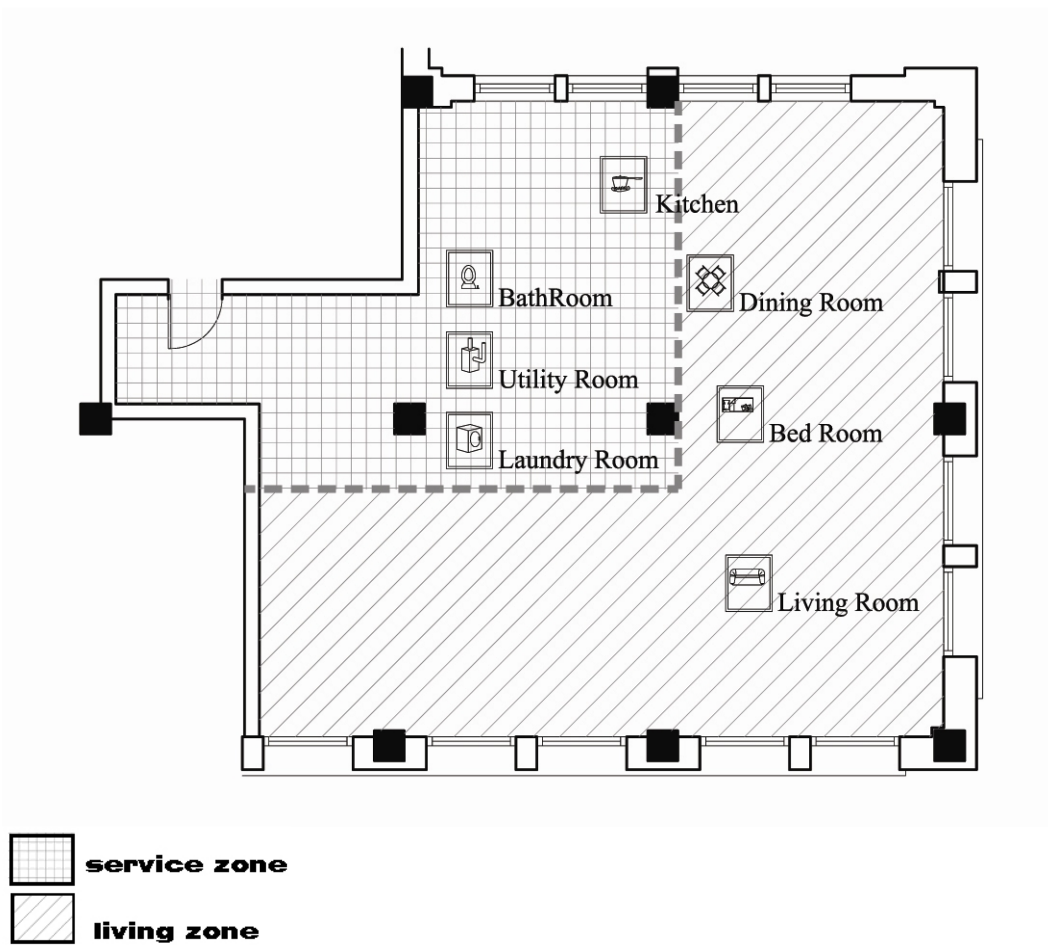
Five basic units are defined as a "hypothesis" with demising walls separating them, as the first step in capacity analysis.



“Margins” are established between units, enabling unit size variation.



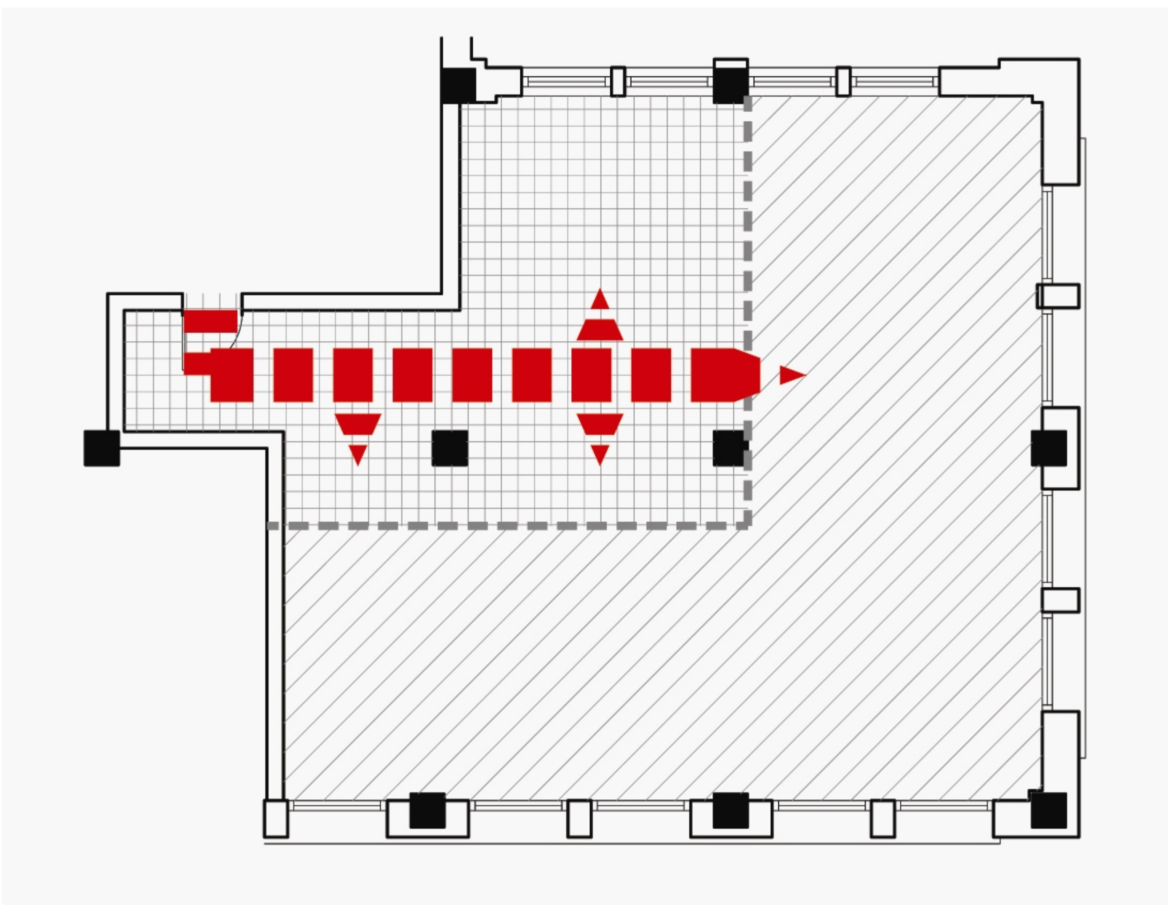
One unit is selected for more detailed study of capacity.



