Summer Scholarship 2014/15

How do dense office fitouts perform?

Report Prepared for

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How do dense office fitouts perform?

1 Issue

1.1 Proposition

To carry out a research project that investigates current literature and the issue of workplace density.

1.2 Description

Since the 1960's, office workplaces have become increasingly open plan, rather than cellular, and more recently the space allocation per person has been reducing.

Fitouts which once provided approximately 20m^2 of Net Lettable Area (NLA) or more per person now target 12-16m^2 and quite commonly provide only 10-12m^2 per person in open plan environments.

The economic benefits of reduced real estate cost are generally obvious.

But:

What impact does this have on productivity?

Are other factors also at play e.g. impact of new technologies, changing work place demographics?

What organisational surveys are already available?

Do management and corporate cultural methods/strategies render other issues with density irrelevant?

This very current issue will not be solved through a single summer-long investigation, but this project will establish some in-house guidelines for current state of the art knowledge to inform office design within Studio Pacific. This will form the basis for a much more comprehensive and systematic investigation into workplace density, the 'forgotten' part of the current focus on productivity in the workplace.

1.3 Scope

This research project analyses the effectiveness of modern open plan office environments within New Zealand. A set of criteria will be established based on existing literature and the questions set out in the above description to analyse the effect various factors have on workplace productivity. Certain case studies will be chosen and then the impact the established criteria have on the individual case studies will be analysed and from this data conclusions will be drawn. This project will be open ended in nature and the purpose of this initial research is to provide Studio Pacific with a guided process to continue further research in this area.

2 Significance

2.1 Existing Literature

As a result of the rapidly changing nature of the workplace, research done even a decade ago is becoming outdated. Literature on office design began with Frederick Taylor's 'The Principles of Scientific Management' and focused on quantifiable data and ways to measure, and thus improve, efficiency (Taylor). Texts remained heavily oriented around numerical evidence into the late 1980's, a key example being Brill et al.'s text 'Using Office Design to Increase Productivity' which addressed issues ranging from layout to lighting and placed a cost value on each quality (Brill, Margulis and Bosti). With the loss in popularity of the cubicle based workplace, literature began to

explore the idea that office efficiency didn't lie in a set of 'ideal' numbers and instead was a product of a range of different work environments.

In the 1990's Francis Duffy displayed a new way of thinking in his book 'The New Office'. He introduced the concept that different people and businesses work differently to each other and creating varying spaces based on these differences would be more efficient than homogenous design. Technological innovation and the more mobile workplace brought about a significant change in the way we approach the work environment, and led to Duffy breaking office types down into four categories; The Hive, The Cell, The Den and The Club, each one supporting different degrees of autonomy and worker interaction. This became an early acknowledgement of corporate identity having an effect on the work environment. (Duffy) Literature around this period maintained a theoretical basis. It is worth noting that those strongest advocates of quantifiable measures in this time were often those associated with the growing furniture industry (following the success of cubicle systems).

The majority of literature being published on offices in the 21st century is glossy coffee table books on the latest interior design of notable companies, giving no indication of how effectively they actually perform as offices. Some reports discuss the pros and cons of systems such as Activity Based Working (ABW) but evidence given is typically anecdotal in nature. An approach needs to be taken that blends the scientific process Taylor used with the collaborative logic of the office landscape movement. There is no ideal solution but there may be rules that can be followed, rules that take into account the varying nature of people and businesses, and the psychological and functional requirements of the work environment.

2.2 Timeline

2.2.1 Advent of the Office (1500's – 1800's)

The concept of an office workplace is purported to have originated with the De Medici family of 16th century Italy as a way of organizing clerical staff so that public and staff members would have easier access to bank workers. This trend of housing banking and administrative staff in a common building for public access continued, becoming popular throughout Europe. The Industrial Revolution introduced other professions to the concept of going somewhere to work and of working in the open plan to maximize efficiency. This allowed for easy supervision of the workers, typically from elevated enclosed offices around the perimeter of the work area. (Klerk)

2.2.2 Open Plan Working (ca. 1900)

Frederick Taylor, regarded as the father of scientific management, sought to make the workplace more efficient by breaking work down by task, like a production line. He supported a standardized work environment where impersonal space enabled the clinical fulfillment of each task. An open work environment, with management supervision overseeing the whole floor, continued. (Taylor)

2.2.3 A New Workplace (ca. 1960)

Eberhard and Wolfgang Schnelle created what became known as Burolandschaft (office landscape), which introduced flexibility to the workplace by breaking down managerial hierarchy, promoting easier communication. This evolution in the way people worked prompted new workstation typologies to emerge, in particular the 'L-shaped' desk which was a response to the new space requirement for a computer monitor. (Caruso St. John)

2.2.4 Action Office (1968)

As a response to the loss of aural and visual privacy introduced by Burolandschaft Robert Propst of Herman Miller released a furniture range titled Action Office One (later superseded by Action Office Two). This range focused on creating individual work areas isolated by high partitions whilst still keeping the dense layout pioneered by Taylor. These became known as 'cubicle farms'. (Herman Miller)

2.2.5 Rejection of the Cubicle Farm (ca. 1980)

Regarded as inhuman and oppressive, due to their stark appearance and dense configuration, the 'cubicle farm' layout has been subject to considerable criticism. Various solutions emerged that sought to address employee needs as a means of

increasing efficiency, this generally meant lowering and/ or removing the partitions. These solutions were criticized as being inefficient; only effective for extroverted employees or certain professions; they didn't represent a better alternative than 'cubicles'.

2.2.6 The Current Situation (Present)

Given a workplace spectrum ranging from rows of isolated cubicles to an adaptable environment where people are encouraged to work in different places each day, there is no clear solution to the problem of 'work place efficiency'. What someone may find a productive environment will differ from another person, between companies or across the day-to-day use of the office. Concepts like Activity Based Working (ABW) and hot-desking, where a combination of shared facilities, activity specific areas and individual workstations cater to a range of working styles, have emerged yet the success of any of these depends on the nature of the building and company itself and is not a solution that would fit all. Overall there is no clear solution on how to respond to density. This research will attempt to establish more specific trends in the hope of finding more specific answers.

3 Hypothesis and Method

Scientific process and anecdotal evidence will establish parameters to assess the success of office spaces in comparison to their density. Using both methods ensures the psychological effect of space on users and people's physical requirements will be taken into account, which will provide a more complete synopsis of office productivity.

We will conduct an analysis of current density measurement systems and establish a 'truer' method of measuring usable space for office workers.

By developing an in-house density measurement system that better reflects available open-plan space, and through comparison of survey data, we will analyze how different densities respond to different key conditions.

Our hypothesis is that the nature of the workstation itself will have a discernible impact on productivity, and as various conditions become 'less desirable' individual productivity will decrease.

This will be examined by establishing a range of different workstation conditions that can be tested, which will give the widest spread of results. Through workplace surveys the impact, or lack of, for each condition will be established.

3.1 Existing Standards and Trade Offs

The current established method of measuring occupation density in buildings is known as Net Lettable Area (NLA) per person/ workstation. There is no international standard for the exact definition of NLA.

As a measure of useable space this method is flawed. If a tenant wishes to know how much space they have available to place workstations then having the core facilities and lift lobby included gives an inaccurate result. An ad hoc solution has been adapted, known as Net Useable Area (or Net Useable Space/ Net Internal Area/ Useable Floor Area etc), where facilities not deemed 'useable tenant space' are removed from the calculation. There exists no standard terminology or definition for Net Useable Area (NUA).

We are proposing a third definition; Net Occupiable Area (NOA). The purpose of this is to isolate the open-plan space within a floor plate so that a truer idea of the projected density can be attained. NOA is equivalent to NUA minus enclosed rooms, such as offices and quiet spaces, and any circulation joining those enclosed areas to the main circulation.

For a graphic illustration of these see Figure 1. These are defined in text form in the next section: "Measurement Definitions".

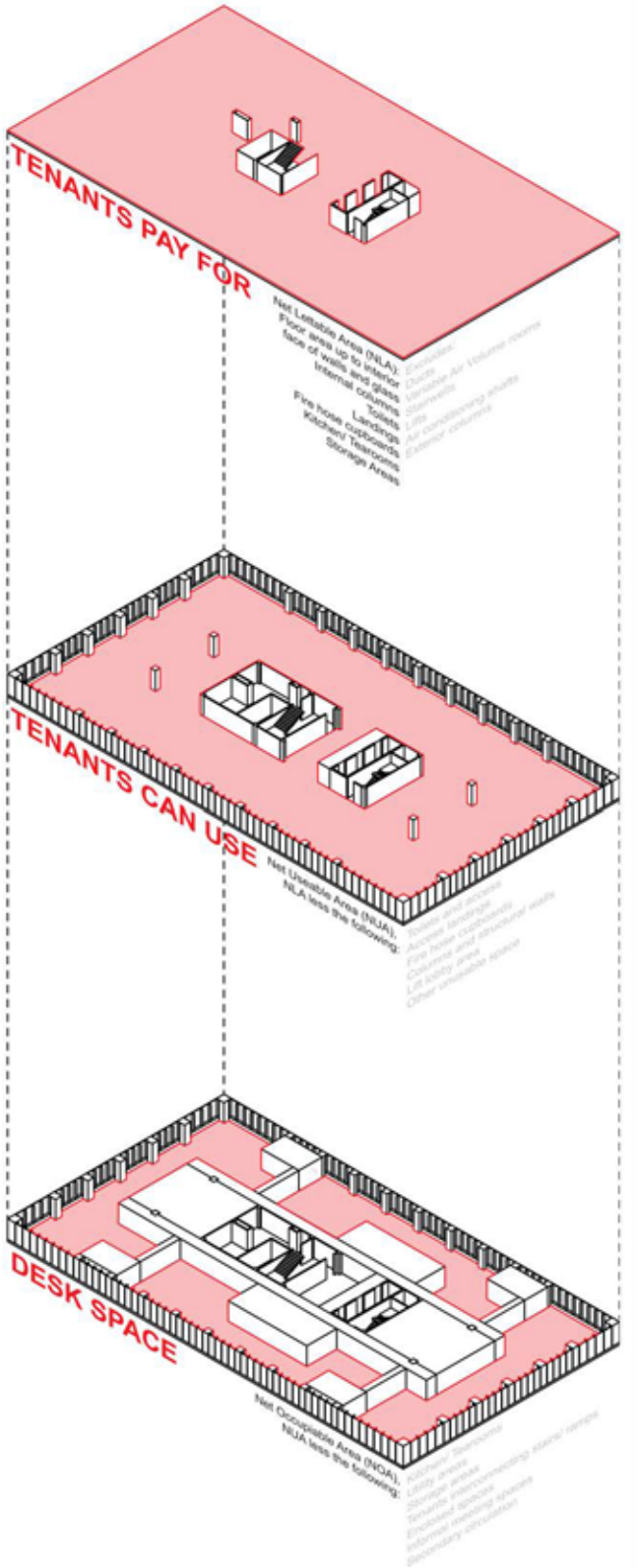

Figure 1 Illustration of the concepts described in section 3.2 - defining the Net Lettable Area (NLA) - what the tenant pays for; Net Useable Area (NUA) - what the tenants can use; Net Occupiable Area (NOA) - where the tenant can actually place desks

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3.2 Measurement Definitions

3.2.1 Net Lettable Area (NLA)

This is what tenants effectively pay for as it is the basis for a standard lease agreement. The current New Zealand definition for Net Lettable Area is defined by the New Zealand Property Council and includes;

Floor area up to interior face of walls and glass (measured at 1.5m above floor level)

Internal columns

Toilets

Landings (where giving access to toilets etc)

Fire hose cupboards

Kitchen/ Tearooms

Storage Areas

But excludes:

Ducts

Variable Air Volume rooms

Stairwells (see above for landings)

Lifts

Air conditioning shafts

Exterior columns

In other countries (e.g. Australia) toilets are not included in the NLA figure. For the purpose of this research we have also excluded external terrace areas.

3.2.2 Net Useable Area (NUA)

This is what tenants can actually use for their fitouts and is not fitout specific, instead reflecting the space that the configuration of the base building makes available to a tenant. NUA is calculated by removing those areas not classed as 'useable space' from the NLA figure. NUA is used in calculations for tenant efficiency, and is considered an industry convention not an official definition. Defined as per NLA less the following,

Toilets and access to (base building provision)

Access landings

Fire hose cupboards

Columns and structural walls

Lift lobby area (defined as an area 1.8m in front of the lift doors as required by NZS 4121 Accessibility Standard, or the whole lobby if this is a separate walled in area)

Unusable space (defined as any area where there is less than 800mm access to it i.e. in the gap between a column and the wall, unusable perimeter zones defined as 200mm in from the inside of the glass line or the line of the spandrel wall)

3.2.3 Net Occupiable Area (NOA)

This is the space available for workstations and reflects the way a tenant is using the space. NOA is calculated by removing all areas not directly useable as open-plan 'desk space'. There is no recognized method to measure this so we have devised our own.

As per NUA less the following:

Kitchen/ Tearooms

Utility areas

Storage areas

Tenants interconnecting stairs/ slides/ ramps

Enclosed spaces (defined by having two or more walls that obstruct movement through the space)

Informal meeting spaces (defined as those areas reserved for 'collaboration' where desks are not allowed i.e. a quiet area)

Secondary circulation (defined as a .85m wide strip that connects areas such as informal meeting spaces to the main circulation, where possible measuring the most direct route, and also any access to fire egress etc)

A low NOA can either reflect an open plan environment supported by collaboration areas, quiet rooms etc or not supported but with a number of cellular offices. The effect of these support facilities is not measured specifically but will have an effect on the data returned through the surveys. This measure could be refined in some way to reflect the degree of 'support' that the NOA is provided with.

The differences between these three concepts of Net Area is illustrated in Figure 2.

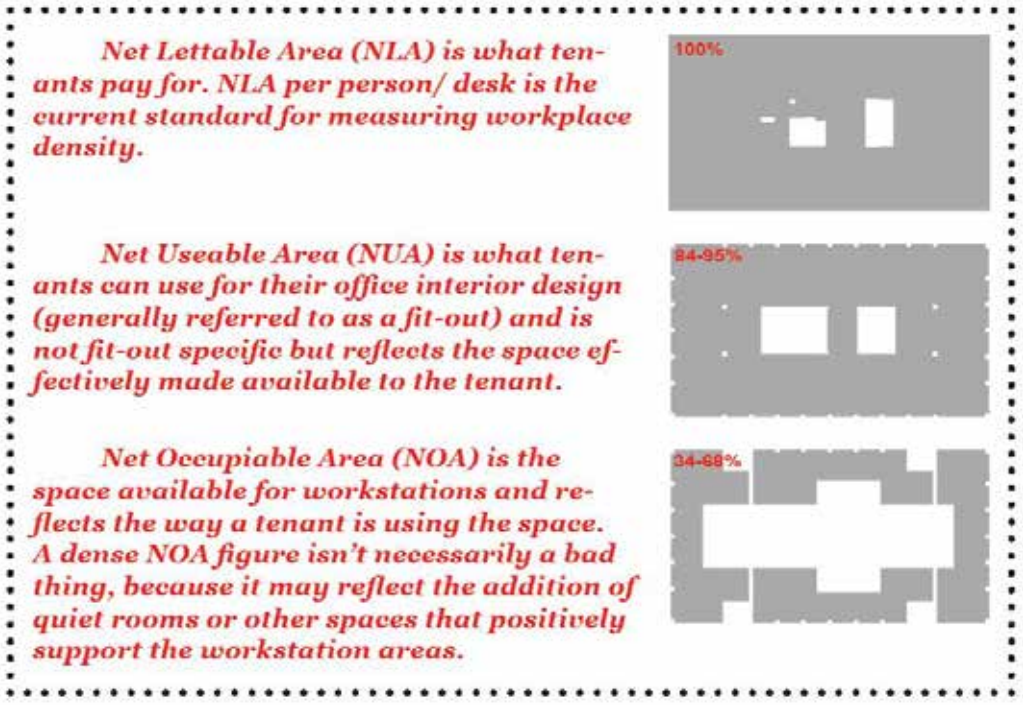


Figure 2 A typical building mapped in terms of NLA, NUA and NOA.

3.3 Table of Densities

Table 1, below, presents a comparison of these density measurements across all case study premises, with a floor-by-floor breakdown for each. Also given is a 'percentage of NLA' figure that shows the difference in values between NLA, NUA and NOA as a percentage; NOA, for example, varies between 34 and 68% of the NLA figure.

Premise	Floor	NLA	Stations (#)	Density	NUA	Density	% of NLA	NOA	Density	% of NLA
SNZ	3	1806	157	11.5	1671	10.6	93	1114	7.1	62
KPMG	7	736	50	14.7	645	12.9	88	310	6.2	42
	8	734	62	11.8	643	10.4	88	330	5.3	45
Beca	3	452	36	12.6	428	11.9	95	309	8.6	68
	4	452	38	11.9	428	11.3	95	309	8.1	68
	8	452	36	12.6	428	11.9	95	309	8.6	68
	9	452	41	11.0	428	10.5	95	309	7.6	68
Customs	3	1222	82	14.9	1135	13.8	93	533	6.5	44
	4	1222	68	18.0	1135	16.7	93	448	6.6	37
Xero	G	685	94	7.3	575	6.1	84	347	3.7	51
	GM	318	45	7.1	290	6.5	91	191	4.3	60
	1	1033	91	11.4	945	10.4	92	347	3.8	34
Trademe	3	758	63	12.0	702	11.1	93	270	4.3	36
	4	1159	139	8.3	1081	7.8	93	617	4.4	53
	5	1040	96	10.8	965	10.1	93	406	4.2	39

Table 1: Density values

These densities have been calculated using a graphical analysis like that illustrated in Figure 3, Figure 4, and Figure 5.

