Space Syntax, Urban Transformation and Liveability
A Campus Case Study

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Abstract: University campuses frequently occupy the leading edge of urban development, with sustainability as an increasing driver (Leal Filho, 2012). A university campus thus represents a useful 'living laboratory' to understand the formation and transformation of built form, towards more sustainable outcomes. The main campus of the University of New South Wales (UNSW) in Sydney, Australia was the focus of a space syntax study in 2007, during a wider project which examined landscape, microclimate and other quantitative and qualitative properties from an environmental and liveability perspective (Osmond, 2010b). The following decade saw significant changes to the campus fabric, affecting both buildings and public realm. This paper discusses the reapplication of space syntax to the 2017 UNSW campus, using the accessibility metrics of connectivity, integration and choice (Xia, 2013). The University's central mall was found to retain its status as the core 'people place', easily accessible from all parts of the campus. However, connectivity and integration values suggest that the post-2007 development of student housing has activated what was a poorly resolved area of the University, with potential for further revitalisation. Also after a decade, the campus boundaries have become less integrated, implying a more inward-looking focus. The research results suggest that the longitudinal application of space syntax methods can shed light on the interaction between urban development and liveability (social sustainability), at least for the microcosm that is a university campus. As well as prompting further research, this project has provided a practical knowledge base to help inform future campus development.

1. Introduction

The quality of higher education institutions is typically evaluated by reputation and satisfaction surveys, research outputs and student retention and graduation rates, which are influenced not only by academic factors but by the perceived quality (summarised here as *ambience*) of their campuses (Hajrasouliha and Ewing, 2016, Painter *et al.*, 2013). Ambience can be seen as one indicator of liveability and the social sustainability of buildings and urban environments. It refers to the experienced and perceived physical and psychological qualities of the environment and results from a complex composition of physical, physiological, psychological, sociological and cultural criteria (Osmond, 2007). Quantification of such qualities, where practically achievable, can inform both evaluation and design of built form.

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Space syntax is one such quantitative and evidence-based approach to explore the relations between urban form occupants/participants and their physical environment. Its basic principle is that the architectural structuring of space creates the material preconditions for patterns of movement, encounter and avoidance (Hillier and Hanson, 1984). Space syntax by definition concentrates on *configuration*, which provides "a partial and incomplete view of the relations between human beings and their created environments" (Hillier and Stutz, 2005: 12). Attributes such as building materials and design features, vegetation and microclimate are also part of what creates place out of space, but fall outside the space syntax system boundary; on the other hand, space syntax methods facilitate quantitative measurement of ambience attributes such as accessibility, walkability, permeability and integration or segregation of spaces across a physical environment (Charalambous and Mavridou, 2012).

The main campus of the University of New South Wales (UNSW) in the Sydney inner suburb of Kensington was the subject of a space syntax case study in 2007. Unsurprisingly after a decade, there have been significant changes in the campus fabric, and also in space syntax methodology and software capabilities. The objective of the present project is to revisit the space syntax analysis of the campus in the light of the extensive campus development over the past decade, to establish a recent knowledge base which can support further ambience-related research and additionally, may help inform future campus development.

The UNSW Kensington campus is located on a 38-hectare site about six kilometres south-east of the Sydney CBD, and as at 2018 accommodated close to 50,000 enrolled students and 6000 teaching and operational staff. The campus is characterised by dense built form, with buildings predominantly of four to eight storeys, a tight network of pedestrian and shared pedestrian/vehicular circulation and approximately 70% impervious surfaces (roofs and paved areas). Buildings are typically of concrete or brick construction, aligned along an east-west/north-south grid with an orthogonal pattern of open space between buildings. The site is bounded by, and morphologically strongly differentiated from, residential areas to the east, south and west, and a major racecourse and ancillary equestrian facilities to the north (Osmond, 2010a).

Leaving aside the many small and large refurbishments of existing buildings, major campus development projects from 2007 to 2017 comprised the following (see also Figure 1).