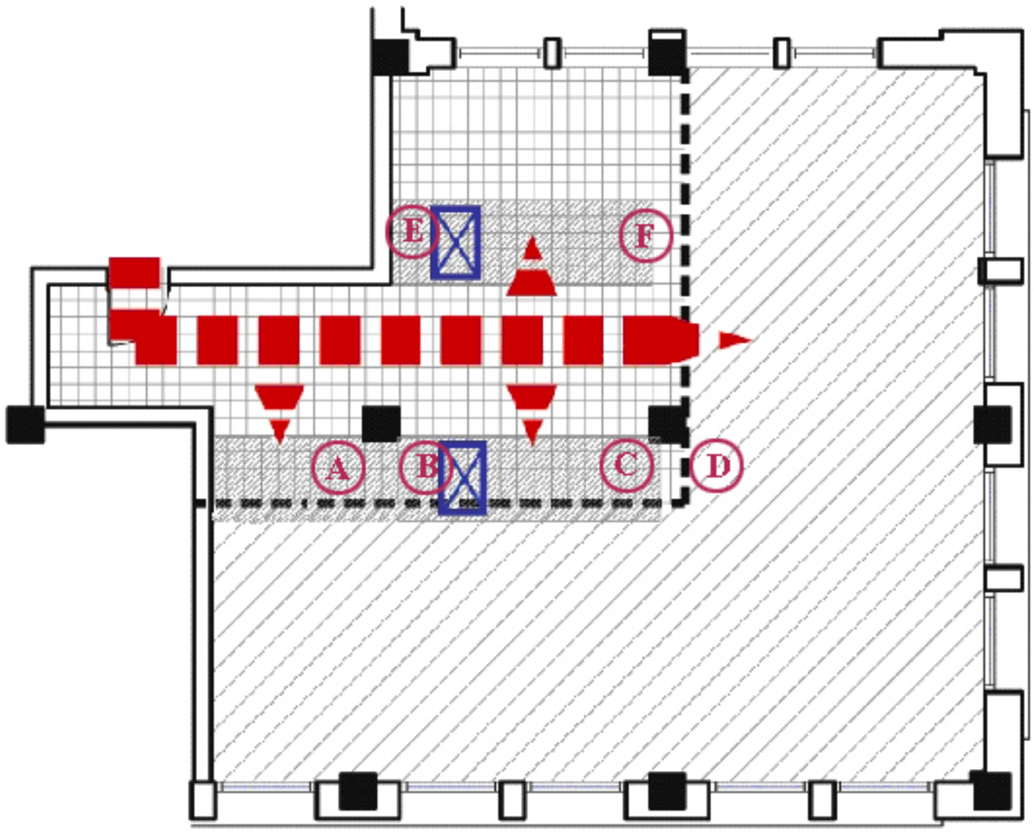
This diagram describes the basic zoning of functions in the selected unit, showing generally where these functions can be optimally positioned.

Rooms needing to be directly next to an MEP stack	Rooms needing to have a continuous wall without door opening connecting to the MEP stack	Rooms with no need to connect to an MEP stack
BathRoom Master Bed Room	Laundry Room Utility Room Kitchen	Living Room Bed Room Storage

Classification of functional areas vis-à-vis their position relative to yet-to-be-determined MEP stacks.