Figure 3 NLA calculation for the simplest plan case study building

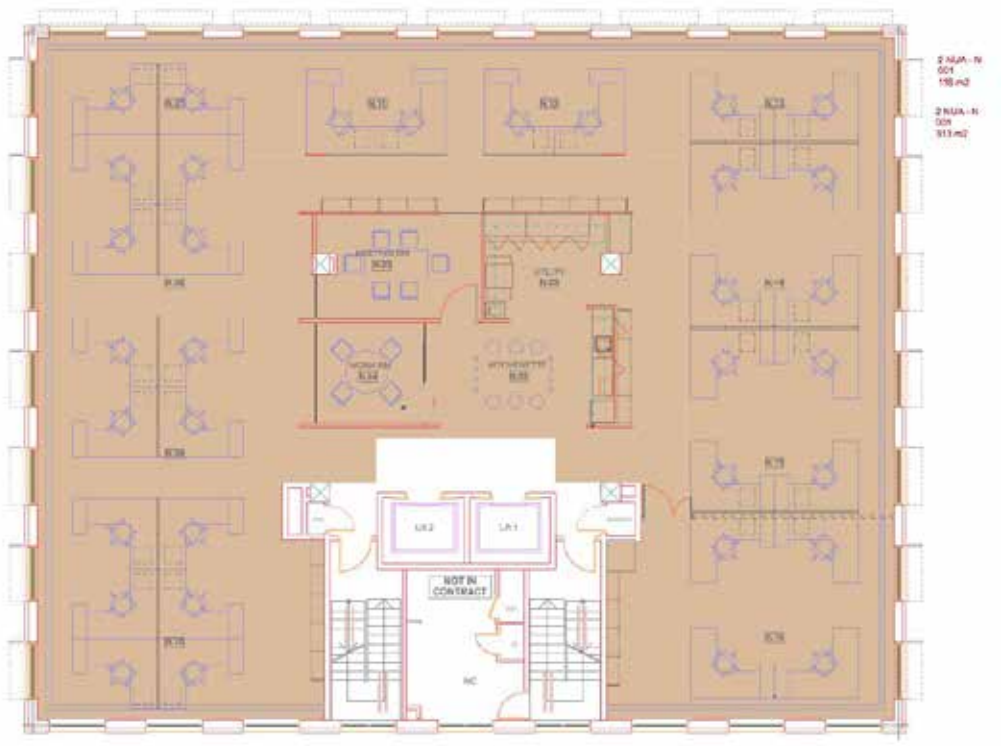


Figure 4 NUA calculation for the simplest plan case study building

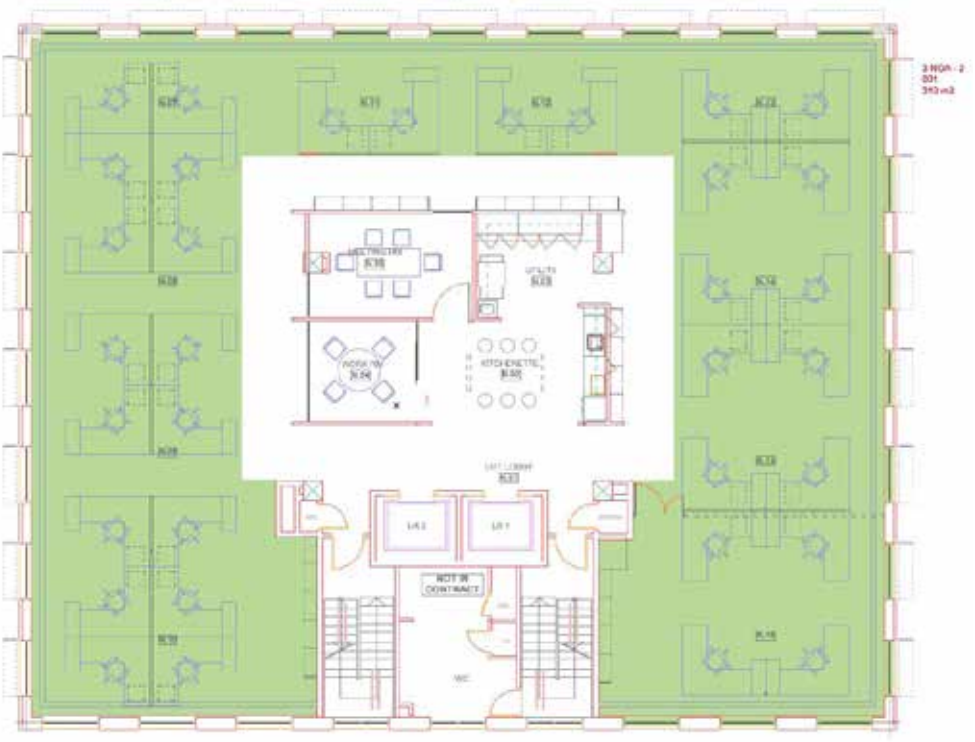


Figure 5 NOA calculation for the simplest plan case study building

4 Workstation Typologies

4.1 Desk Typology Selection

In order to test our hypothesis concerning the impact of workstation typologies we created a list of variables that would allow the nature of the actual workstation itself to be surveyed. To arrive at eight workstation typologies a range of conditions were brainstormed and those hypothesized to have the largest impact were combined to make the typologies below. The conditions were broken down into two categories; Type and Modifier, where the Type of desk describes the physical construction of the desk and the Modifier describes what contextual conditions affect it. A table of those initial brainstormed conditions can be seen below in Table 2.

Type	Modifier
120 Degree	Middle (of a row of desks)
Rectangular A (1200mm long)	Window (by a window)
Rectangular B (1400mm long)	Shallow (shorter than 800mm deep)
Rectangular C (1600mm long)	Deep (longer than 1200mm deep)
Rectangular C (1800mm long)	Office (in an enclosed office)
'L'-Shaped	Circulation (by a circulation route)
	Screened (behind a screen higher than 1500mm)
	Partitions (with a partition higher than 2000mm)
	No modifier

Table 2 Brainstormed conditions

Out of the Type category the 120^{O} desk was removed, as it was unlikely to be common enough to meet the recommended 30 sample minimum for the survey. The rectangular desks were amalgamated into the '*< or equal to 1600mm long'* and *'> than 1600mm long'* types in order to both get the required minimum return rate for each type as well as to test the Property Management Centre of Expertise (PMCoE) recommended desk size of 1600mm long (Property Management Centre of Expertise).

In the modifier category shallow and long desks were removed as they weren't predicted to have a large impact and would be an uncommon condition. Offices were excluded as they were outside the scope of this project. Screens and partitions were removed, as they were too uncommon and too subjective to reliably measure. The three conditions remaining were 'in the middle of a group of desks', 'by a window' or 'close to a main circulation route'. Proximity to a window is already assessed within the selected standard survey, which leaves 'middle', 'circulation' and 'no modifier'.

As such the possible workstation typologies are; (shown in Figure 6)

1. Rectangular desk (< *or equal to 1600mm long*)
2. Rectangular desk (< *or equal to 1600mm long*) in the middle of a group
3. Rectangular desk (< *or equal to 1600mm long*) along a main circulation route
4. Rectangular desk (>*1600mm long*)
5. Rectangular desk (>*1600mm long*) in the middle of a group
6. Rectangular desk (>*1600mm long*) along a main circulation route
7. 'L-shaped' desk
8. 'L-shaped' desk along a main circulation route

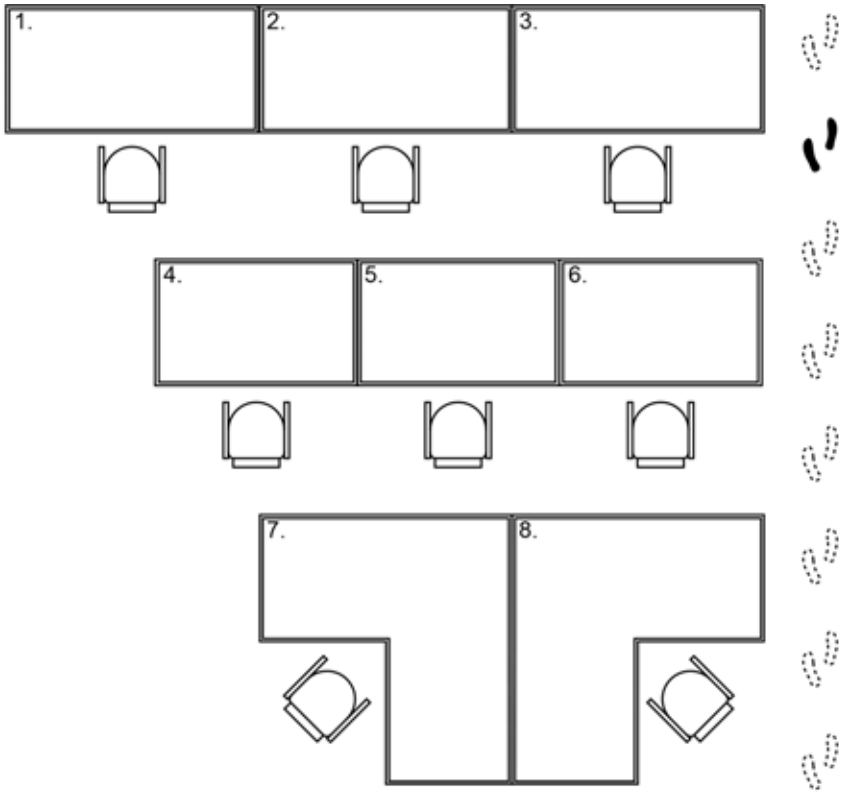


Figure 6 Diagram of the different desk types

Note: Due to the added privacy of an 'L-shaped' desk the effect of being in the middle of a group is predicted to be negligible and is thus excluded.

4.2 Desk Typologies

Introduction

The following is a more detailed description of each desk type and our hypothesis for each one. Anecdotal evidence suggests that users have a preference for which type of desk they use, so by isolating each type we can establish whether the anecdotal evidence is reflected in survey data collected from each station.

1. Rectangular workstation (< or equal to 1600mm long)

The rectangular workstation is increasingly common and the simplest type of desk (especially as CRT monitors no longer need to be accommodated, with benefits including space efficient design and ease of arrangement. Potential downsides include aesthetically 'dull' design and lack of built-in adjacent surfaces. The rectangular workstation category has been broken up into the '< or equal to 1600mm long' and '>1600mm long' categories. The Accident Compensation Corporation (ACC) recommended length for combination computer and clerical work is 1600mm minimum (solely computer work is a minimum of 1200 mm) (ACC).

A hypothesis tested in this research was the expectation that rectangular workstations in the middle of a group will be evaluated less favourably by their users than standard ones but better than those near circulation. Those that are shorter are also expected to be less favoured.These workstation typologies are relevant because they are the 'standard' workstation types and will form a reference point by which to measure the performance of the other typologies. It is hypothesized that as workers get closer together their productivity and satisfaction will decrease, therefore rectangular workstations should perform worse when they are less than or equal to 1600mm long as opposed to greater than 1600mm long.

2. Rectangular workstation (< *or equal to 1600mm long*) in the middle of a group

A rectangular workstation typology as described previously with the addition of being placed in the middle of a group i.e. with a desk immediately either side. This is expected to reduce privacy and create a feeling of being 'cramped' thus producing different results to a standard rectangular workstation.

Anecdotal evidence suggests that this is the least favoured desk location.

These typologies are relevant because the effect of being in the middle of a group is expected to vary from that of the standard rectangular workstation typologies.

3. Rectangular workstation (< *or equal to 1600mm long*) along a main circulation route

As with the previous rectangular workstation description with the added condition of being placed alongside a main circulation route. It is hypothesised that the added noise and distractions and the reduced privacy of being in close proximity to a main circulation route will have a negative affect on the results of a rectangular workstation.

This workstation typology is relevant because it isolates a specific condition and will allow for an analysis that takes into account the additional influence circulation may have on the rectangular workstation. We predict rectangular workstations will perform worst overall when by main circulation.

4. Rectangular workstation (>*1600mm long*)

Similar to <1600mm.

5. Rectangular workstation (>*1600mm long*) in the middle of a group

Similar to <1600mm.

6. Rectangular workstation (>*1600mm long*) along a main circulation route

Similar to <1600mm.

7. 'L-shaped' workstation

An 'L-shaped' desk consists of rectangular surfaces at right angles to each other. This enables an additional surface (approximately 1.5 times the area of a standard rectangular desk) to be used at the expense of taking up more floor space. Due to its shape, the 'L-shaped' workstation requires a different pattern of configuration than a rectangular desk. This typology gives the user the chance to orient towards either surface or at a 45^{O} angle (effectively giving the user three orientations as opposed to one).

Another hypothesis tested in this research was the expectation that 'L-shaped' workstations in the middle of a group will be evaluated less favourably by their users than standard ones. 'L-shaped' desks will perform better than similar rectangular desks because their design is different from the rectangular workstation, enabling different configurations and ways to work at the desk, which is predicted to produce a positive effect. These workstation typologies are relevant because they are a common type and will allow for a contrast to the rectangular desks. It is hypothesized that as workers gain a greater desk area to work with they will become more productive and satisfied.

8. 'L-shaped' workstation along main circulation route

As with the previous 'L-shaped' workstation description with the added condition of being placed alongside a main circulation route. It is hypothesized that the added noise and distractions and the reduced privacy of being in close proximity to a main circulation route will have a negative affect on the results of an 'L-shaped' workstation.

This typology is relevant because it is expected to vary enough from the standard 'L-shaped' workstation typology to justify its separation. 'L-shaped' workstations near circulation should perform worse than a standard 'L-shaped' desk, and better than a rectangular desk near a circulation route.

5 Building Use Studies Survey Data

The research proposed to gain the opinions of the people using various desks of the types listed in Section 6 at varying levels of NOA within a range of buildings. Physical surveying was selected as the data collection tool as it allowed for the collection of anecdotal evidence as well as empirical data, and it allowed for a broader range and greater sample size than personal observation and other data collection tools.

5.1 Building Use Studies Survey

5.1.1 Introduction

The selected survey tool is the Building Use Studies (BUS) survey which was developed by Adrian Leaman in conjunction with the Usable Buildings Trust and is currently owned by Arup. It originated in 1985 as part of a study of 'sick' buildings. It was then developed further for the 1995 PROBE studies conducted by Adrian Leaman and Bill Bordass analyzing new commercial and public buildings. Now it is used as a well-established Post-Occupancy Evaluation (POE) tool commercially available to test various performance criteria against a benchmarked standard. (Arup)

5.1.2 Why We Chose It

As a leading author in current POE literature Adrian Leaman's expertise in conducting and analyzing POE data is an invaluable resource. In addition having a benchmark of considerable historical data ensures contextualized results and shows atypical data trends better.

The BUS survey has a range of questions designed to target all general areas of a premises that have an impact on occupants. These range from physical needs, such as meeting rooms, to environmental needs, like air quality. By choosing key variables from the survey we can isolate the impact various desk types have on each variable and, through comparison, establish how well each desk type performs against the others.

The alternative would be to develop our own POE survey, which would specifically address those variables we expect to have an impact. However, in order to do this effectively, an extra process would be needed to devise and test the survey. Without benchmark data it would be impossible to draw conclusions about the case study buildings outside of the context of the other case study buildings.

6 Selection of Case Study Buildings and Characteristics

In order to produce a diverse cross-section of results, a range of case study premises were sought. Key qualities considered were;

- Nature of work environment (traditional or progressive)
- Public or private sector
- Range of Densities

Our goal was to survey between six and ten premises, with two of each factor i.e two public and two private sector buildings. This would give us the variety we needed to ensure the data wasn't skewed by local contextual influences. The following is a table of those organisations approached:

Organisations	Predominant Nature of Work	Public/ Private Sector	Density	Agreed to Participate	Selected to Survey
Statistics NZ	Paper/ IT	Public	Medium	Yes	No
Ministry of Business and Innovation	Paper/ IT	Public	Medium	No	
Bank of NZ	IT	Private	High	No	
KPMG	Paper/ IT	Private	Medium	Yes	Yes
Deloitte	IT	Private	Medium	No Response	
Beca	Paper/ IT	Private	Medium	Yes	Yes
Spark	IT	Private	High	No Response	

Inland Revenue Department	Paper/ IT	Public	Medium	No	
NZ Customs	Paper/ IT	Public	Low	Yes	Yes
Xero	IT	Private	High	Yes	Yes
Contact	IT	Private	Medium	Late Response	No
NZ Transport Authority	Paper/ IT	Public	Medium	No	
Trademe	IT	Private	High	Yes	Yes
NZ Treasury	Paper/ IT	Public	Low	No	

Table 3: List of case study premises

Note: All premises considered were new enough such that conditions, like working air conditioning, were reasonably consistent across all case studies, in order to prevent skewed results.

7 Analysis of the POE data

7.1 Choice of Variables

The following variables have been predicted to have the highest correlation between desk type and productivity. A review of the literature shows a trend in those factors that most impact user satisfaction in the open-plan. Key factors for reporting the 'success' of an environment are personal comfort (Leaman and Bordass 8), noise (Kim and de Dear), lighting and windows (Yildirim, Akalin-Baskaya and Celebi) and perceived productivity (Sullivan, Baird and Donn). In this survey each of these has been analysed in comparison to proximity to a main circulation route or window.

7.1.1 Overall Comfort

A measure of perceived general comfort rated on the BUS survey as a scale from one to seven, with one being unsatisfactory and seven being satisfactory.