1. 2009: New College Village postgraduate student housing, including shared apartments and individual self-catered studios for over 300 residents.
2. 2010: 1021-bed UNSW Village student housing, replacing a number of single storey fibre cement buildings which housed administrative/operational and some teaching functions.
3. 2010: Six storey, 17,000 m² Lowy Cancer Research Centre.
4. 2011: Single storey double height Solar Industrial Research Facility.
5. 2012 Five storey, 15,000 m² Tyree Energy Technologies Building.
6. 2014: Reconstructed Kensington Colleges student housing, four to eight storey medium density buildings accommodating 900 students.
7. 2015: Eight storey, 23,500 m² Material Science and Engineering Building
8. 2017: Nine storey, 21,730 m² Biosciences Building Stage 1

Overall, the campus has become denser and more "urban", to accommodate a growing student population within fixed spatial boundaries.

2. Theoretical and conceptual framework

Space syntax both as a theory and a set of practical methods and techniques focuses on the architectural *configuration* of space, whether at building or city scale. Configuration refers to the "act of turning the continuous space into a connected set of discrete units" (Bafna, 2003: 17). Space syntax analysis provides the tools to describe, explain and interpret configured, inhabited spaces so their underlying social logic can be explained (Bafna, 2003). Space is first subdivided into two nonhierarchical classes, two-dimensional convex spaces and one-dimensional axial lines. A convex space is identified where "all points within that space can be joined to all others without passing outside the boundary of the space" (Hillier, 1988: 68), or from the observer's perspective, a space such that any two people located anywhere in that space can see each other. An axial line, on the other hand, may be understood as a line along which any two points are mutually visible.

Hillier points out that "people move in lines, interact in convex spaces, and experience space as a series of 'isovists'" (Hillier, 1998: 38). The isovist (Benedikt, 1979) – essentially the *visual field* – represents a third geometric element used in space syntax, for example as applied in visibility graph analysis (Turner, 2001).

The convex map decomposes open space into the least set of "fattest" convex spaces, i.e. in relation to their area: perimeter ratio; the axial map comprises "the least set of longest straight lines of sight and direct access" which pass through all the convex spaces (Hillier, 1993: 21). The topological *graph* associated with the axial and/or convex map is used to generate a series of metrics which form the basis of "classic" space syntax analysis. The values of these graph-based metrics are re-applied to the axial or convex *map*, and typically visualised as colours or intensity of grey scale (as here) and/or presented in tables.

These metrics provide a means of describing a space, for example a street or room, in terms of its position in the extended spatial network, and also to explain it *functionally*. Each space contributes to how all the spaces in the system affect one another, hence a global order emerges from local properties. In space syntax, the axial graph treats the lines of the axial map as nodes and the intersections as edges. Three commonly applied metrics are connectivity, integration and intelligibility, which may be calculated for an individual node (e.g. axial line) or averaged over the system as a whole. Table 1 lists the specific space syntax metrics used in this research.

Table 1. *Common space syntax metrics applied in this project.*

Metric	Description
Connectivity	A local measure of the number of axial lines directly accessible from a given axial lines, which generally equates to the number of street intersections.
Integration	Calculates the degree to which an axial line (street) is integrated with or segregated from the whole system (global or 'radius n' integration) or from a partial system consisting of streets a set number of steps away (local integration, often r3 = three steps).
Intelligibility	A measure of the correlation between connectivity and integration, used to estimate the predictability of the global structure of an environment through interpretation of its local configurational properties.
Choice	Choice measures movement flows through spaces and can help predict vehicular and pedestrian movement potential. Spaces located in shortest paths from all origins to all destinations will show high global choice.

3. Methodology

Axial maps of the UNSW campus were drawn as a separate layer on 2007 and 2017 AutoCAD plans of the campus, validated through fieldwork and analysed with the Depthmap space syntax software to generate data relating to connectivity, integration and choice, as defined above. UCL Depthmap 7.12 (Turner, 2007) was used for the original 2007 analysis; to ensure consistency, the 2007 axial map was re-analysed using a more recent version, Depthmap X (Varoudis, 2012), together with the 2017 axial map.