Circulation flow within the unit to each functional area



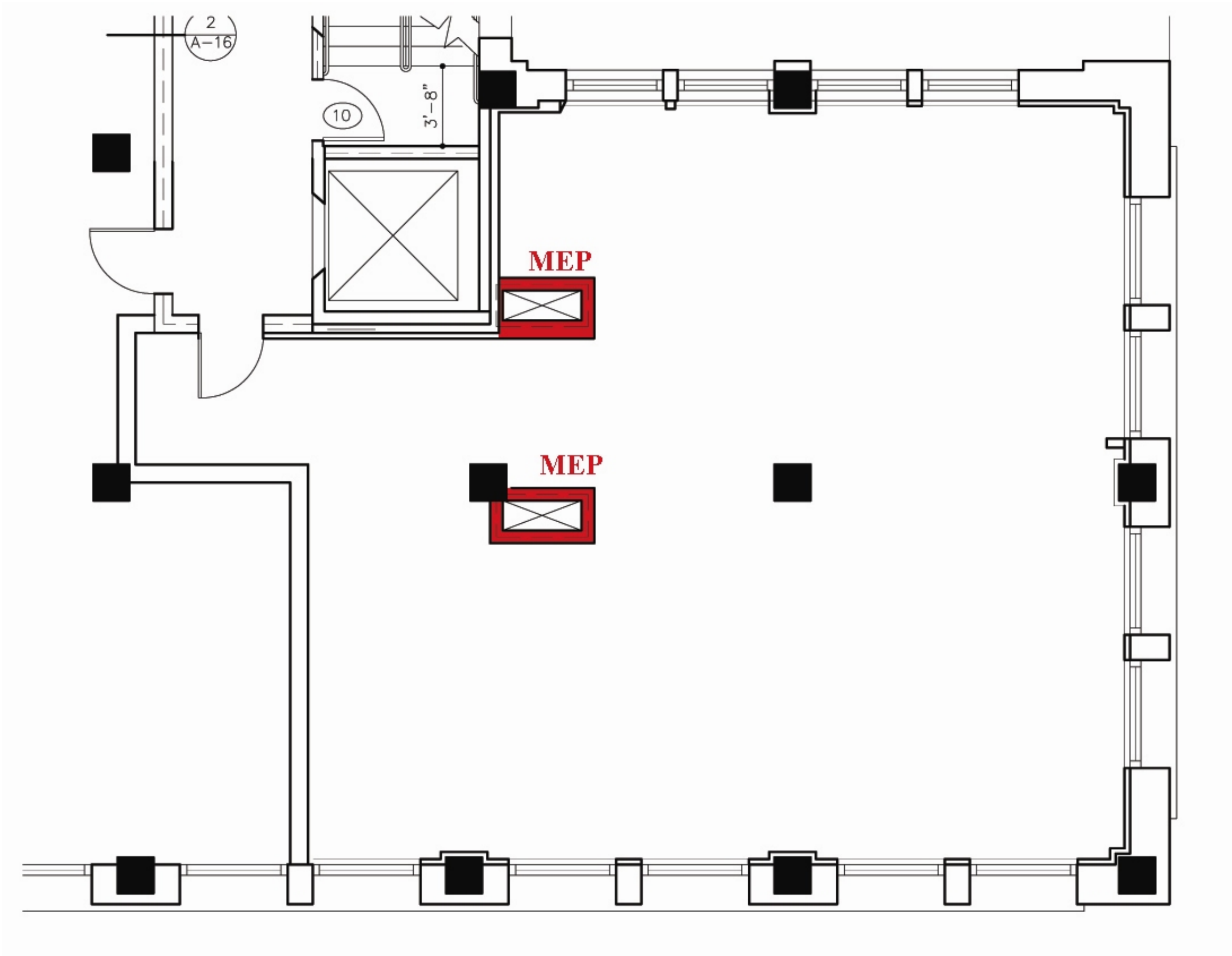
 Suitable zone for MEP stacks

 Circulation flow

Suitable zones for MEP stacks with possible placements (A-F)

Elimination of unsuitable MEP placement

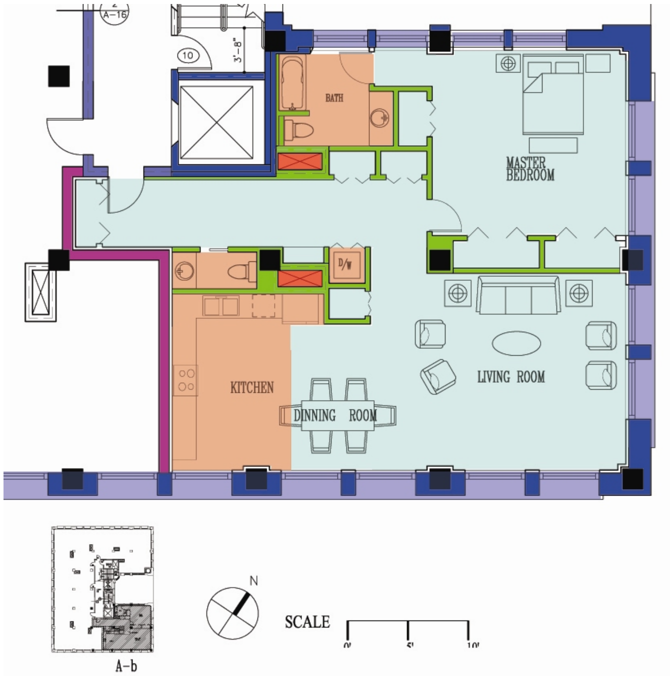
Optimal MEP stack locations can be selected by eliminating certain options based on a kind of "dialogue" as follows. "A" can be eliminated because it narrows the space of potential circulation into the functional area. When locating MEP stacks, it is recommended to "think" or foresee potential rooms around the MEP stack. In principle, an MEP stack should be surrounded by functional areas needing direct or close connection to an MEP stack - either directly, or via uninterrupted walls. "C" and "D" can be eliminated because they are located on the "right" side of the service zone, making them too far away from the left side of the service zone. Similar to the situation of "C" and "D", "F" can be eliminated. Therefore "B" and "E" are defined as most suitable to develop unit variations.