7.1.2 Overall Lighting

A measure of perceived general internal lighting conditions rated on the BUS survey as a scale from one to seven, with one being unsatisfactory and seven being satisfactory.

7.1.3 Perceived Productivity

A measure of general perceived productivity, based on environmental conditions, rated on the BUS survey as a scale from -40% to 0% and up to +40% in 10% increments. *Note data is output both as a percentage rating and as a raw score, see Appendix 8.2.3.*

7.1.4 Overall Noise

A measure of perceived general comfort with noise levels rated on the BUS survey as a scale from one to seven, with one being unsatisfactory and seven being satisfactory.

7.1.5 Noise Interruptions

A measure of how often occupants are affected by unwanted noise interruptions, rated on the BUS survey as a scale from one to seven, with one being not at all and seven being very frequently.

7.1.6 Space at Desk

A measure of perceived space at desk rated on the BUS survey as a scale from one to seven, one being too little space at desk and seven being too much space at desk.

7.2 Analysis

All categories returned results as expected, judging by previous research and anecdotal evidence, with the following two exceptions.

7.2.1 Circulation

It was anticipated that the proximity to main circulation routes would produce lower survey scores due to the negative effect of distractions both visually and aurally. However the data returned showed a general trend towards the opposite, scoring desks by circulation routes better across almost every variable. The one case study

that performed as expected was the Customs building. The following table displays the difference in results between the desks near circulation and the non-circulation desks.

The values given in Table 4 are calculated by deducting the average score for each category for non-circulation desks from the average score for each category for circulation desks. If the result is positive circulation desks scored better and if the result is negative circulation desks scored worse, except in the case of Noise Interruptions, Productivity % or Space at Desk where the change is noted in the table. This method is intended to quickly show which desk types scored 'better' and whether this result was anticipated or not.

Circ-NonCirc (most-least dense)	**Beca**	**Customs**	**KPMG**	**Trademe**	**Xero**
Overall Comfort	-0.00543	-0.08544	0.35753	0.21135	0.42835
Overall Lighting	0.32609	0.03243	0.17625	0.00381	0.21913
Noise Interruptions (lowest is best)	0.16667	0.4	-0.17647	0.08822	0.48333
Noise Overall	-0.45281	-0.16129	0.24904	0.3061	0.66265
Productivity % (-ve to +ve)	1.82609	-0.833333	3.84453	1.73508	0.32468
Productivity Raw Data	0.18261	-0.08333	0.38445	0.17351	0.03247
Space at Desk	NonCirc	Circ	NonCirc	NonCirc	NonCirc
Contrary to hypothesis	Circulation scores better than Non-Circulation				
Hypothesised	Circulation scores worse than Non-Circulation				

Table 4: Circulation scores minus non-circulation scores

In all but Customs the majority of the results were counter-intuitive. The difference in values was small in most instances but the overall trend is clear i.e. those desks near circulation are scoring more positive values across most categories.

Note: A higher score is a more satisfactory score except in Noise Interruptions where it represents more interruptions and in Space at Desk where the category that scored best is shown.

7.2.2 Windows

It was anticipated that those desks near windows would perform better as the proximity to a view has been shown, in previous surveys, to improve user satisfaction. However building specific conditions such as use of natural ventilation, glare, air conditioning etc all have an impact on whether being near a window is a positive condition. The following table displays the difference in results between the desks near windows and the non-window desks.

The values given in Table 5 are calculated by deducting the average score for each category for non-window desks from the average score for each category for window desks. If the result is positive window desks scored better and if the result is negative window desks scored worse, except in the case of Noise Interruptions, Productivity % or Space at Desk where the change is noted in the table. This method is intended to quickly show which desk types scored 'better' and whether this result was anticipated or not.

Win-NonWin (most-least dense)	**Beca**	**Customs**	**KPMG**	**Trademe**	**Xero**
Overall Comfort	-0.05248	-0.3375	0.25	-0.00381	-0.20455
Overall Lighting	0.05494	0.05357	0.27016	-0.05252	-0.07792
Noise Interruptions (lowest is best)	0.0061	-0.4381	0.51152	0.15614	0.17105
Noise Overall	0.21613	0.12667	-0.125	-0.29394	0.18831
Productivity % (-ve to +ve)	1.0373	0.041667	-1	0.77751	2.09155

Productivity Raw Data	0.10373	0.00417	-0.1	0.07775	0.20915
Space at Desk	Win	Win	NonWin	Win	Win
Contrary to hypothesis	Window scores worse				
Hypothesised	Window scores better				

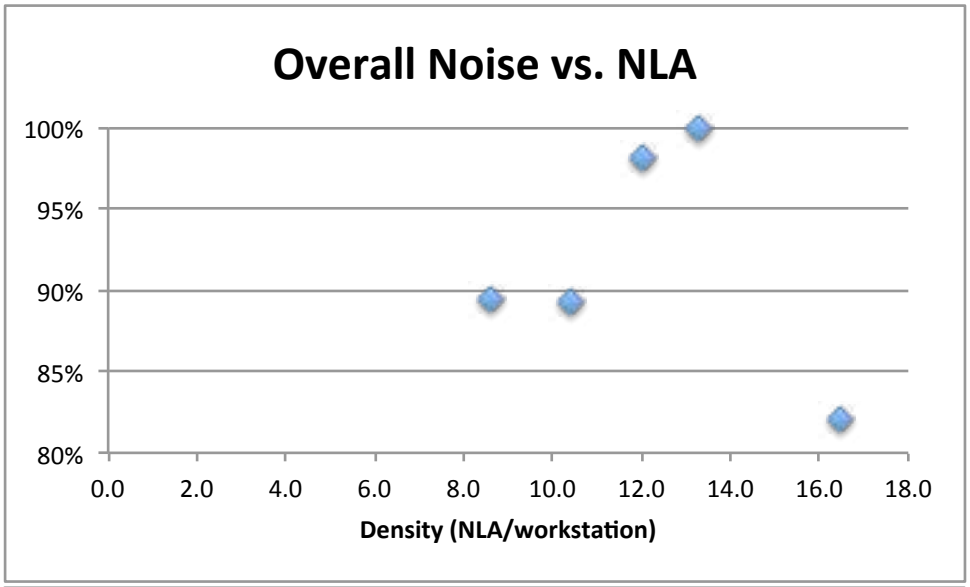
Table 5: Window scores minus non-window scores

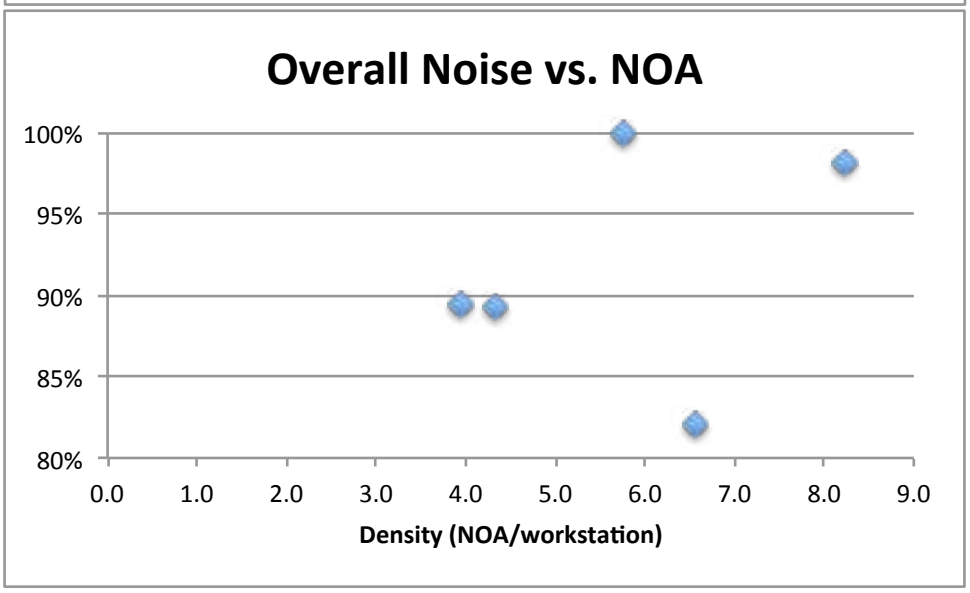
In the Customs building desks near windows score better the majority of the time. Xero and Beca window desks score better on around half of the categories. KPMG the window desks only score better in productivity and space at desk. Overall this represents variations in building conditions and there is no clear trend across all the case studies, except that window desks don't have as much of a positive impact as anticipated.

7.3 Relationship to Density

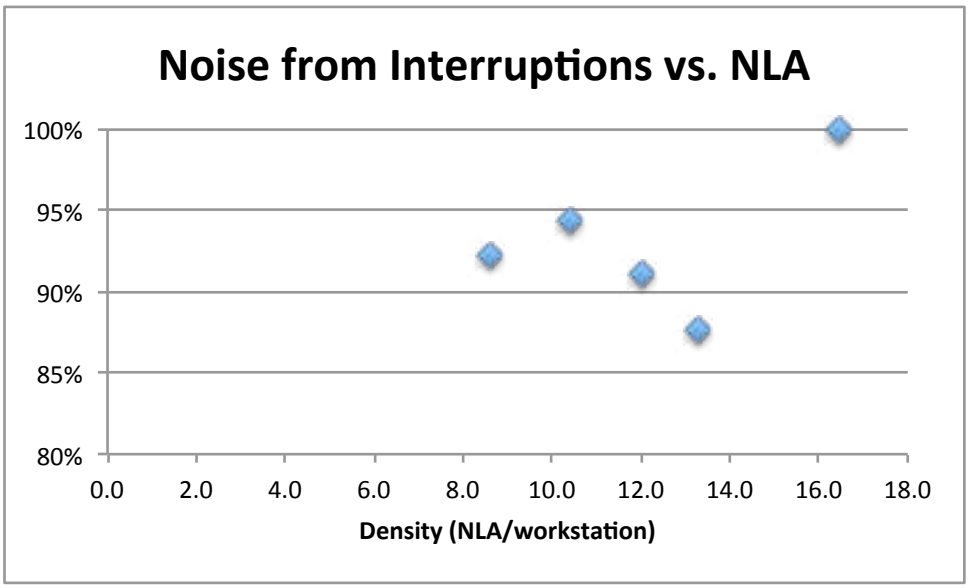
In both tables 4 and 5 the premises have been ordered left to right from least dense (NOA) to most dense. It appears that more unintuitive results occur in 'more dense' environments in both tables.

In figures 7-14 below the survey data has been standardised and is displayed as a percentage against both NLA and NOA. With all key variables, results fluctuate across the case study premises. Of great significance is the lack of negative trend in the data. As the premises get denser there appears to be a neutral trend, showing density to have neither a negative or positive effect.





Figures 7 & 8 Overall Noise in comparison with Density



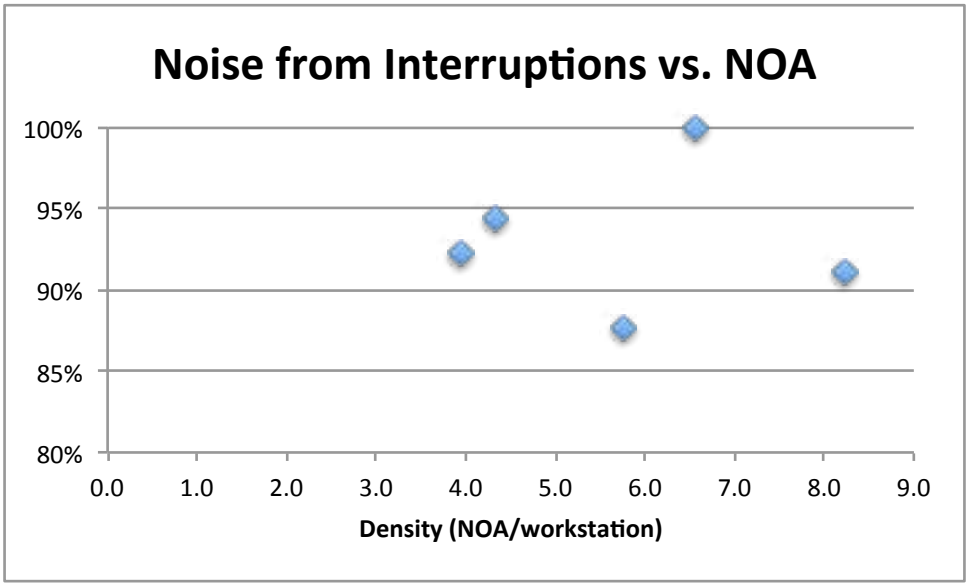
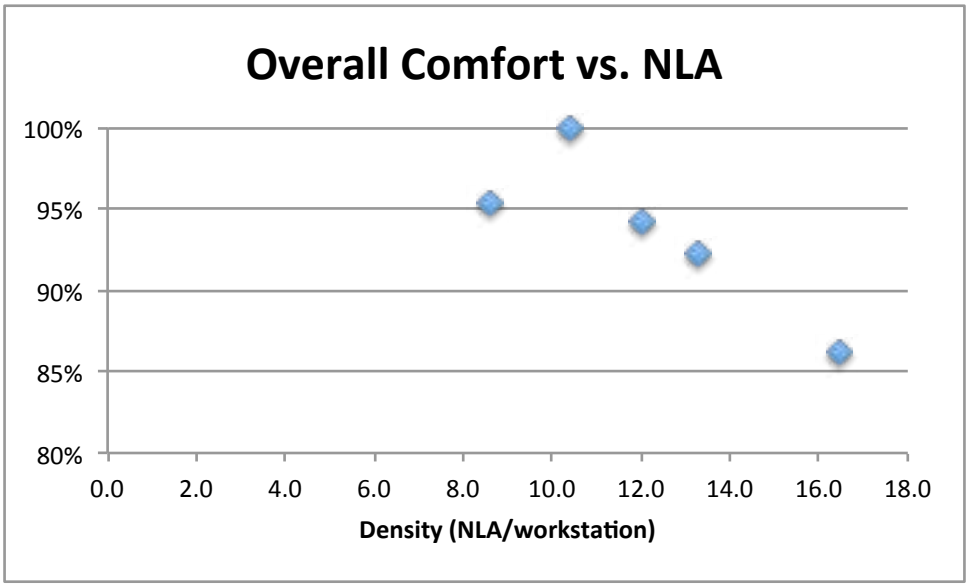
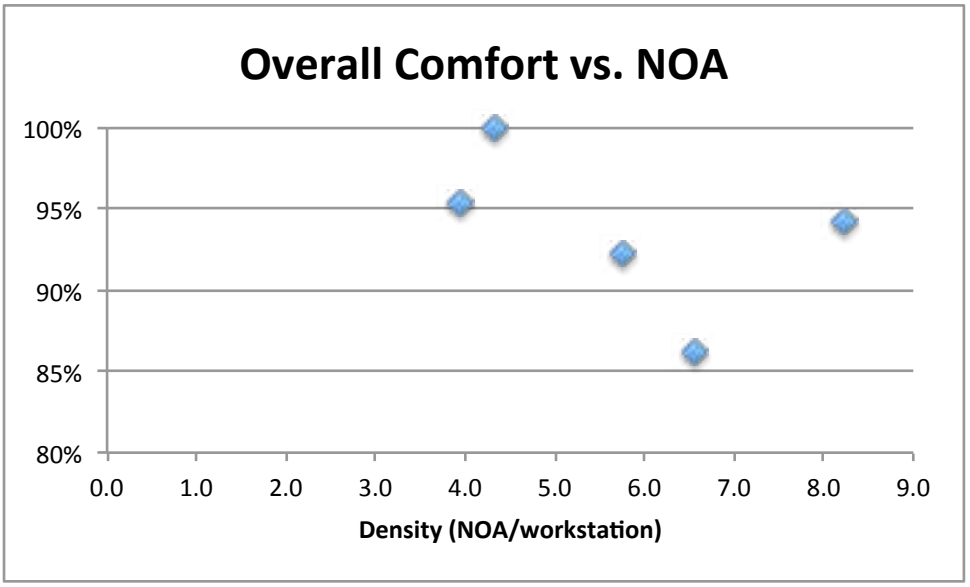
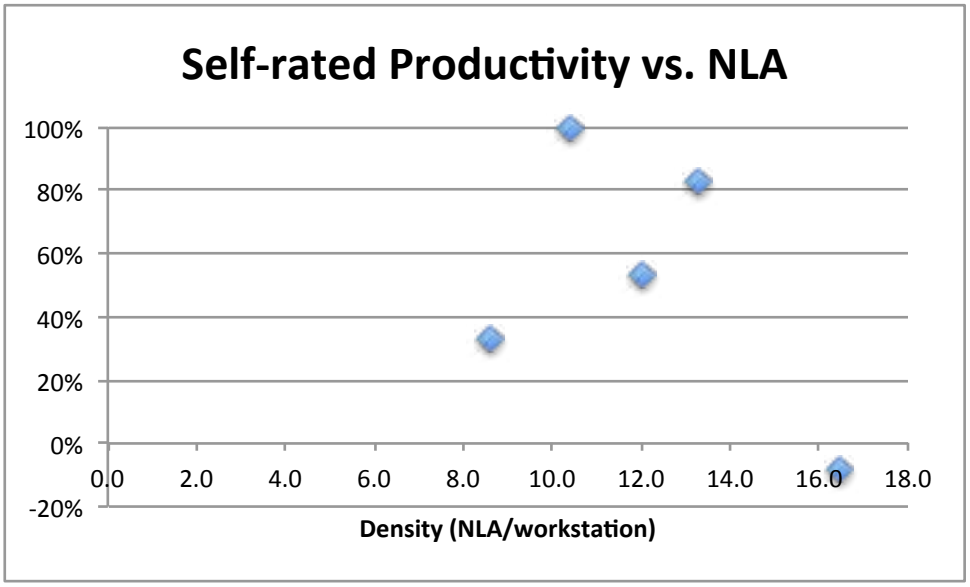