The UNSW campus includes pedestrian-only and shared pedestrian/vehicular routes, so separate analyses were conducted for the total movement network and the shared network in both 2007 and 2017. The *intelligibility* of the overall network and the shared vehicular/pedestrian routes was also calculated, as per Table 1 above.

Direct connections through building ground floors were included, and walls or fences where gates are normally kept closed were regarded as barriers. On the other hand, "desire lines" – unofficial shortcuts across lawns or other areas of open space – were ignored in the analysis.

An additional dataset collected in 2017 which was not considered in 2007 is the disability access through the campus, which includes the vehicular circulation network, some of the shared network, dedicated links through existing buildings and ramp access adjacent to existing stairways.

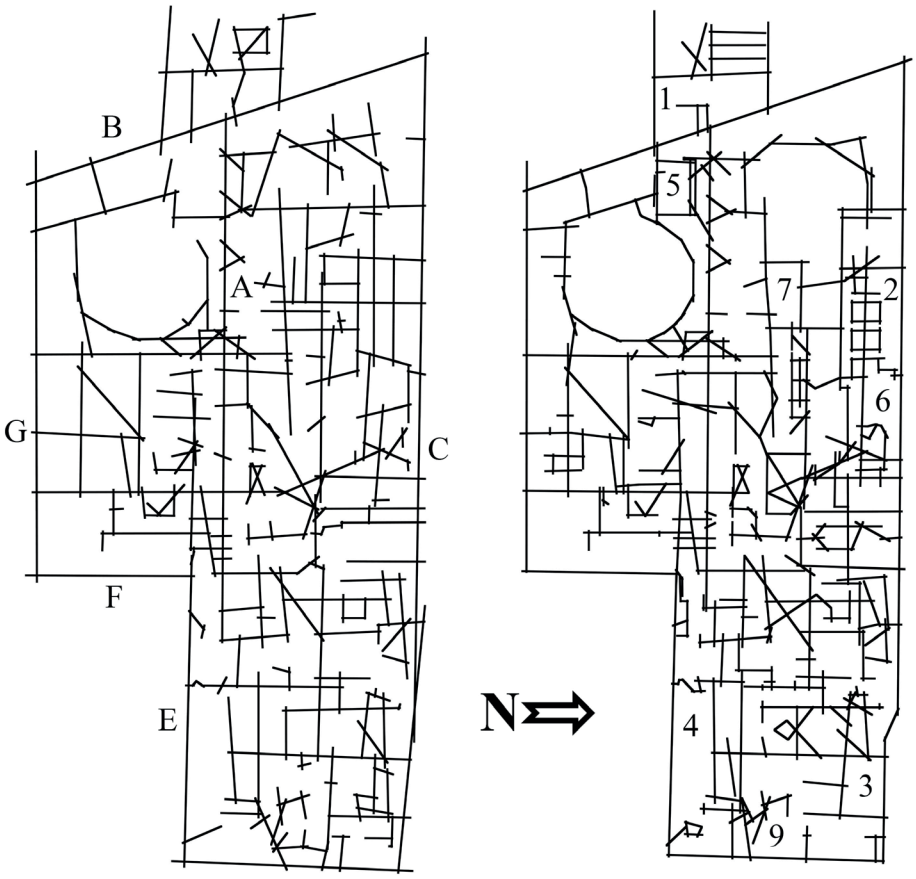

Figure 1. *Axial maps of the UNSW Kensington campus in 2007 (left) and 2017 (right), including both pedestrian-only and shared pedestrian/vehicular routes. The routes referred to in Table 2 below are listed on the 2007 map, and the major development projects discussed above are numbered on the 2017 map.*

4. Results and discussion

As noted above, the assessment focused on connectivity, integration, choice and intelligibility. Routes which have a greater number of intersections (i.e. higher connectivity) are shown as black and dark grey in Figure 2; conversely, poorly connected routes are depicted in light grey. The main difference between 2007 and 2017 is the greater number of routes through the campus, reflecting the need to provide access to a variety of new buildings. The most highly connected routes – the roads around the University's perimeter (high vehicle connectivity), the central pedestrian mall (highest pedestrian connectivity) and several shared north-south routes – remain much the same over the decade. On the other hand, fewer shared routes and more pedestrian-only paths are evident as the University has become physically denser and its student population has grown, particularly around the student accommodation to the north of the site.