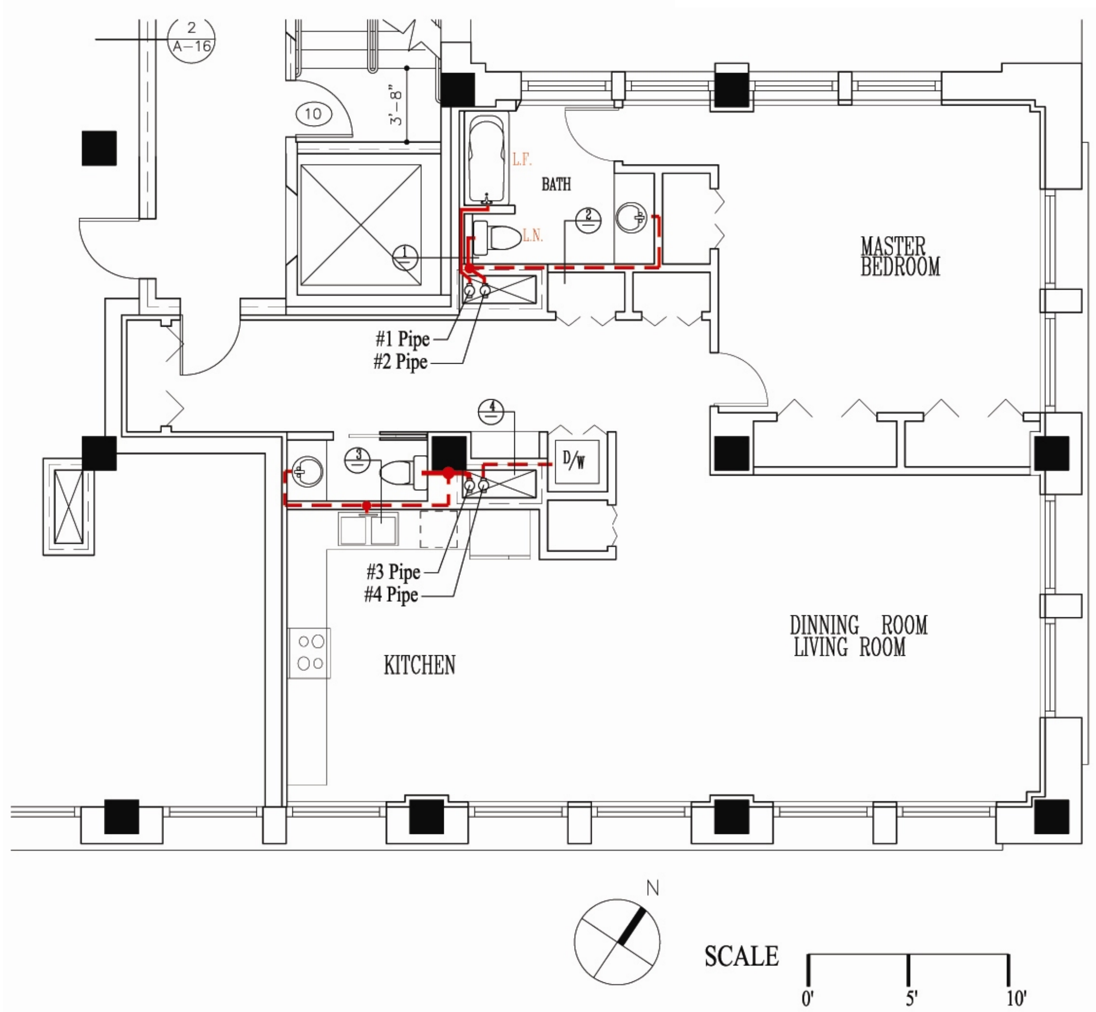


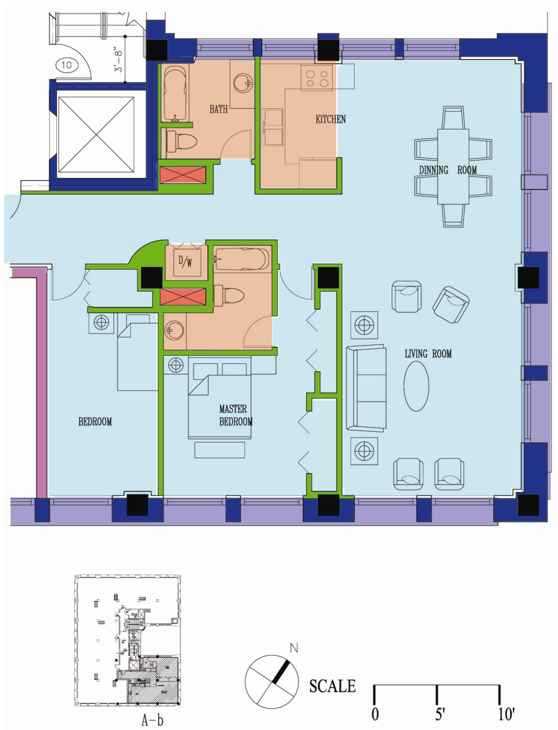
Two MEP stacks are recommended, based on the capacity analysis and are shown above.