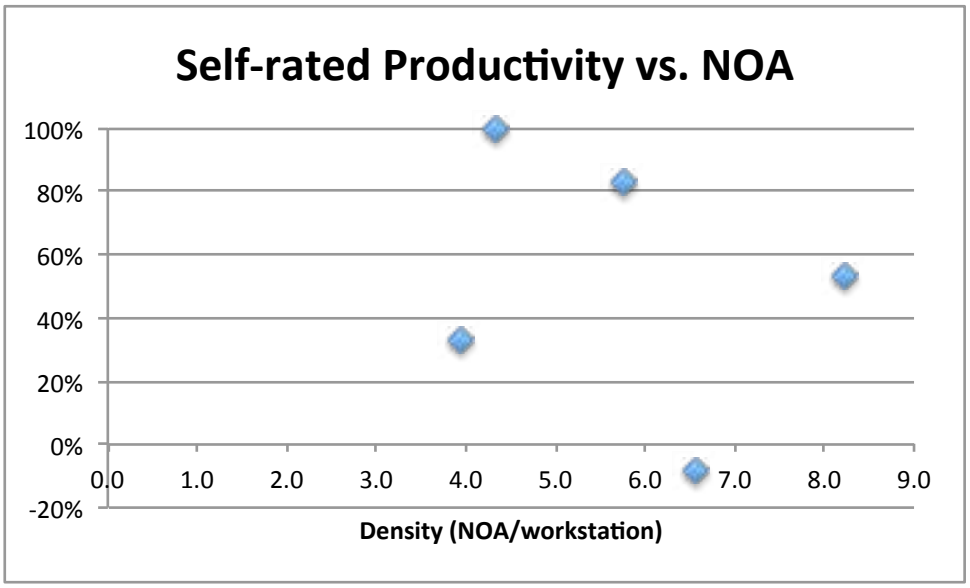
Figure 9 & 10 Noise from Interruptions in comparison with Density





Figures 11 & 12 Overall Comfort in comparison with Density





Figures 13 & 14 Self-rated Productivity in comparison with Density

8 Conclusion

Research within the existing literature showed a lack of sophistication in the way density was measured. The proposed Net Occupiable Area (NOA) is a definition of density that is more readily applicable to designing new office layouts. A denser Net Occupiable Area value doesn't represent a worse space, instead potentially reflecting spaces that have shared program, such as collaborative areas, which give benefits beyond purely desk space. This index offers a way to analyse actual desk space in terms of immediate density, rather than across the whole floor. Net Lettable Area (NLA) and Net Usable Area (NUA) do not provide an accurate impression of the possible density of desks, as can be seen by the difference in data trends in comparison to Net Occupiable Area (NOA).

The survey data returned counter-intuitive results across all variables by showing a neutral, rather than the hypothesized negative, trend as density increased. The implication this gives is that density, within the work environment, appears to make no difference to worker productivity at all. This could have a huge impact on the way office layouts are planned in terms of maximising worker satisfaction and increasing productivity.

Analysis of desks near circulation also returned counter-intuitive results in that the most common result was that desks near a main circulation route gave generally better

scores than those away from circulation routes. Anecdotal evidence suggested the opposite would be true, citing added distractions and noise as having a negative impact on concentration levels and subsequent productivity. This is further evidence to suggest that the current approach to workplace density is misinformed if not incorrect.

9 Further Research

In both cases unintuitive results appeared: density appears to have little impact on productivity and desks near circulation routes appear to be more productive. In order to fully validate both conclusions a more comprehensive study should be undertaken that takes into full account any additional influences each work environment had. The corporate approach to the work environment, especially seat and team allocation, should be analysed.

The following factors may have contributed to circulation route desks being preferred so should be investigated:

-Seat allocation policies may have given circulation route seats to newer employees who tend to be happier with their workplace overall. However this is unlikely the case in many of the case study buildings as people work in teams and there is no obvious hierarchy of new/ old employees.

-In open plan environments the desks in the middle may experience greater noise by virtue of having a desk either side. Possible, but it is unlikely that the circulation route desks will be quieter due to foot traffic.

-Closer proximity to core facilities may outweigh disruptions found along circulation routes.

-In several of the case study buildings there are many ‘lesser’ paths of circulation that could dilute the negative effects of being near circulation. This is true but both KPMG and Beca have one key circulation route and they both returned unintuitive results too.

-Loss of focus due to interruptions could be outweighed by potential for collaboration. This would depend on the nature of work and is unlikely to have shown for so many of the case study buildings.

-Results may have been distorted by variations in the actual number of desks occupied over the survey period.

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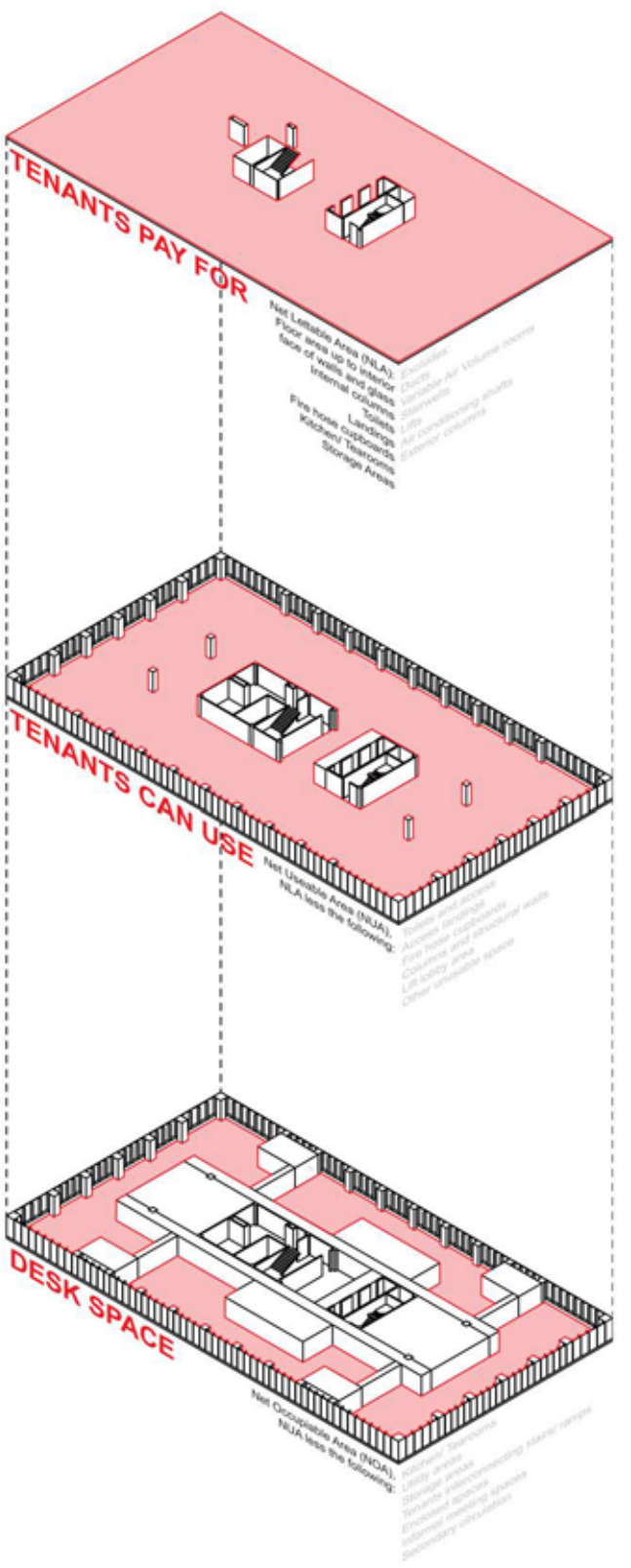
11 Appendix

11.1 Density Measurements Diagram



11.2 Density Percentage Comparison

Net Lettable Area (NLA) is what tenants pay for. NLA per person/ desk is the current standard for measuring workplace density.

Net Useable Area (NUA) is what tenants can use for their office interior design (generally referred to as a fit-out) and is not fit-out specific but reflects the space effectively made available to the tenant.

Net Occupiable Area (NOA) is the space available for workstations and reflects the way a tenant is using the space. A dense NOA figure isn't necessarily a bad thing, because it may reflect the addition of quiet rooms or other spaces that positively support the workstation areas.

11.3 Raw Data

11.3.1 Overall Comfort

Two-Way Mean Table

Building:	Custom House	Trademe	KPMG	Xero	Beca	
LOCATION						Row Means
Not Next to Circulation	5.19355	5.93571	5.37931	5.63415	5.63043	5.69817
Next to Circulation	5.10811	6.14706	5.73684	6.0625	5.625	5.67808
Column Means:	5.14706	5.97701	5.52083	5.70408	5.62791	

Grand Mean = 5.52869

Two-Way Mean Table For: COMFOVER

Building:	Custom House	Trademe	KPMG	Xero	Beca	
WINDOW						Row Statistics
1	5.1	5.97468	5.6875	5.54545	5.60377	5.62273
2	5.4375	5.97849	5.4375	5.75	5.65625	5.76305
.	4	7				5
Column Statistics:	5.14706	5.98266	5.52083	5.70408	5.62353	

Grand Mean = 5.52881

11.3.2 Overall Lighting

Two-Way Mean Table

Building:	Custom House	Trademe	KPMG	Xero	Beca	
LOCATION						Row Means
Not Next to Circulation	5.4	6.17266	5.37931	5.84337	5.67391	5.87768

Next to Circulation	5.43243	6.17647	5.55556	6.0625	6	5.85034
Column Means:	5.41791	6.17341	5.44681	5.87879	5.82955	
Grand Mean = 5.70082						

Two-Way Mean Table For: LTOVER						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
WINDOW						Row Statistics
1	5.42857	6.14103	5.625	5.81818	5.84906	5.83945
2	5.375	6.19355	5.35484	5.8961	5.79412	5.89243
.	5.5	7				6
Column Statistics:	5.41791	6.17442	5.44681	5.87879	5.82759	
Grand Mean = 5.69959						

11.3.3 Perceived Productivity

Two-Way Mean Table (Percentage)						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
LOCATION						Row Means
Not Next to Circulation	0	5.32374	3.21429	1.81818	2.17391	3.35423
Next to Circulation	-0.833333	7.05882	7.05882	2.14286	4	3.68794
Column Means:	-0.461538	5.66474	4.66667	1.86813	3.02326	
Grand Mean = 3.2582						

Two-Way Mean Table (Raw Data)						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
LOCATION						Row Means
Not Next to Circulation	5	5.53237	5.32143	5.18182	5.21739	5.33542
Next to Circulation	4.91667	5.70588	5.70588	5.21429	5.4	5.36879
Column Means:	4.95385	5.56647	5.46667	5.18681	5.30233	
Grand Mean = 5.03893						

Two-Way Mean Table For: PROD%						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
WINDOW						Row Statistics
1	-0.625	6.15385	4	3.5	3.46154	3.56808
2	-0.666667	5.37634	5	1.40845	2.42424	3.38843
.	5	10				6.66667
Column Statistics:	-0.461538	5.75581	4.66667	1.86813	3.05882	
Grand Mean = 3.29218						

Two-Way Mean Table For: PROD						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
WINDOW						Row Statistics
1	4.9375	5.61538	5.4	5.35	5.34615	5.35681
2	4.93333	5.53763	5.5	5.14085	5.24242	5.33884
.	5.5	6				5.66667
Column Statistics:	4.95385	5.57558	5.46667	5.18681	5.30588	
Grand Mean = 5.04115						

11.3.4 Overall Noise

Two-Way Mean Table						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
LOCATION						Row Means
Not Next to Circulation	4.16129	4.37037	4.86207	4.33735	5.08696	4.48765
Next to Circulation	4	4.67647	5.11111	5	4.63415	4.58621
Column Means:	4.07463	4.43195	4.95745	4.44444	4.87356	
Grand Mean = 4.34221						

Two-Way Mean Table For: NSEOVER						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
WINDOW						Row Statistics
1	4.06	4.27273	4.875	4.59091	4.9434	4.4633
2	3.93333	4.56667	5	4.4026	4.72727	4.55285
.	5.5	6				5.66667
Column Statistics:	4.07463	4.44048	4.95745	4.44444	4.86047	
Grand Mean = 4.34156						

11.3.5 Noise Interruptions

Two-Way Mean Table						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
LOCATION						Row Means
Not Next to Circulation	4.26667	4.21481	4	4.05	4	4.12853
Next to Circulation	4.66667	4.30303	3.82353	4.53333	4.16667	4.32168
Column Means:	4.48485	4.23214	3.93333	4.12632	4.07955	
Grand Mean = 3.96516						

Two-Way Mean Table For: NSEINTERRUPTION						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
WINDOW						Row Statistics
1	4.42857	4.32468	4.28571	4.26316	4.09434	4.28302
2	4.86667	4.16854	3.77419	4.09211	4.08824	4.12653
.	3	4				3.33333
Column Statistics:	4.48485	4.23952	3.93333	4.12632	4.09195	
Grand Mean = 3.96914						

11.3.6 Space at Desk

Two-Way Mean Table						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
LOCATION						Row Means
Not Next to	4.19355	4.65957	4.39286	4.42857	4.12766	4.45921

Circulati Next to Circulation	4.08333	4.88235	4.78947	4.66667	4.47619	4.53691
Column Means:	4.13433	4.70286	4.55319	4.47059	4.29213	
Grand Mean = 4.40984						

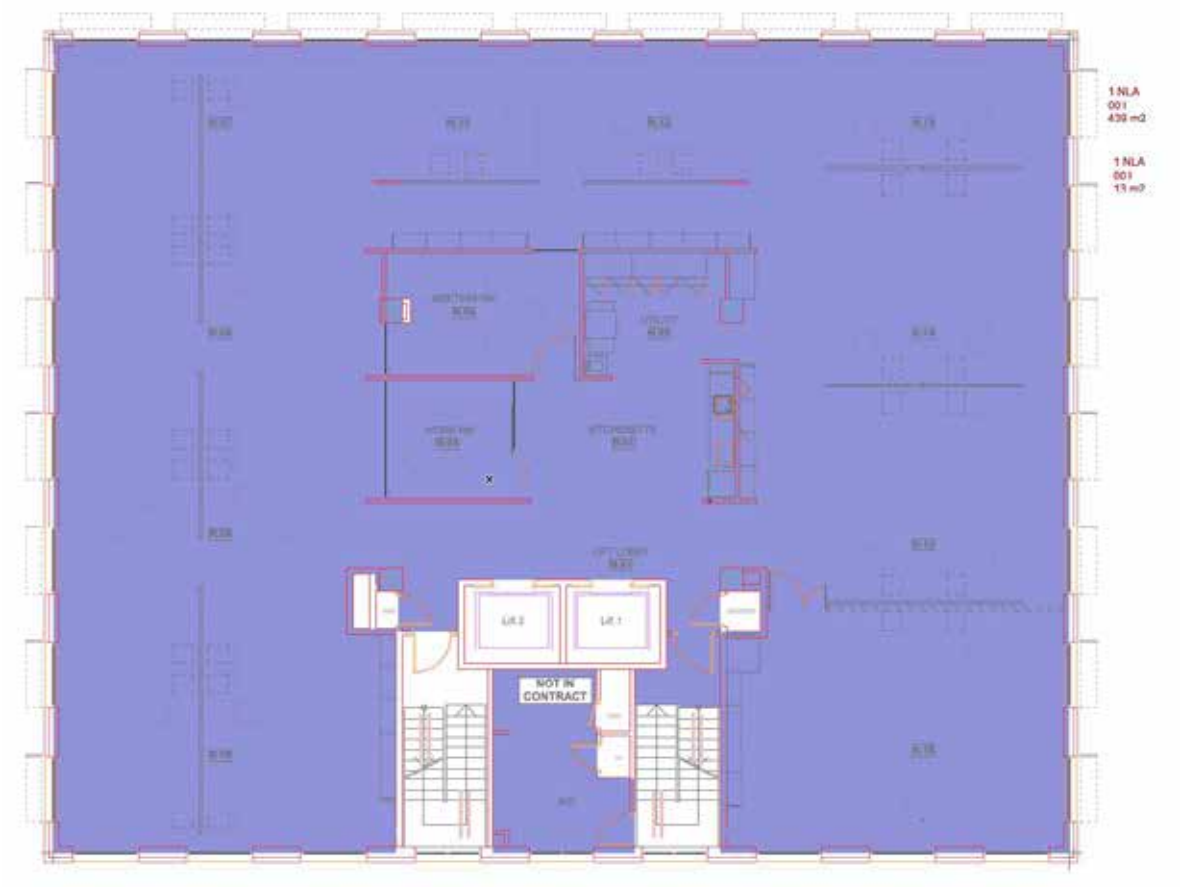
Two-Way Mean Table For: SPACEDESK						
Building:	Custom House	Trademe	KPMG	Xero	Beca	
WINDOW						Row Statistics
1	4.18367	4.60759	4.73333	4.3913	4.27778	4.41818
2	3.8125	4.80851	4.46875	4.49367	4.32353	4.54118
.	5.5	3				4.66667
Column Statistics:	4.13433	4.7069	4.55319	4.47059	4.29545	
Grand Mean = 4.41152						