Figure 3 depicts the degree of integration or segregation of the campus shared and pedestrian-only routes in 2007 and 2017; again, darker lines indicate more integrated spaces. Numerous space syntax studies have demonstrated that integration strongly correlates with the co-presence and observed movement of people (or, in the case of vehicular routes, cars) (Haq, 2003, Penn, 2003). More integrated spaces facilitate social *encounter* within an environment.

The UNSW campus grid, including pedestrian-only routes is relatively well integrated, with more segregated pathways providing access to individual buildings and other destinations. This contrasts with the University's less well integrated shared route structure, which was designed to allow vehicle access for deliveries and access to multi-storey perimeter parking without compromising the pedestrian setting. The most integrated pedestrian spaces are the campus central mall, Anzac Parade to the west and High Street to the north of the site. These streets interface with 10 pedestrian and vehicular access points to the campus (nine from High Street), which help to channel the movement flow between the University and the outside world. Notably, the number of High Street intersections with both campus and race course fell from 18 to 12 and the integration value decreased between 2007 and 2017, as new buildings along the campus boundary were constructed over previous pedestrian paths.

Another feature of the 2017 space syntax analysis was an exploration of disability access at UNSW (specifically, wheelchair access). Figure 4 depicts the axial map of wheelchair access via roads and ramps through the campus. Anzac Parade, High Street and Barker Street (to the south) are the most integrated spaces for vehicles and wheelchair access as they provide the most efficient routes to access the most destinations.

The main change between 2007 and 2017 consisted of a shrinkage of the campus integration core to the area around the central mall and its intersecting routes, as newly constructed buildings replaced former through-routes, and additional segregated pathways were opened up to service the new student accommodation and other projects. As with previous comments regarding changes to connectivity, the overall transition as shown in the integration maps has been towards a more pedestrian-focused campus. An example of this is the emergence of the UNSW Village pathway (Figures 2 and 3) as another high connectivity and relatively high integration value campus route.

One aspect which has not markedly altered is the relative segregation of what is known as "upper campus" (the eastern section) from the rest of the campus. This is a consequence of a 16 metre change in level over approximately 150 metres between "upper" and "lower" campus, which reflects the underlying geology. This change in level has ensured that the main links between the two parts of the campus remain via stairways.