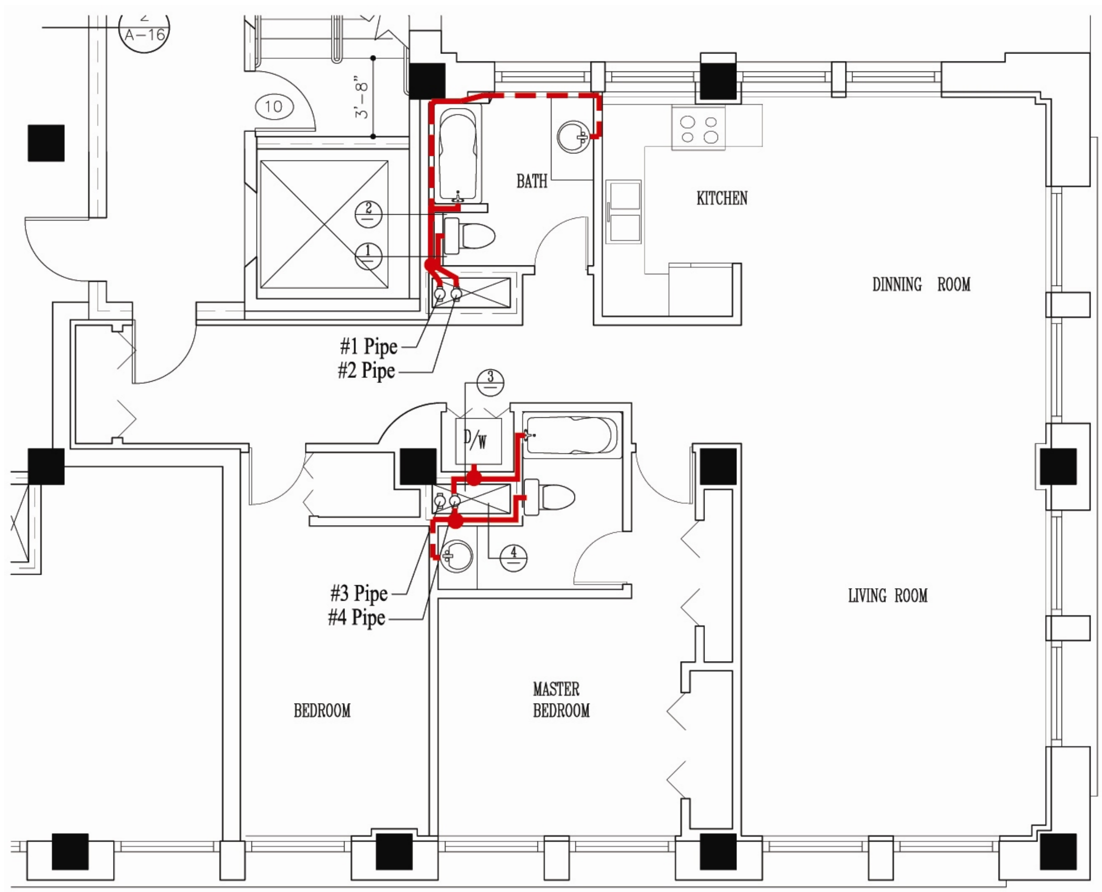
Note that the walls surrounding the proposed MEP stacks are RED, indicating that they are not Base Building elements (shown in BLACK), and are installed as part of the FIT-OUT contract. This means that the floor penetrations are fire-stopped.

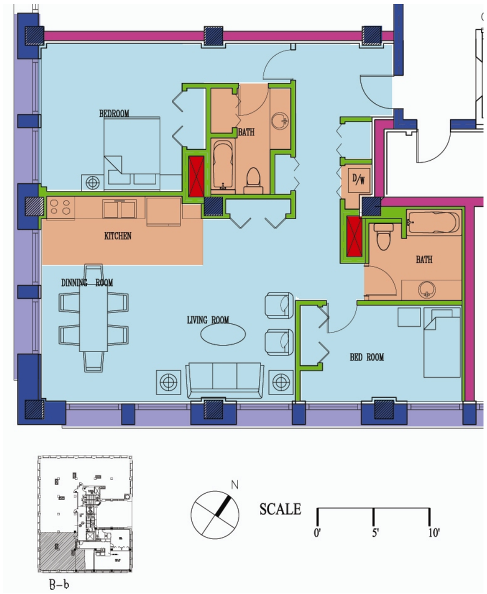
In the following pages, several dwelling units are shown with their floor plans along with a detail diagram showing the position of piping in each of them.