11.4 Density Measurement Floor Plans

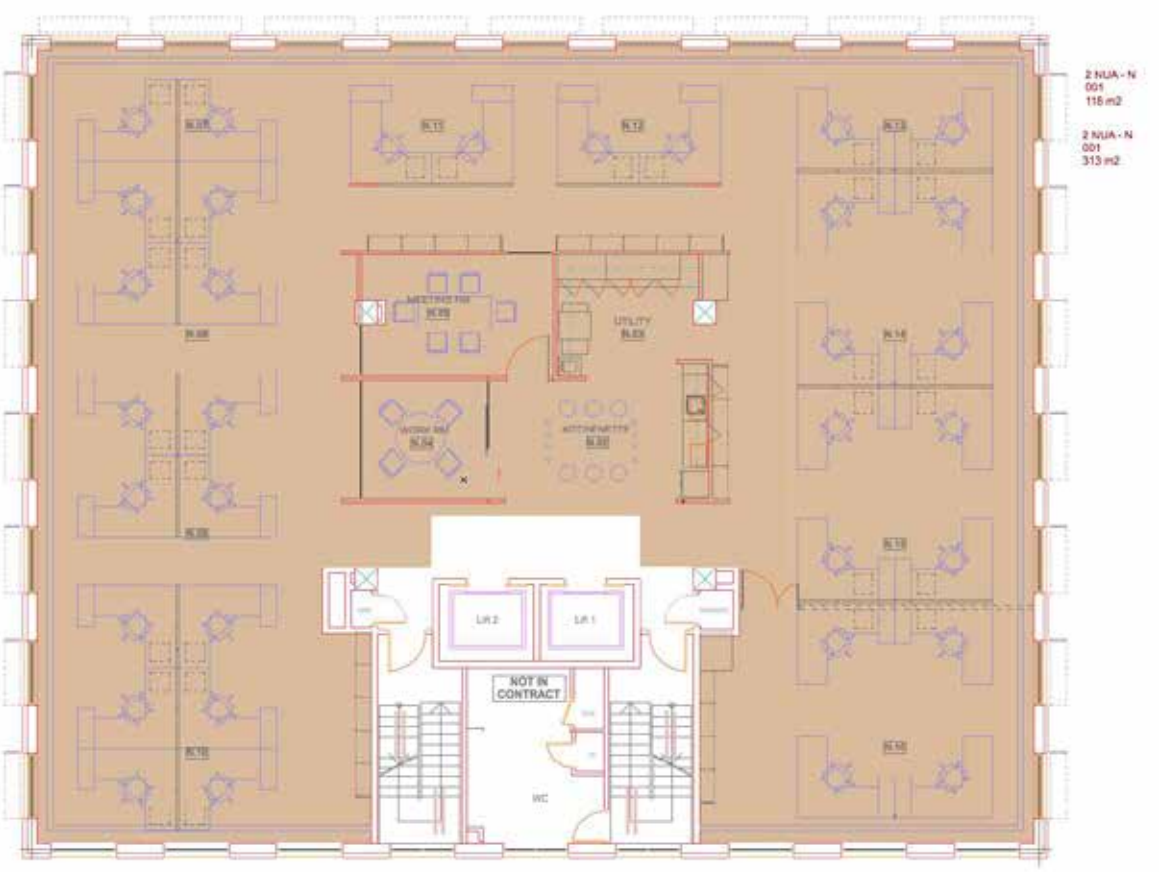
NB: Not to scale.

11.4.1 Beca

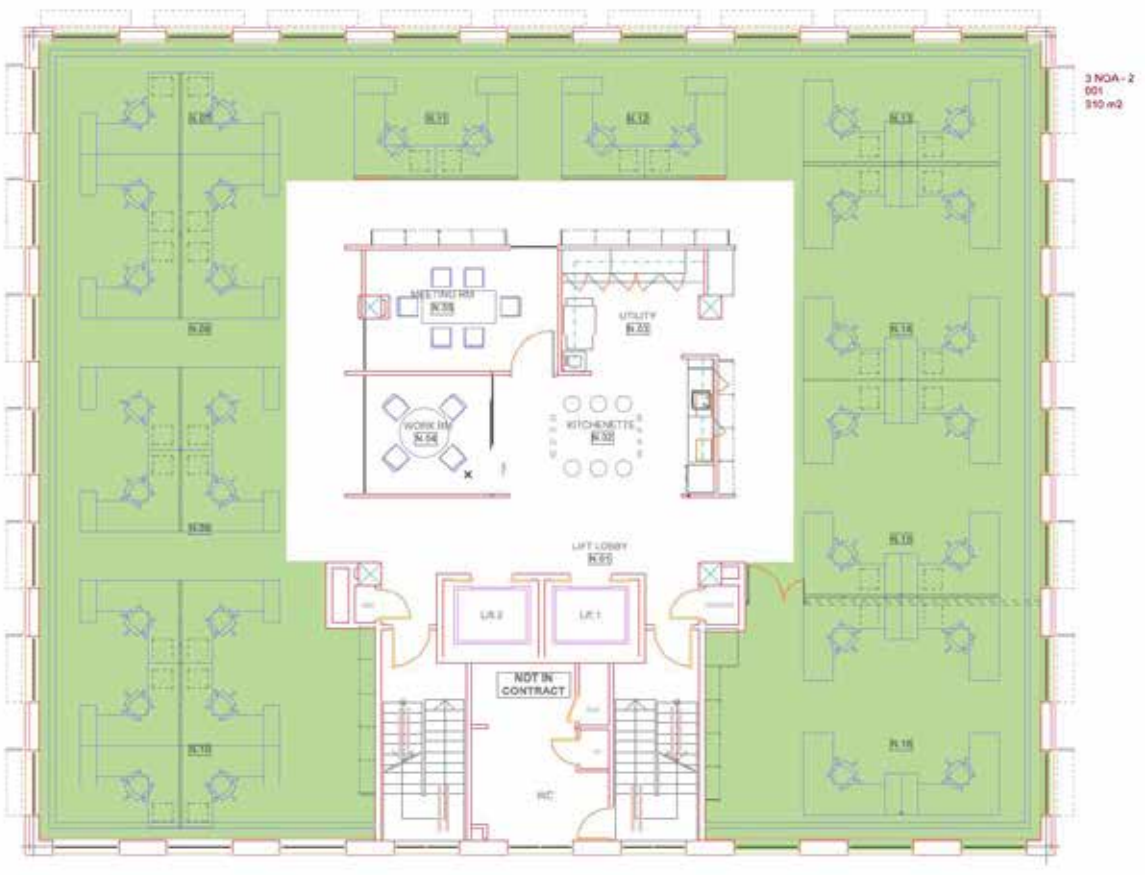
All floor plans are identical for each floor.



NLA for Floors 3, 4, 8, 9



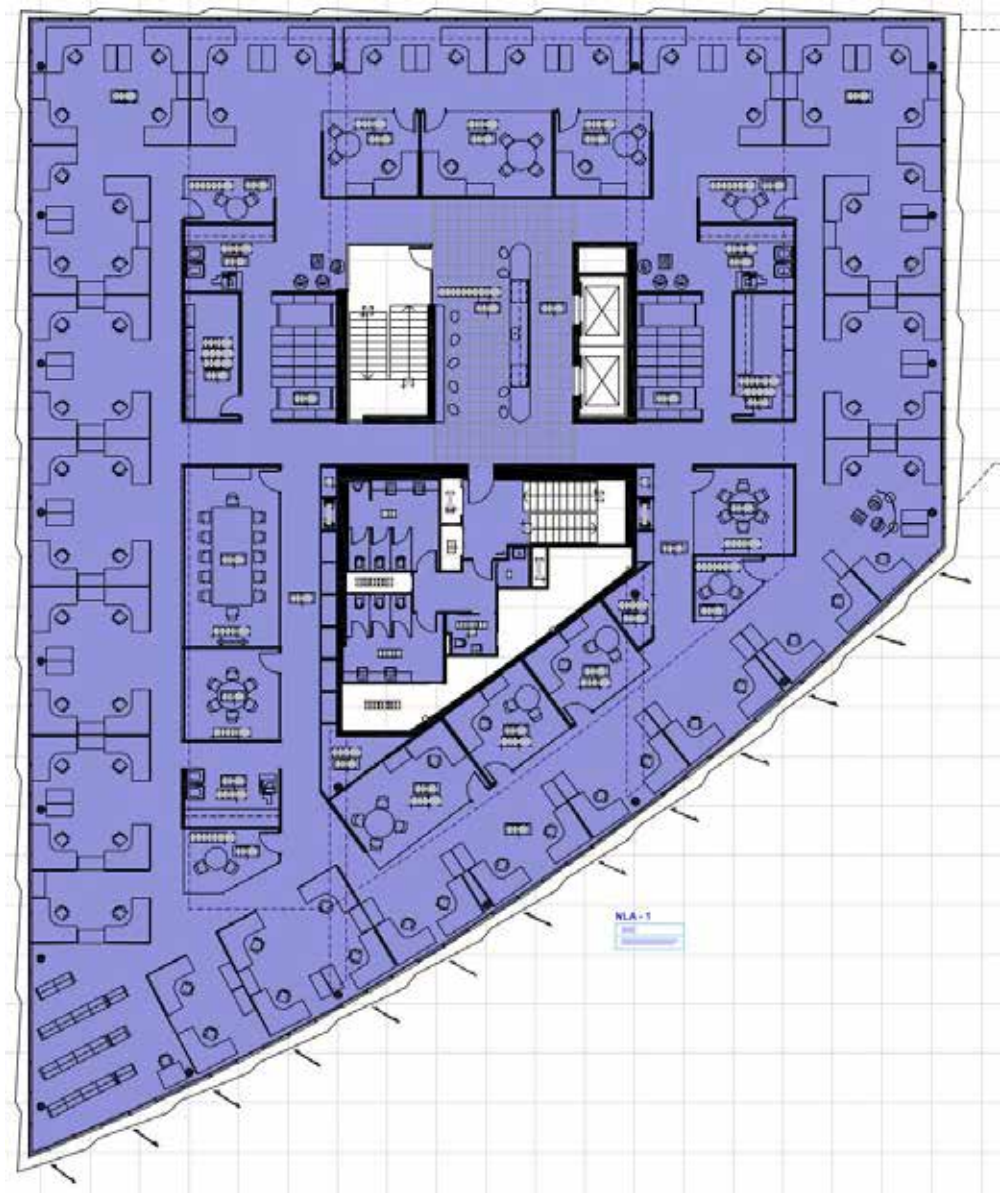
NUA for Floors 3, 4, 8, 9



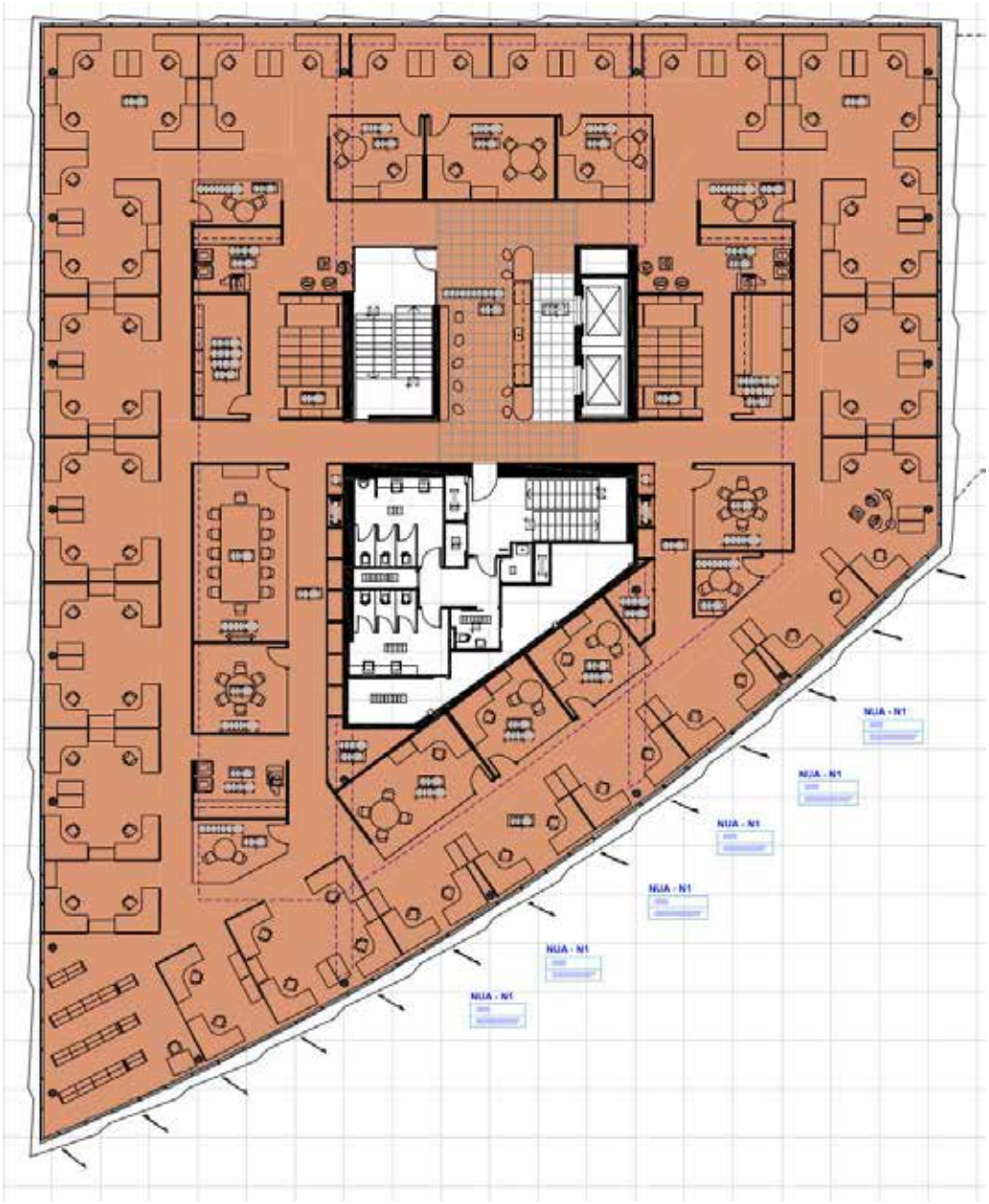
NOA for Floors 3, 4, 8, 9

11.4.2 NZ Customs

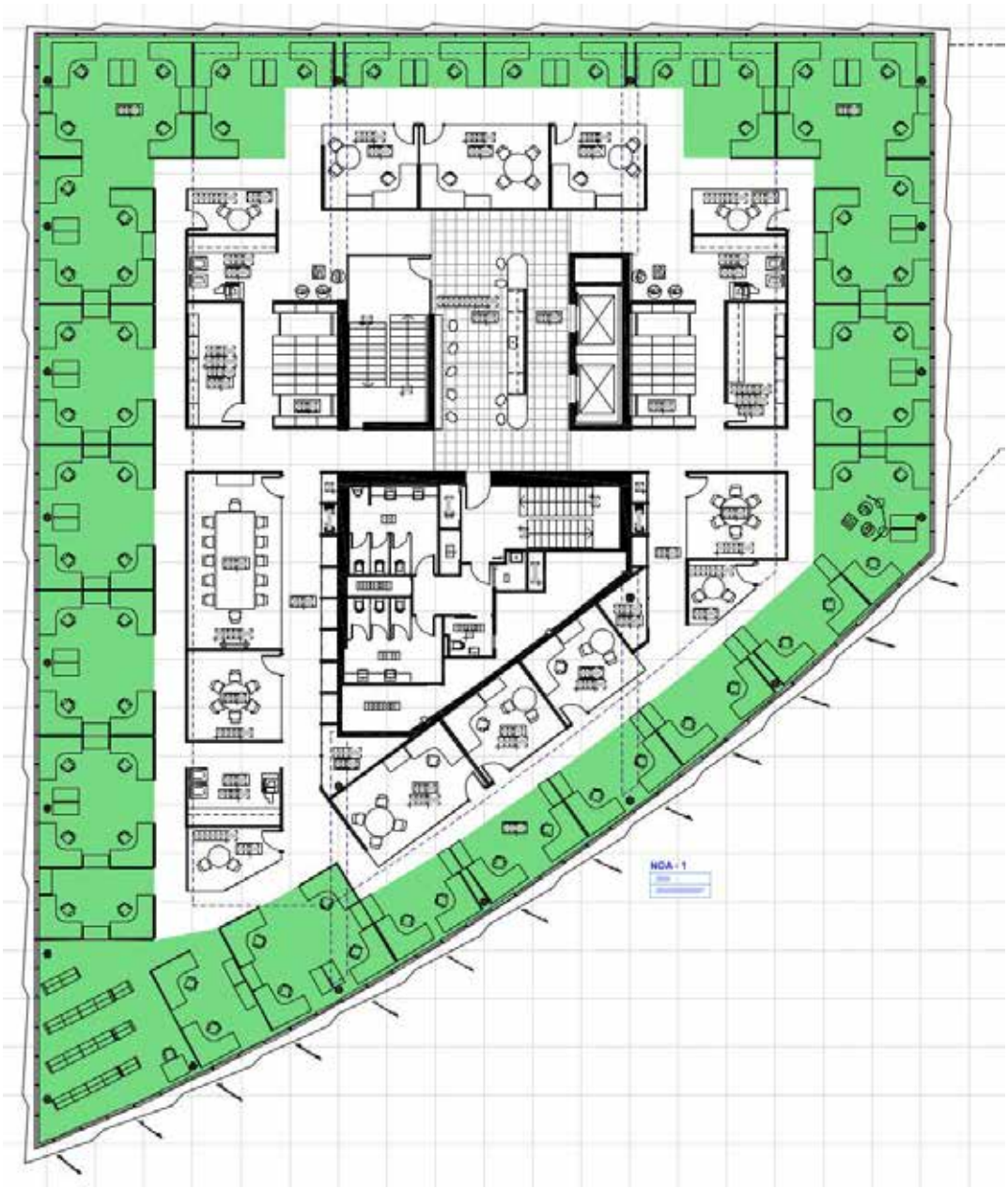
NLA and NUA are identical for both floors.