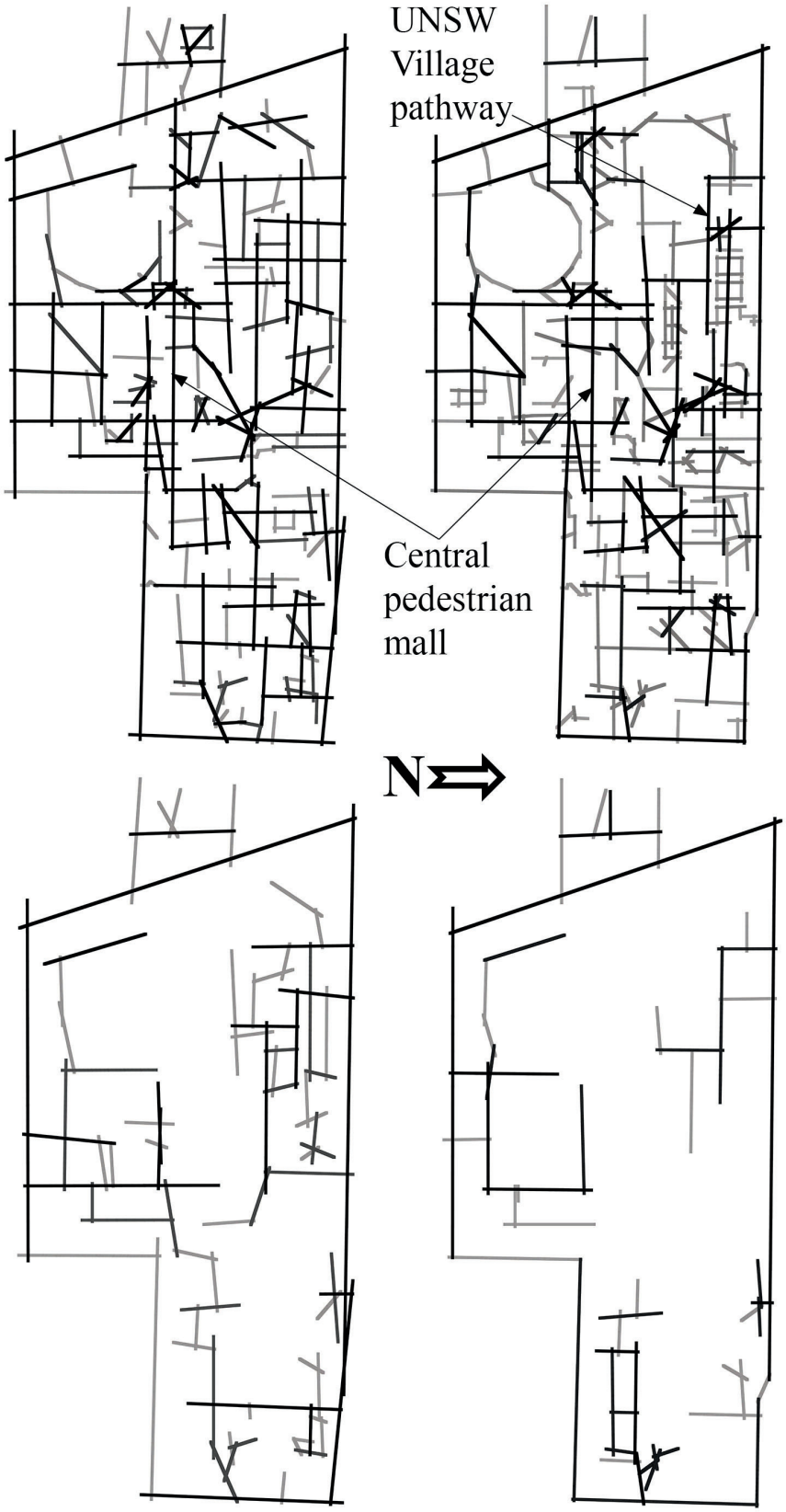

Figure 2. *UNSW campus connectivity. Top left = 2007, top right = 2017, pedestrian only plus shared routes. Bottom left = 2007, bottom right = 2017, shared vehicular/pedestrian routes. Darker lines indicate greater connectivity.*