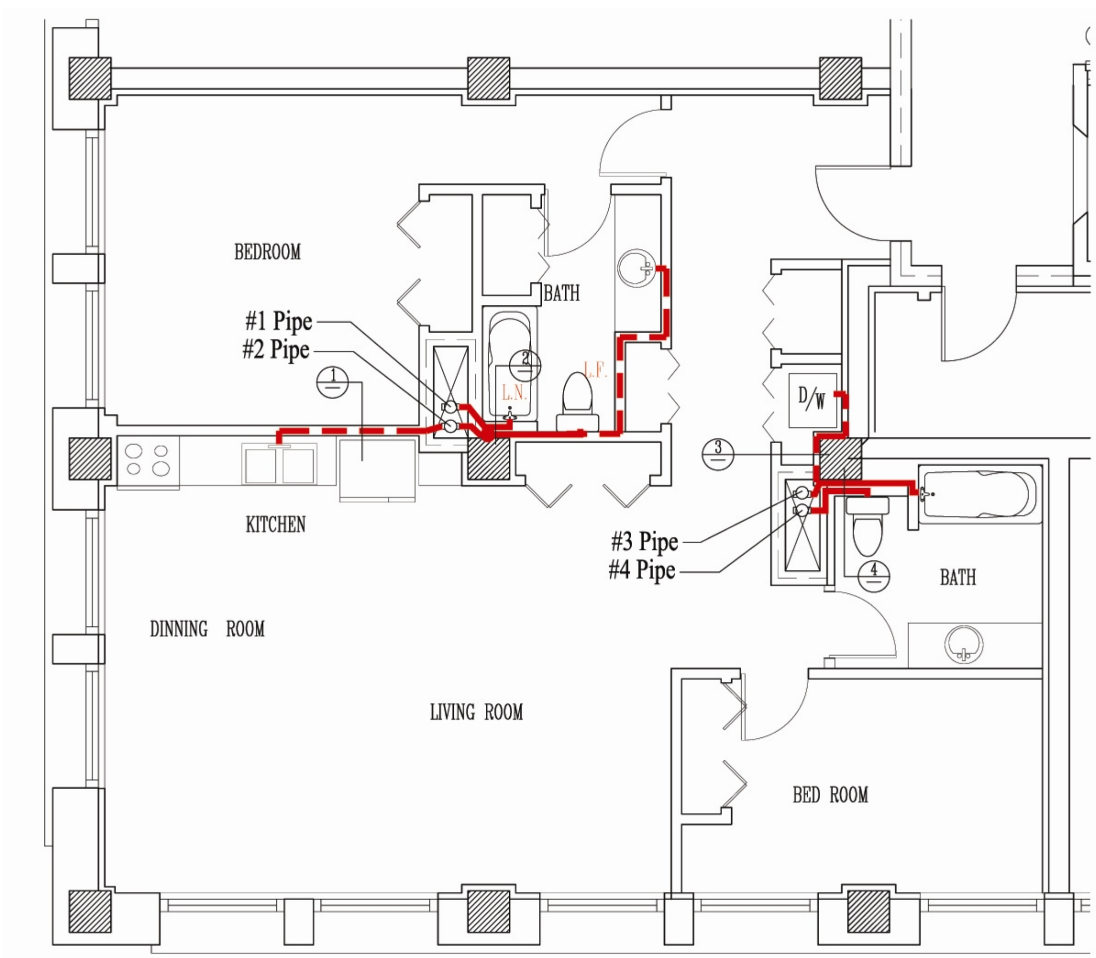

A-16
10
3'-8"
BATH
MASTER BEDROOM
D/W
KITCHEN
LIVING ROOM
DINNING ROOM
A-b
N
SCALE

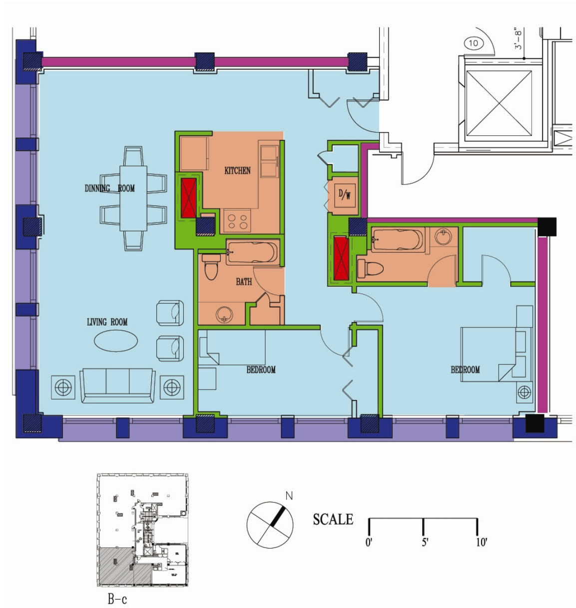

2
A-16
10
3'-8"
L.F.
BATH
L.N.
1
2
MASTER BEDROOM
#1 Pipe
#2 Pipe
4
3
D/W
#3 Pipe
#4 Pipe
KITCHEN
DINNING ROOM
LIVING ROOM
N
SCALE
0'
5'
10'


10
3'-8"
BATH
KITCHEN
DINNING ROOM
D/W
LIVING ROOM
BEDROOM
MASTER
BEDROOM
A-b
N
SCALE
0
5'
10'