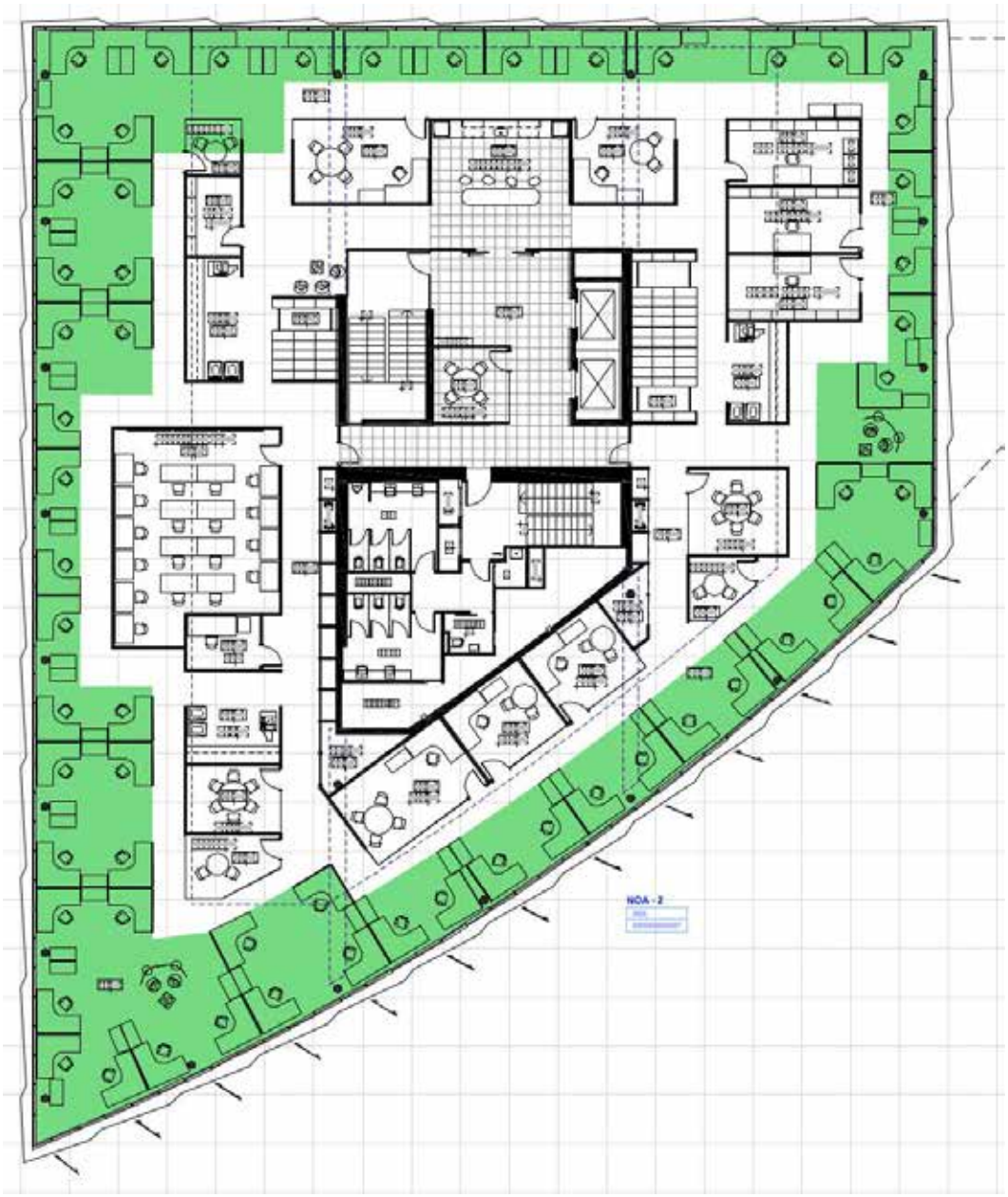
NLA for Floors 3 and 4



NUA for Floors 3 and 4



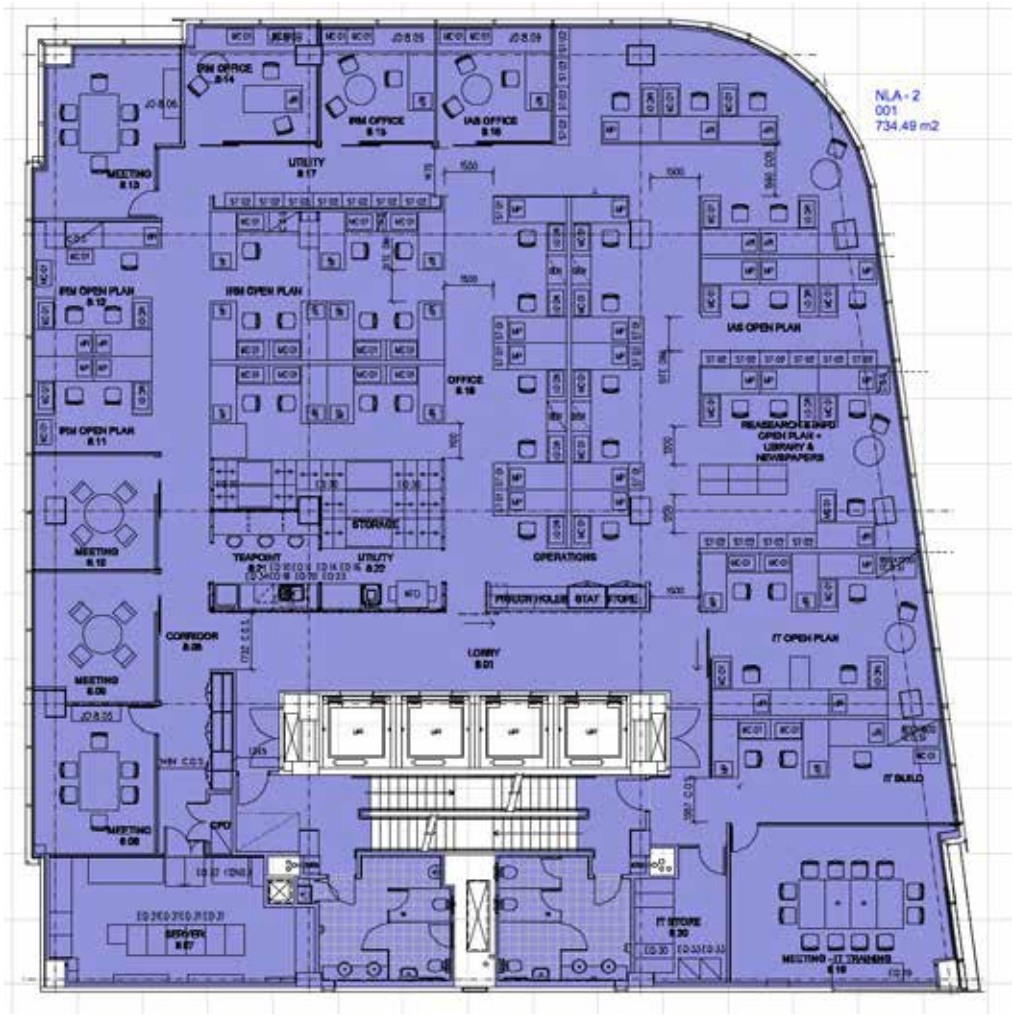
NOA for Floor 3



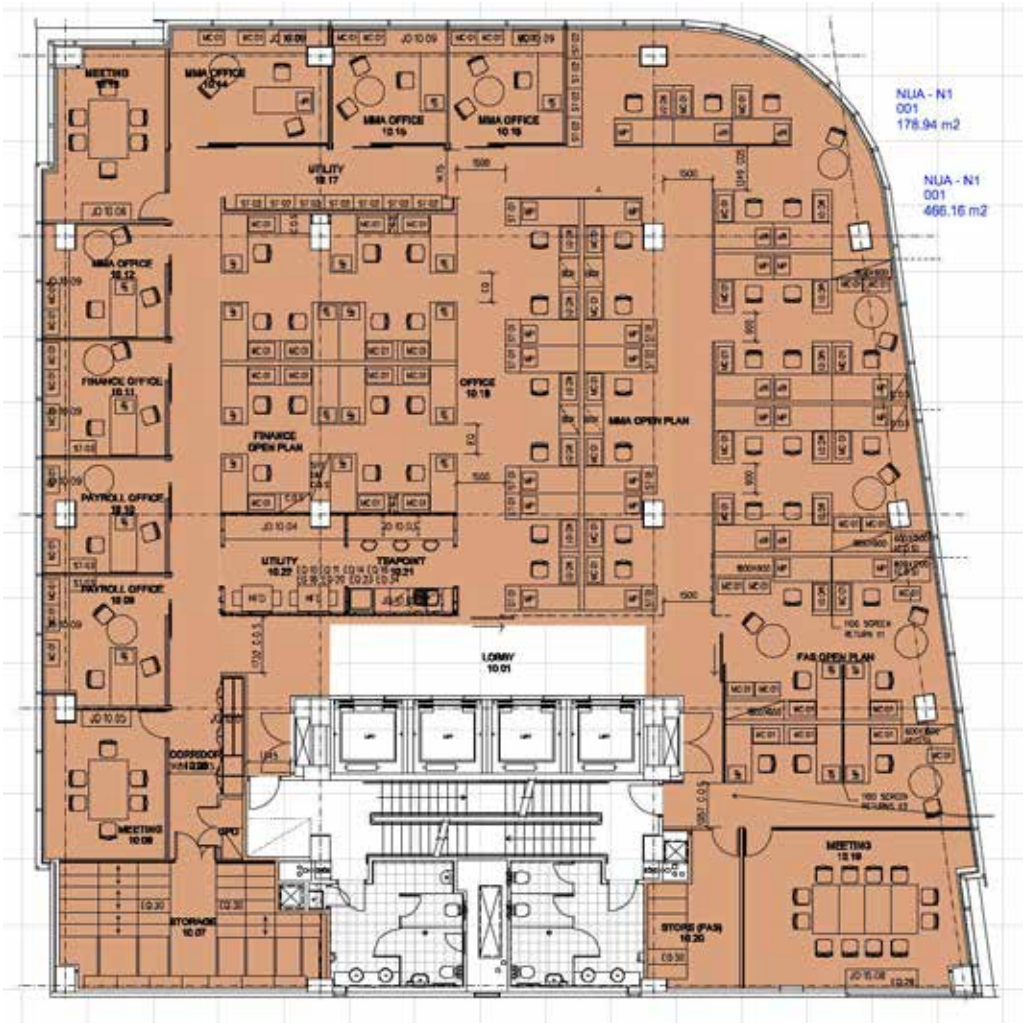
NOA for Floor 4

11.4.3 KPMG

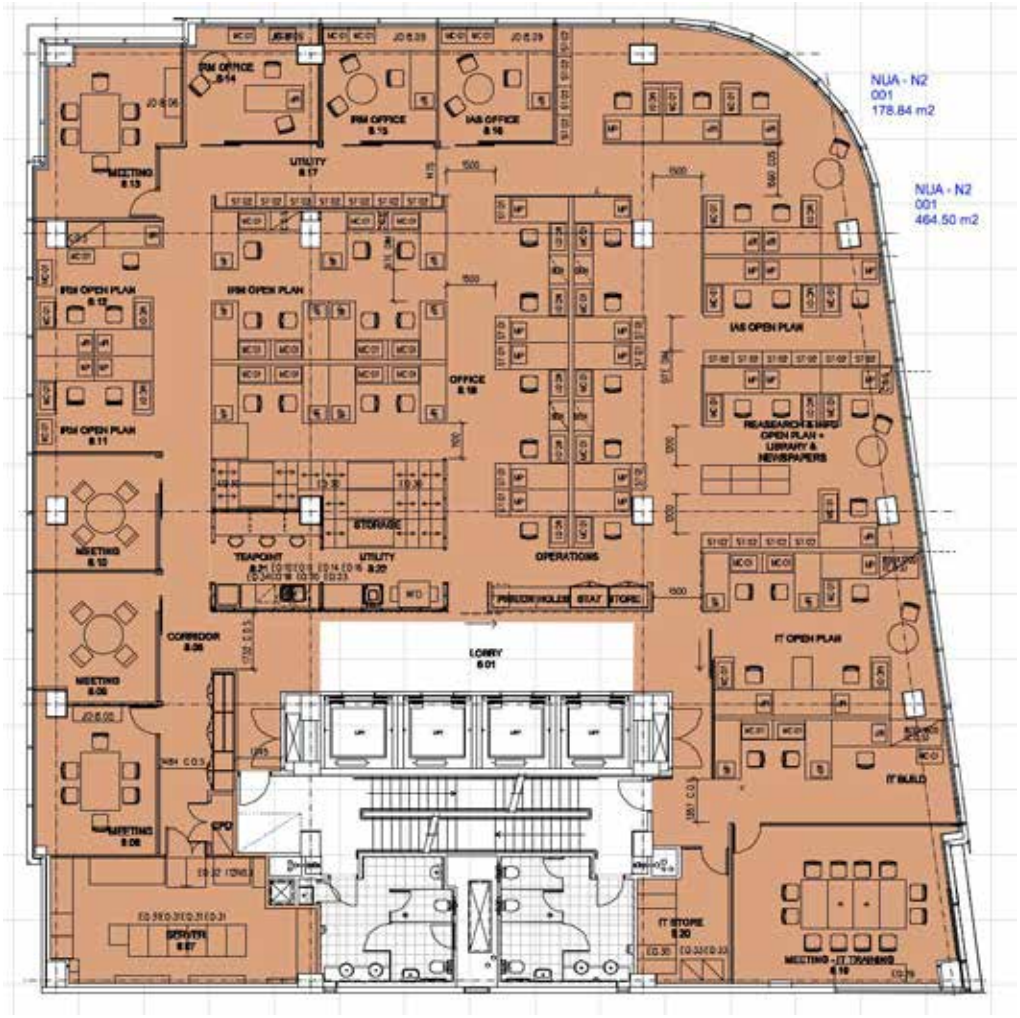
NLA for Floor 7



NLA for Floor 8



NUA for Floor 7

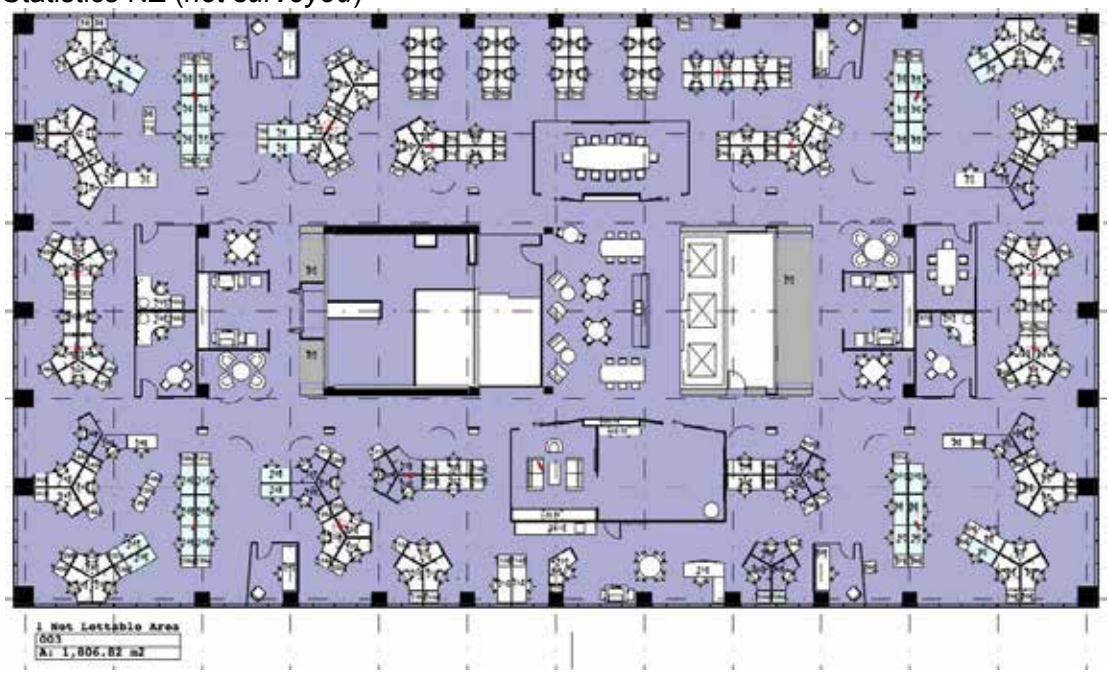


NUA for Floor 8

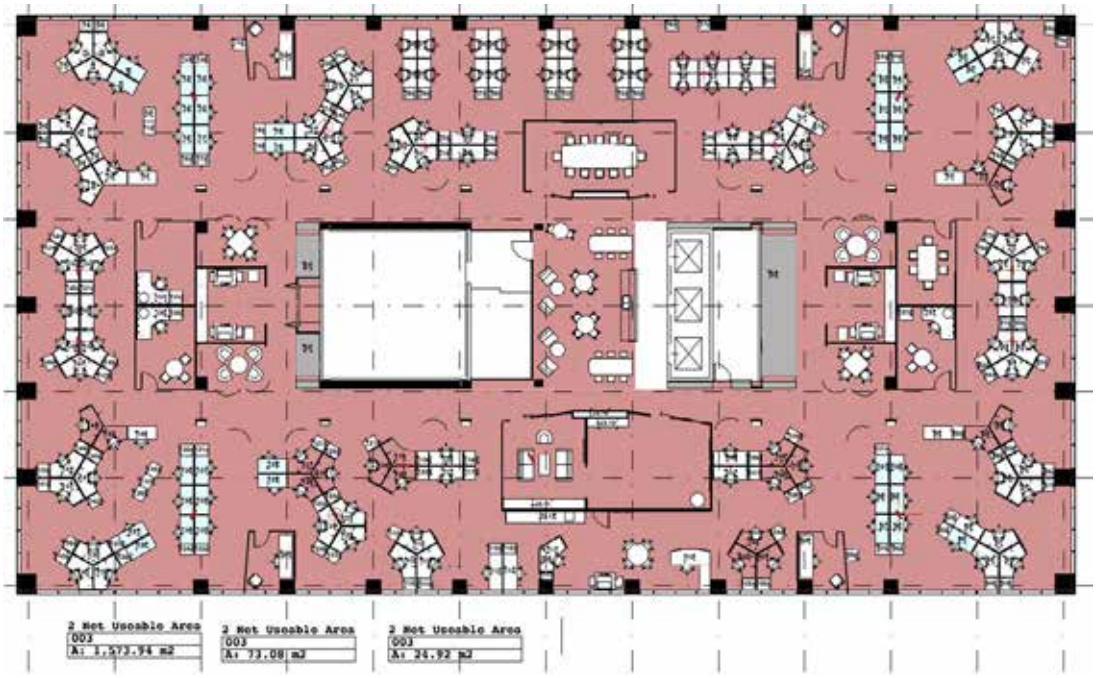
NOA for Floor 7