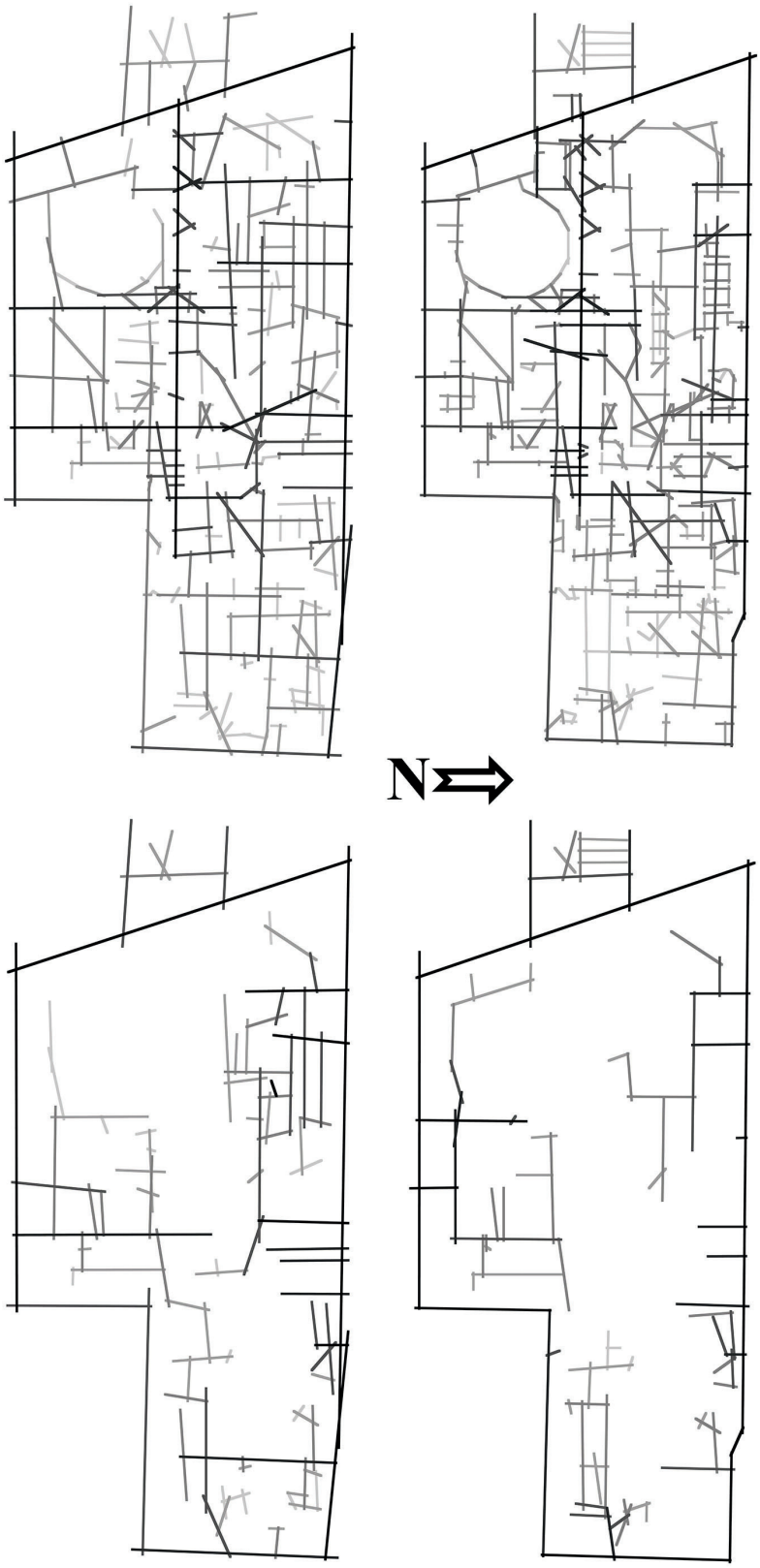

Figure 3. *UNSW campus integration. Top left = 2007, top right = 2017, pedestrian only plus shared routes. Bottom left = 2007, bottom right = 2017, shared vehicular/pedestrian routes. Darker lines indicate more integrated routes.*

Table 2. *Metrics for key external and internal routes (see Figure 1 for location of routes).*

	Spaces	2007		2017		
	Connectivity	Integration	Connectivity	Integration	Choice	
A	UNSW central mall	27	1.63	27	1.94	62891
B	Anzac Parade	8	2.18	9	1.90	47591
C	High Street	18	2.31	12	1.88	59146
D	Botany Street	5	1.60	7	1.33	20112
E	Oval Lane	6	1.50	6	1.35	18790
F	Willis Street	2	1.62	3	1.44	7722
G	Barker Street	8	2.02	6	1.65	15661
	UNSW Village pathway	N/A	N/A	17	1.33	13484

Table 2 indicates the values for connectivity, integration and choice for a set of key external and internal movement corridors. As noted in Table 1, choice measures predicted movement flows through spaces; this metric was not obtained for the 2007 data. The central mall and High Street show the greatest choice; certainly the observed pedestrian flows along this route reflect the high value calculated for this metric.

5. Conclusions

The objectives of this project were first to compare and contrast the UNSW Kensington campus of 2007 with the denser and more urbanised 2017 version, and second to develop a space syntax database of the campus to help support further research and to provide an input to the campus development process.