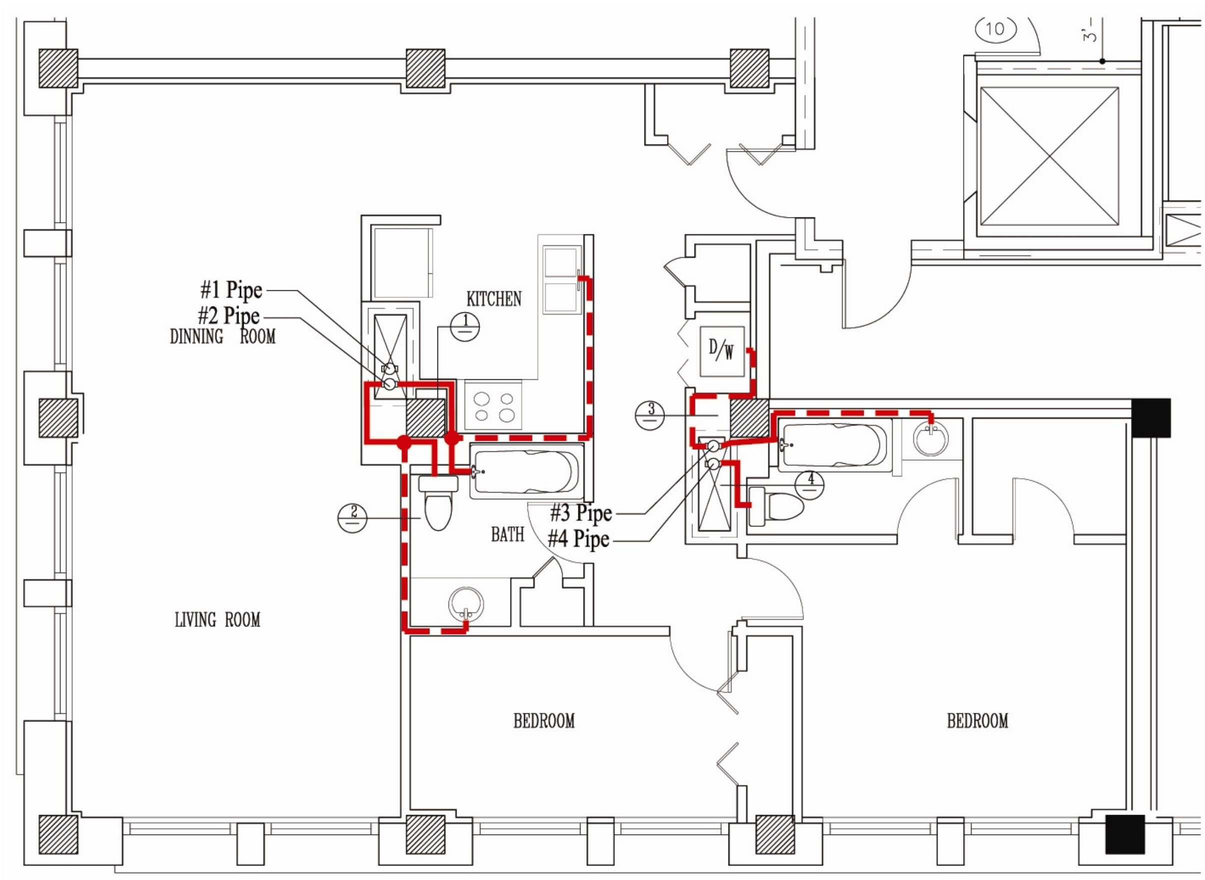

A-16
10
3'-8"
BATH
KITCHEN
DINNING ROOM
2
1
#1 Pipe
#2 Pipe
3
D/W
4
#3 Pipe
#4 Pipe
LIVING ROOM
BEDROOM
MASTER
BEDROOM


BEDROOM
BATH
D/W
KITCHEN
BATH
DINNING ROOM
LIVING ROOM
BED ROOM
N
SCALE
0'
5'
10'
B-b

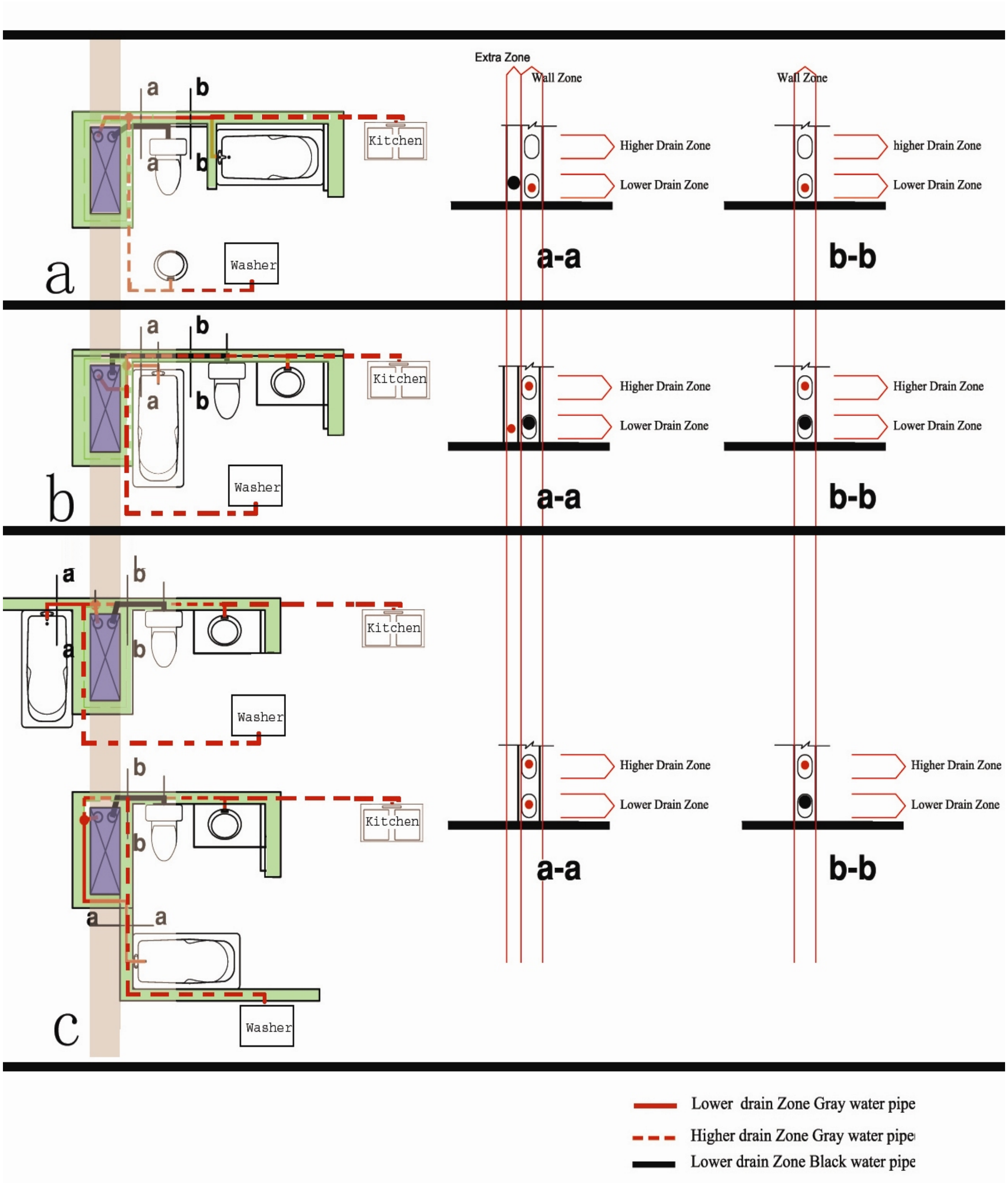

BEDROOM
BATH
#1 Pipe
#2 Pipe
L.N.
L.F.
D/W
KITCHEN
#3 Pipe
#4 Pipe
BATH
DINNING ROOM
LIVING ROOM
BED ROOM



KITCHEN
DINNING ROOM
D/W
BATH
LIVING ROOM
BEDROOM
BEDROOM
N
SCALE
0'
5'
10'
B-c

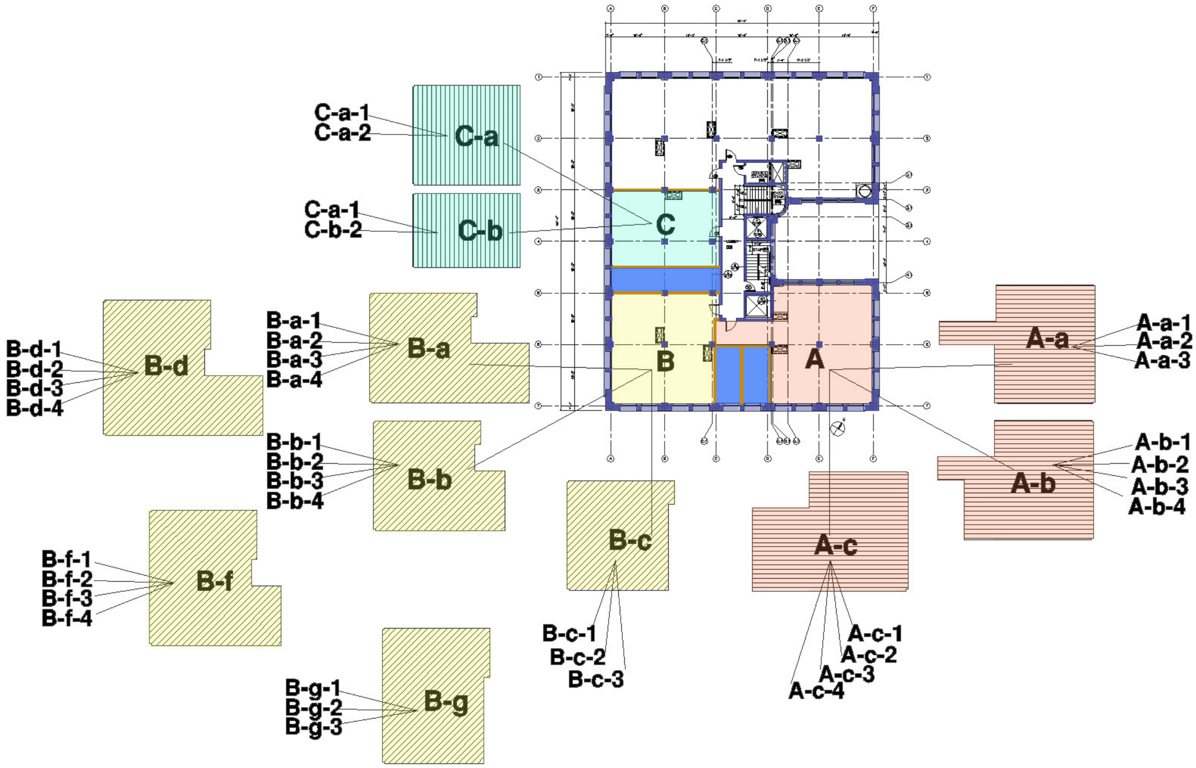


10
#1 Pipe
#2 Pipe
DINNING ROOM
KITCHEN
1
D/W
3
2
4
#3 Pipe
#4 Pipe
BATH
LIVING ROOM
BEDROOM
BEDROOM



This diagram shows a summary or composite of basic unit variations and the implications for managing "piping routing" inside FIT-OUT walls (shown here in GREEN).

In some cases, single walls are used; in other cases, double walls are needed.



Summary

The diagram above is a summary of the capacity of the floor plate of the given building. It demonstrates that decisions about unit size and unit layouts on one floor can be made independently of the decisions about unit sizes and floor plans on floors above and below. The assumptions have been that no new products are needed to accomplish this objective.

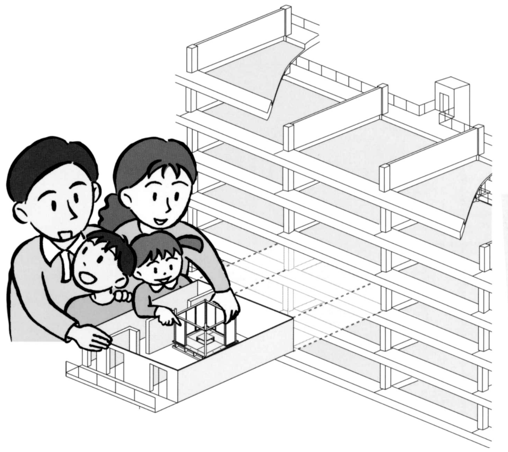
A major trade-off