NOA for Floor 8

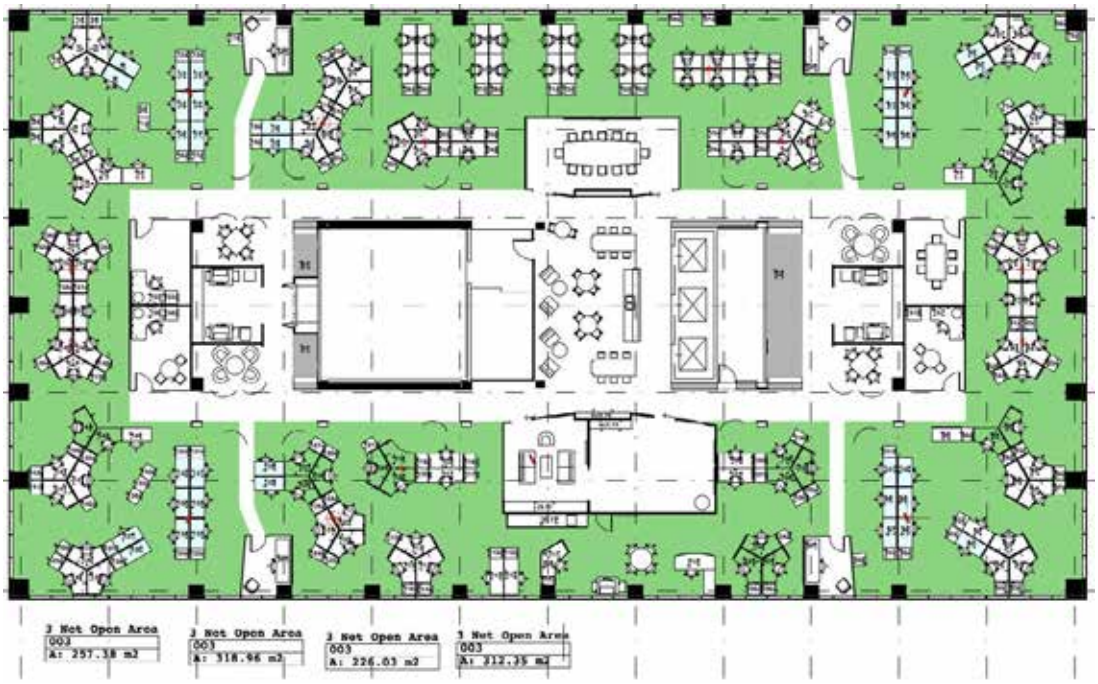
11.4.4 Statistics NZ (*not surveyed*)



NLA

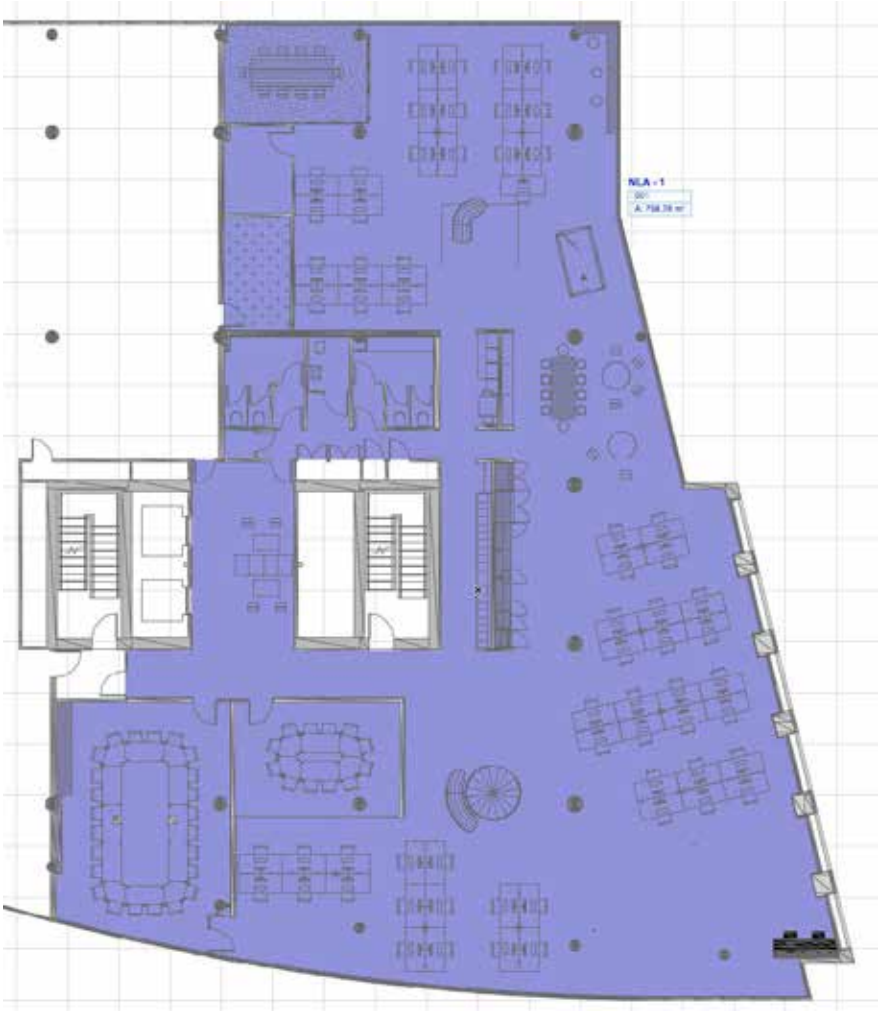

2 Net Useable Area
003
A: 1,573.94 m2
2 Net Useable Area
003
A: 73.08 m2
2 Net Useable Area
003
A: 24.92 m2

NUA

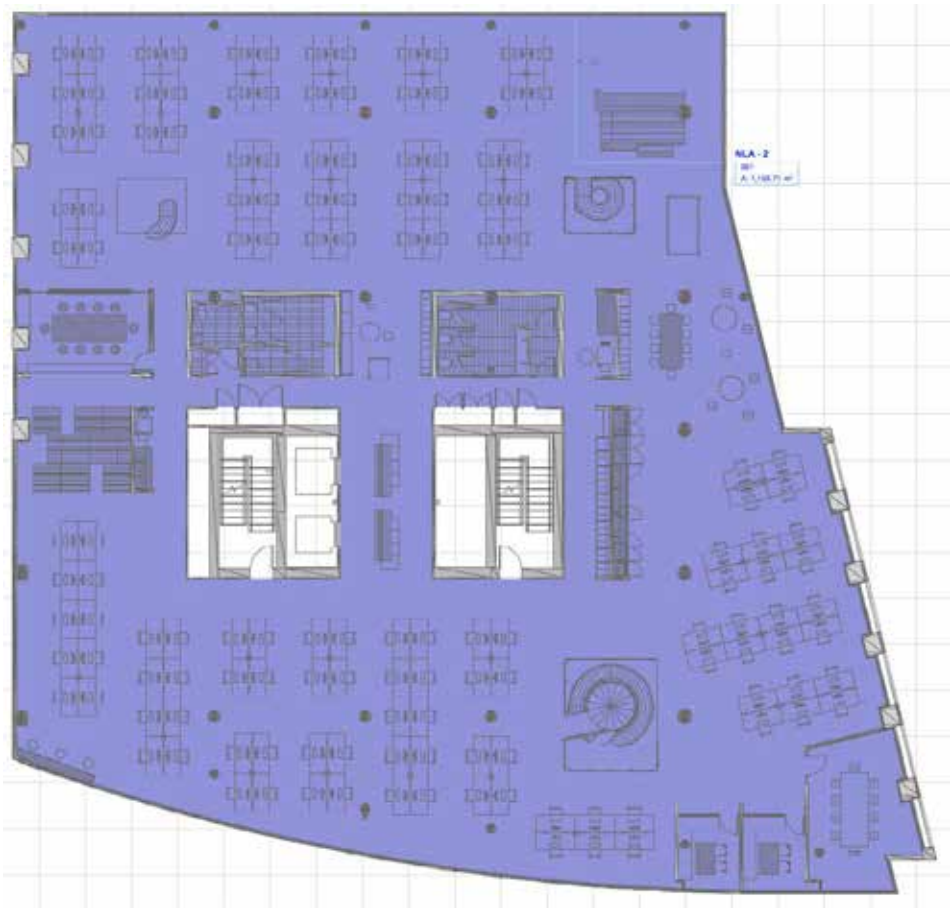

3 Net Open Area
003
A: 257.38 m2
3 Net Open Area
003
A: 318.96 m2
3 Net Open Area
003
A: 226.03 m2
3 Net Open Area
003
A: 212.35 m2