The main findings of this study include:

- The most highly integrated campus spaces in both 2007 and 2017 coincide with observed pedestrian and vehicular movement, with the University's central mall being a core example.
- Between 2007 and 2017 integration values fell for campus's bounding streets but increased for the central mall. This emphasises the importance of the mall as the 'heart' of the university, which is not merely a movement corridor but a destination for events such as markets and entertainments.
- However, it is noteworthy that the mall does not extend to the eastern end of the campus, which arguably contributes to the discernable segregation of the upper campus from the lower.
- Nevertheless, the upper campus precinct has become more integrated internally, likely as a result of clearer demarcation of pedestrian and vehicular movement corridors consequent on the construction of new buildings over the past decade.
- The analysis also indicates the presence of another arterial route, the UNSW Village pathway. This route is related to the residential part of the campus; its high connectivity and relatively high integration correlate with the social activities happening there already and point to the potential for additional placemaking in and around this space.

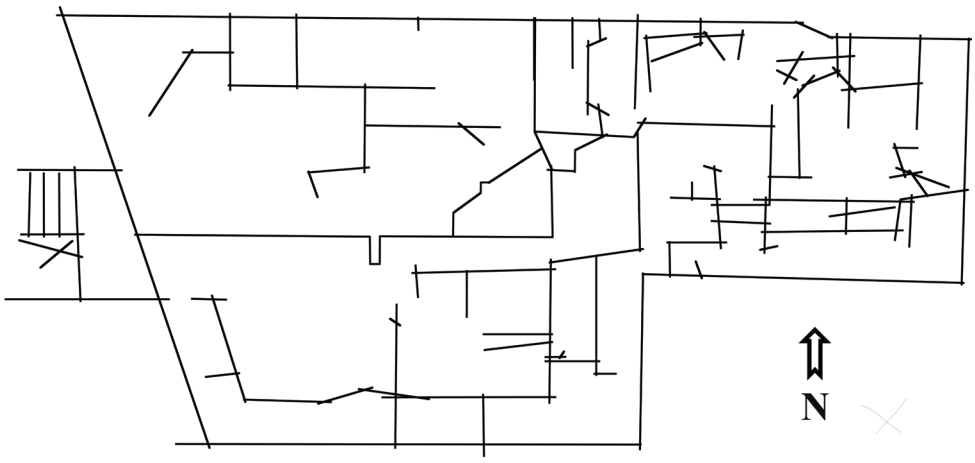

Figure 4. *Axial map of wheelchair access in and around the UNSW campus.*

– While the main campus routes are accessible, wheelchair access to the "fine structure" of the campus is heavily reliant on lift access and could be improved.

As noted in Table 1, intelligibility, the correlation between connectivity and integration, provides a measure of the predictability of the global structure of an environment through interpretation of its local configurational properties. Intelligibility assumes that cognition of small-scale spaces both precedes and facilitates cognition of large-scale spaces (Jiang *et al.*, 2000) – or what *can* be seen is a good guide to what *cannot* be seen (Hillier, 1996). This investigation found a relatively low level of intelligibility for the campus as a whole (and particularly for the shared pedestrian/vehicular system) in both 2007 and 2017. In other words, the local spatial structure is not particularly predictive of the global. The overall effect is not conducive to efficient wayfinding, which is consistent with the lived experience of the UNSW campus. On the other hand, the central mall is relatively more intelligible and individuals using this route can more easily orient themselves to the campus as a whole.

The project confirms that space syntax can provide valuable quantitative tools to illuminate the broadly qualitative relationship between the physical environment and human inhabitation of space, considered here as *urban ambience*. Further, longitudinal application of the methodology can shed light on the interaction between urban development, *liveability* (spaces which encourage human co-presence and interaction) and *sustainability* (reduction of vehicle use and improved pedestrian movement), taking the university campus as a microcosm of urban form more generally. There is, however, the proviso that a university campus is frequently developed on a single lot, so the circulation network is far more susceptible to modification than that of a typical precinct of similar size. But in summary, space syntax offers urban morphologists another useful way to understand the formation and transformation of built form, potentially with a view towards more sustainable planning and design outcomes.

As always, more questions could be asked, including how UNSW staff, students and visitors actually use and navigate the campus spatial network. So as with much space syntax research, the results can be further elucidated through application of qualitative environment/behaviour methods.

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