In BASE BUILDING design, there is a major trade-off to consider in regard to positioning horizontal drainage piping serving individual units:

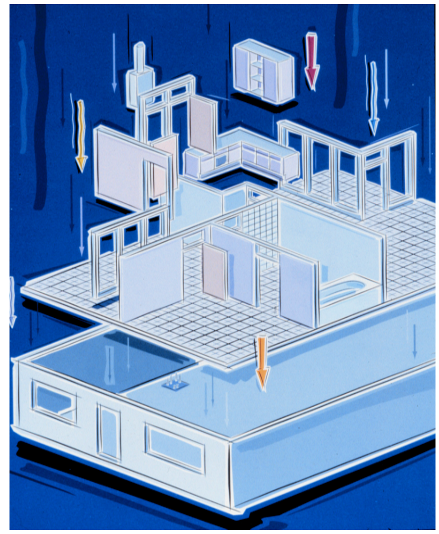
a. Should the space-per-dwelling-unit be reduced because of thicker interior walls needed to hold horizontal piping?
b. Should the ceiling height (in existing buildings) be reduced, or floor-to-floor heights of new building be increased by the use of raised floors, an additional floor layer, or other floor-related pipe management solutions, under or in which horizontal piping can be routed to the vertical MEP stack without interfering in the space of the dwelling below, or
c. Should additional vertical pipe shafts be used to reduce the length of horizontal piping within dwellings?

In a) above – in the example shown in this report – horizontal piping was handled in either single or double standard metal-stud walls.

In b) above, S/I housing in Japan, China and Taiwan uses a raised floor of approximately 30cm. The Matrix Tile system for handling gray-water and water supply lines requires 13cm additional height.



The concept of the autonomous dwelling unit



FIT-OUT determined per unit

The distinction of BASE BUILDING and FIT-OUT in a townhouse development

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