NOA

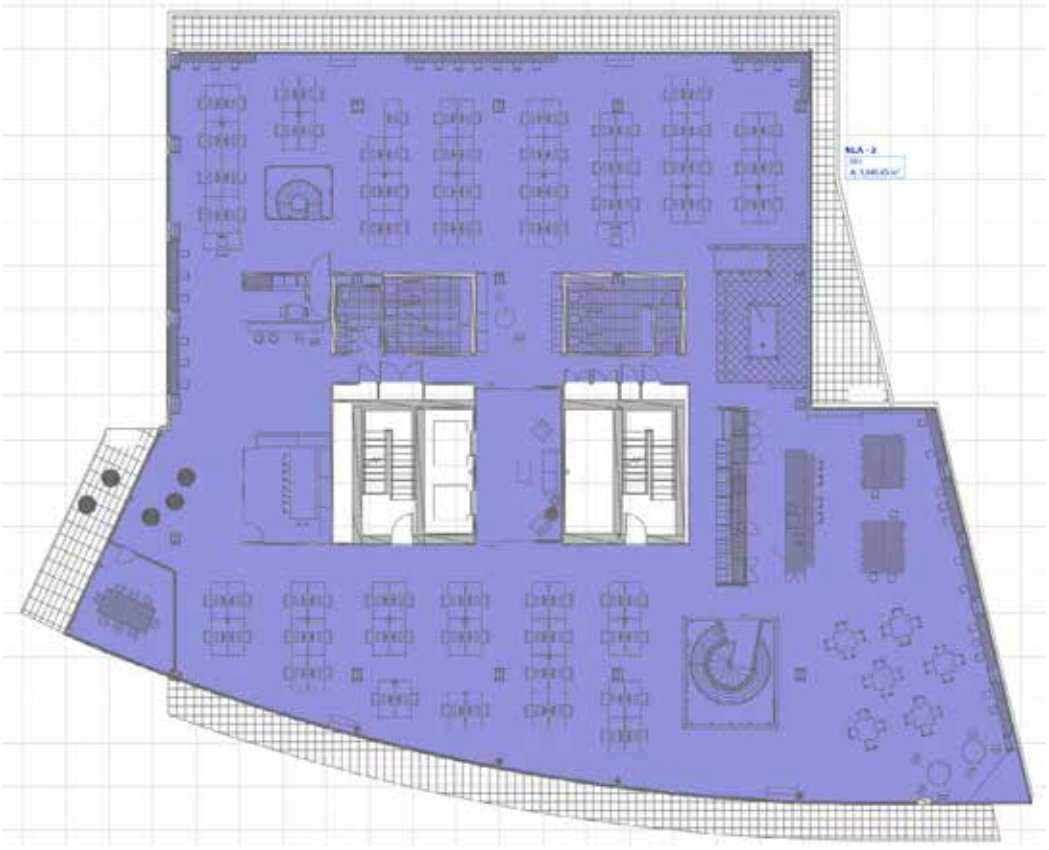
11.4.5 Trademe



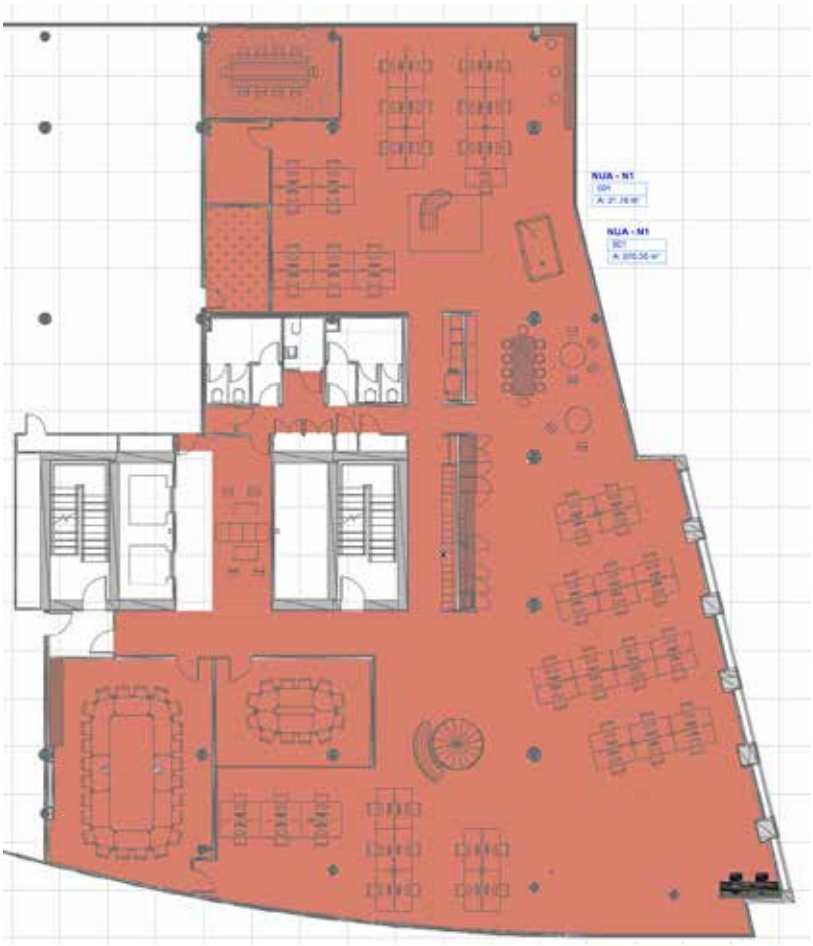
NLA for Floor 3



NLA for Floor 4



NLA for Floor 5



NUA for Floor 3

NUA for Floor 4

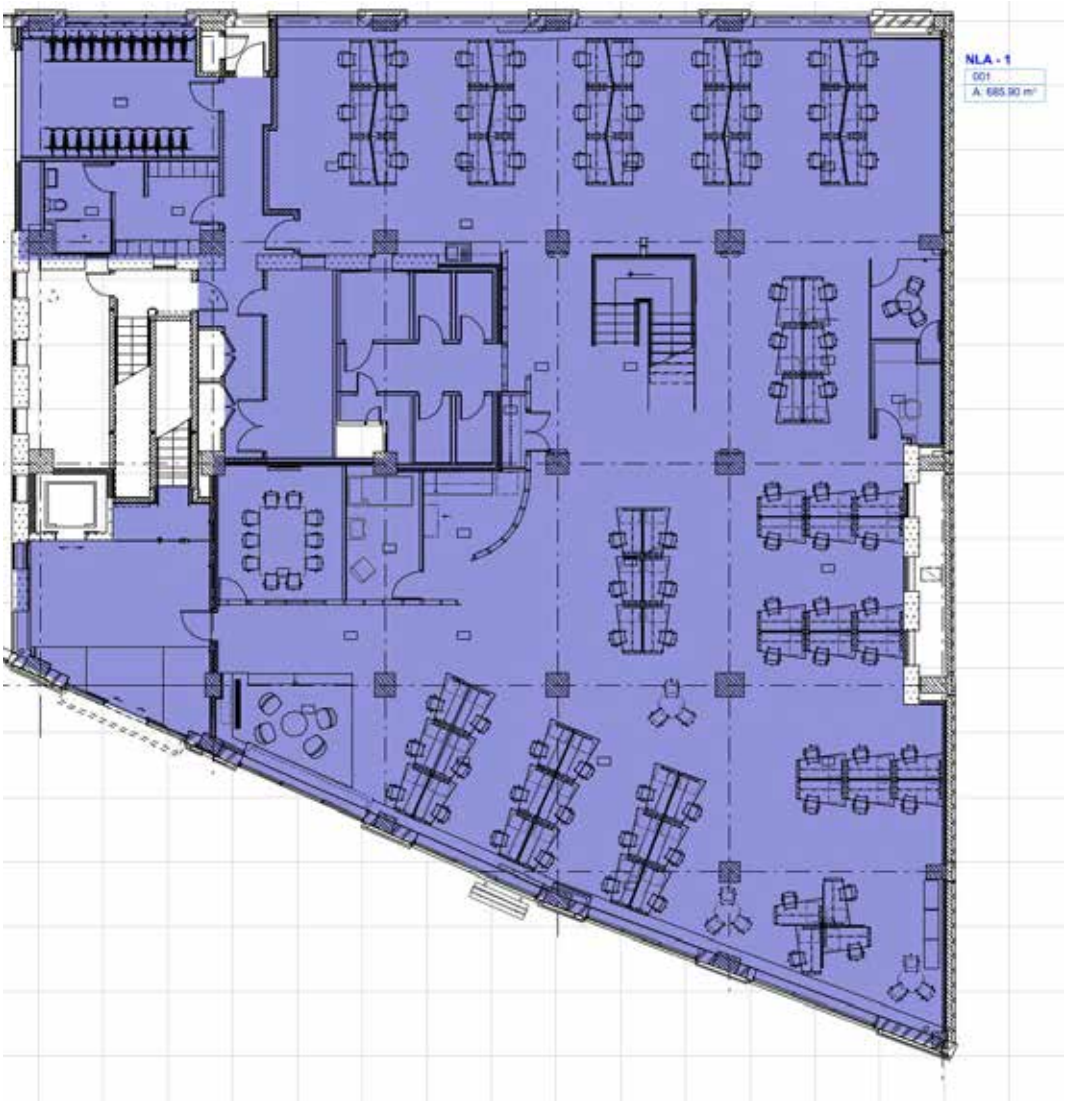
NUA for Floor 5

NOA for Floor 3

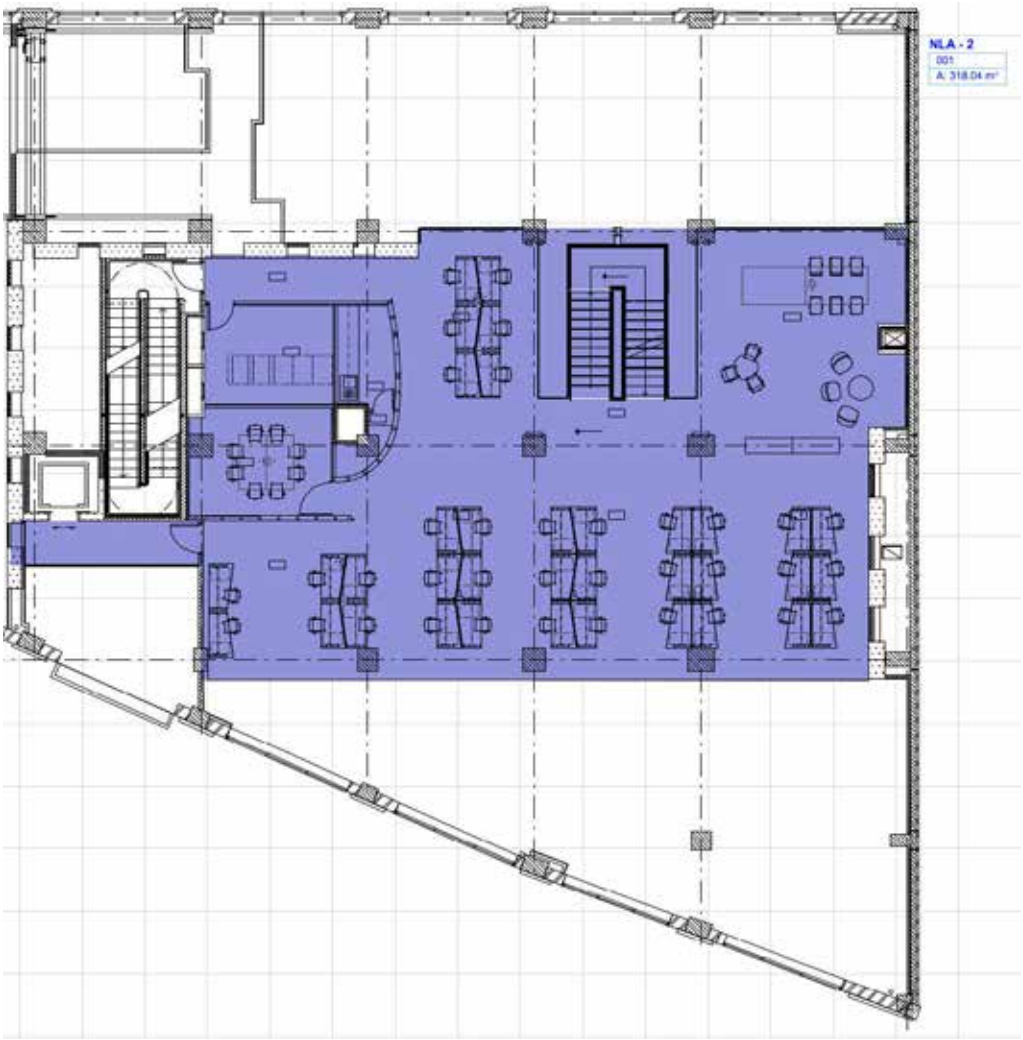
NOA for Floor 4

NOA for Floor 5

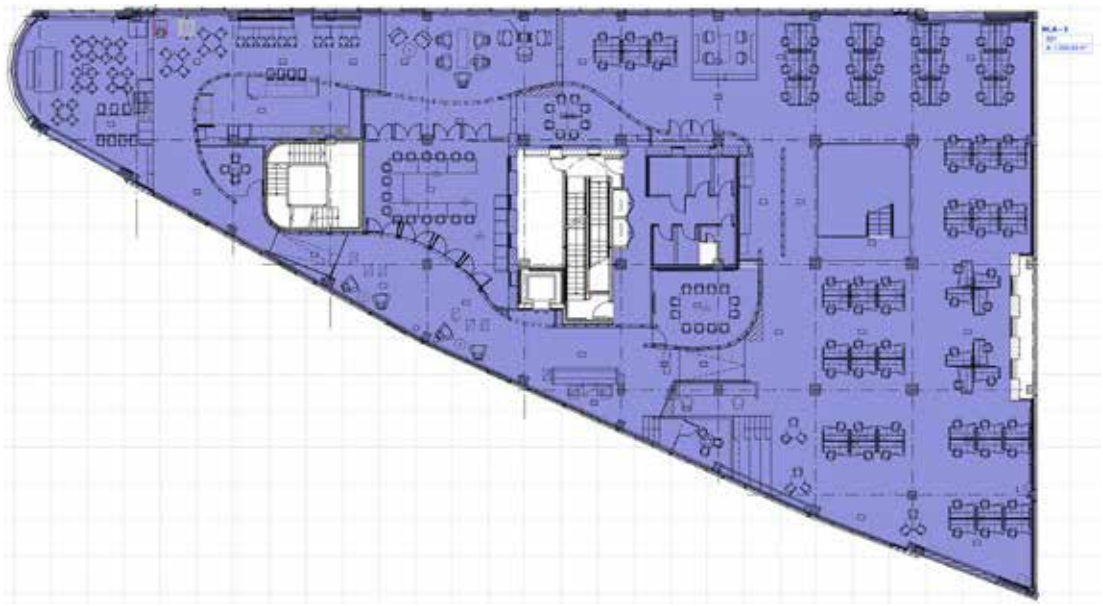
11.4.6 Xero



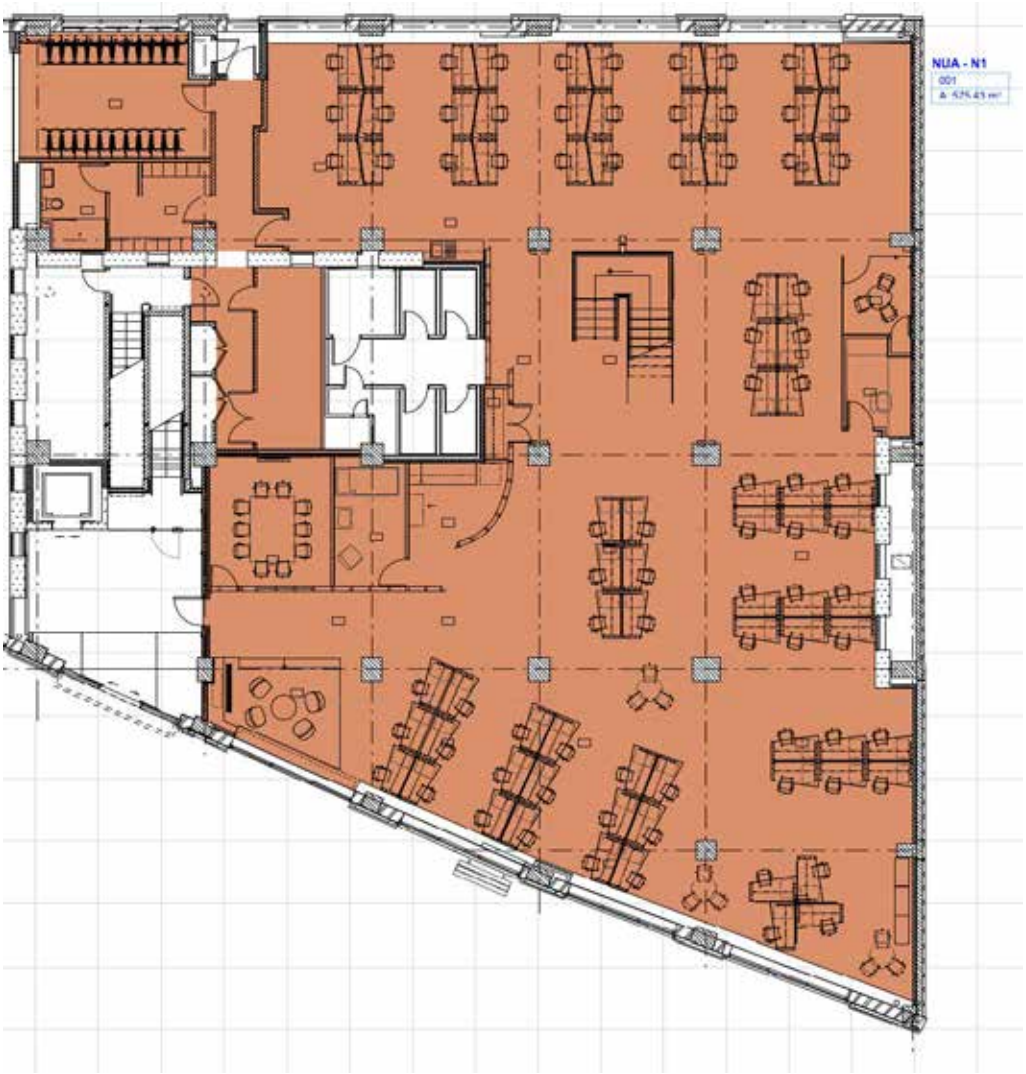
NLA for Ground Floor



NLA for Mezzanine Floor

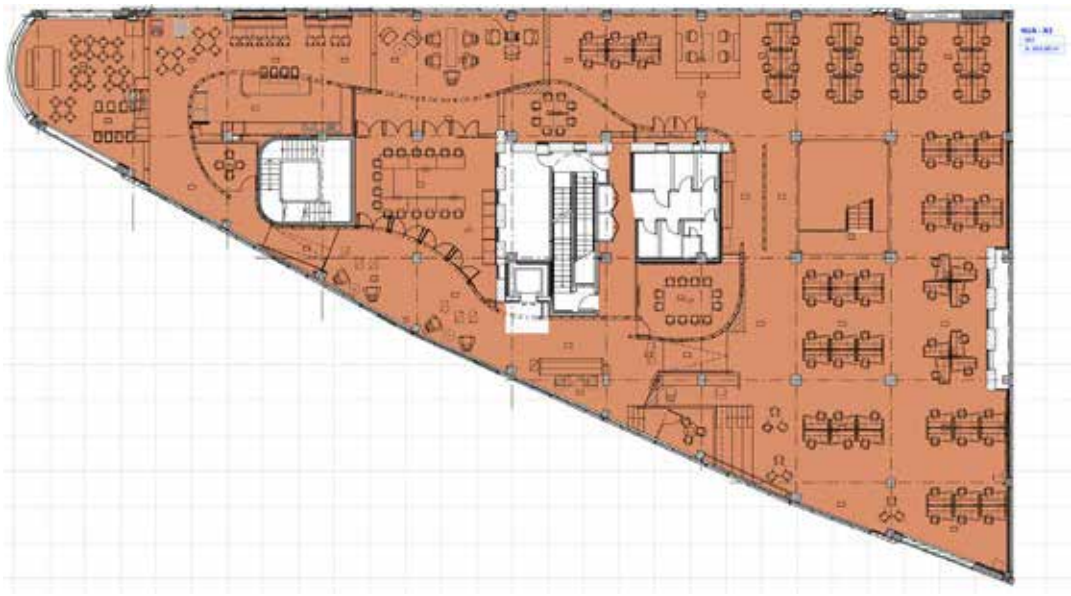


NLA for Floor 1

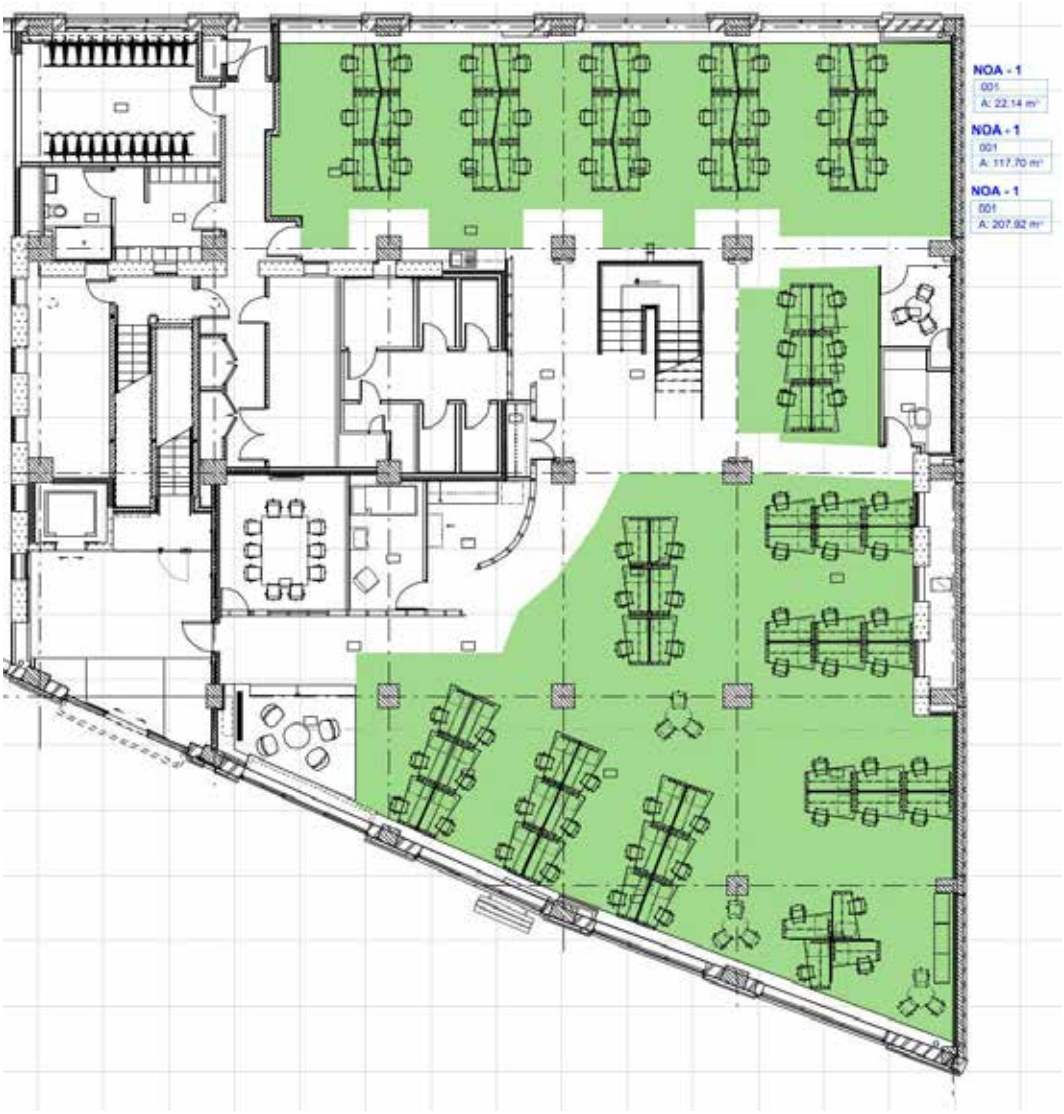


NUA for Ground Floor

NUA for Mezzanine Floor



NUA for Floor 1



NOA for Ground Floor

NOA for Mezzanine Floor

NOA for Floor 1