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Research

A Justified Plan Graph Analysis of the Early Houses (1975-1982) of Glenn Murcutt

Abstract. The Justified Plan Graph (JPG) technique was developed in the late 1970s and refined in the following two decades as a means of undertaking qualitative and quantitative research into the spatial structure or permeability of buildings. Famously used by Space Syntax researchers to uncover the social logic of architectural types, the technique remains an important, if not widely understood, approach to the analysis of the built environment. This paper uses the JPG method to undertake a three-stage analysis of the early houses of Pritzker Prize winning architect Glenn Murcutt; the stages are visual analysis, mathematical analysis and theoretical analysis. Through this process the paper offers a rare application of the JPG method to multiple works by the same architect and demonstrates the construction of a series of "inequality genotypes", a partial "statistical genotype" and a partial "statistical archetype" for these houses. Instead of seeking to uncover the social structure of Murcutt's housing, the paper analyses the architect's distinctive approach to ordering space within otherwise simple volumes or forms. The ultimate purpose of this analysis is to offer an alternative space-based, rather than form-based, insight into this architect's work.

Introduction

Architectural design analysis – the investigation of the properties, qualities and ideas found in a specific architect's work – remains almost exclusively focussed on questions of form and tectonics [Gelernter 1995; Frampton 1995; Baker 1996]. While stylistic, phenomenal and semiotic debates still occur about particular buildings, the canonical works of architectural history remain steadfastly focussed on formal properties, revisiting the key volumetric and material qualities of a building until, over time, a seemingly definitive reading of an architect's work has been reached. For example, the works of the Australian architect Glenn Murcutt have, over time, begun to be described in a highly consistent manner. With few exceptions, Murcutt's early rural domestic architecture has been delineated by historians as providing an exemplar of Arcadian minimalism – a rigorous modern evocation of the form and tectonics of the primitive hut. For example, Philip Drew proposes that Murcutt's talent lies in his the capacity to shape "a minimalism that is austere and tough so that all that remains is an irreducible core" [1986: 60]. Rory Spence describes Murcutt's early houses as constituting a clear formal type: "the long thin open pavilion" [1986: 72]. Francoise Fromonot argues that Murcutt's houses are all "variations on the same theme" and that these design "prototypes" represent a "relatively homogenous body of work. An analysis of [which] reveals a number of constants which could be called *characteristic*, analogous to those identifiable in specimens which illustrate a *species*" [2003: 60]. Drew, Fromonot and Spence are not alone in identifying in each of these houses a local variant of a more

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universal type. Yet, despite this apparent accord concerning formal qualities, relatively little has been said about Murcutt's architecture in terms of its spatial structure.

Space is the inverse of form [Ching 2007]; it is defined by walls and controlled by doors. A building form may also shape exterior space, but internal space is completely controlled by form [Unwin 2003]. Given this seemingly contingent relationship, it might be assumed that an analysis of spatial configuration in the architecture of Glenn Murcutt would simply support the more common formal reading. However, despite extensive critique of his buildings from formal, environmental, aesthetic or phenomenal perspectives, the spatial structure of the work remains only superficially described. For example, a number of passing references are made to Murcutt's plans featuring clear separation between served and service zones [Drew 1985, 2001; Beck and Cooper 2002; Frampton 2006]. Other than this general observation, Juhani Pallasmaa is the only critic to comment directly on spatial configuration, when he asserts that for Murcutt, order in form is as important as order in "organising and structuring" space [2006: 19]. He reinforces this point by proposing that Murcutt "doesn't merely aestheticise the human domicile"; he structures his designs to support "a humanised reading and meaning [of] the human condition itself" [2006: 17]. Pallasmaa's assertion is broadly that the rigour and simplicity of Murcutt's formal resolution is reflected in a similarly rigorous and refined spatial structure.

In response to the lack of spatial analysis to complement the existing, extensive formal analysis, the present paper uses the Justified Plan Graph (JPG) method to construct a graphical, mathematical and theoretical analysis of the spatial configuration of the first five of Murcutt's famous rural houses: the Marie Short House, the Nicholas House, the Carruthers House, the Fredericks Farmhouse and the Ball-Eastaway House. These houses were acknowledged in Murcutt's 2002 Pritzker Prize citation as being instrumental in shaping his international reputation. In much the same way that Fromonot [2003] describes these houses as specimens of the same species, in Space Syntax terms, they could be regarded as constituting important local *phenotypes* that represent singular variations of an overarching *genotype*.

While the theory and use of the JPG is well developed [Hillier and Hanson 1984; Hillier 1995], and stable computational versions of the method are available, there are relatively few examples of its application for the analysis of sets of architects' works. This paper seeks, in part, to revive the method through its application in two ways. First, the mathematical potential of the JPG has rarely been applied in longitudinal design analysis in this way and only a small number of precedents exist [Hanson 1998; Major and Sarris 1999; Bafna 1999]. Second, the paper proposes the construction of a simple statistical archetype from the various genotype examples in the longitudinal set. Notwithstanding these variations of the methodology, Murcutt's architecture has rarely been subjected to any form of mathematical or computational analysis in the past. The only exceptions to this include a shape grammar analysis of form undertaken by Hansen and Radford [1986a; 1986b].

In the following section a brief overview of Space Syntax and the JPG method is provided. Thereafter, the three major precedents to this study are considered in order to derive an approach for the research. Once this is outlined, then each of the five houses is described in chronological order, commencing with a traditional historical description before producing a JPG for visual analysis, mathematical analysis and then review. In the penultimate section the results of all five works are discussed together in the context of the set of inequality genotypes as a precursor to constructing a statistical archetype. Finally the conclusion contextualises the results and reflects on Pallasmaa's [2006] claims about the nature of Murcutt's planning.

While only a limited description of Space Syntax and the JPG method is included hereafter, the conceptual, mathematical, and theoretical background to the present paper appeared in the previous issue of the *Nexus Network Journal* (Ostwald 2011). That same paper also includes full worked examples of the method, a complete set of the formulas and an explanation of the nomenclature (i, TD, H^*, etc.).

The JPG method

Space Syntax promotes a conceptual shift in understanding architecture wherein "dimensional" or "geographic" thinking is rejected in favour of "relational" or "topological" reasoning [Hillier and Hanson 1984]. That is, the approach focuses on space, not form, and, more particularly, on non-dimensional qualities of space like permeability, control or hierarchy. This shift in thinking commences with the process of translating architecturally defined space into a series of topological graphs that may be visually inspected, mathematically analysed (graph *analysis*) and then interpreted (graph *theory*) in terms of their architectural, urban, social or spatial characteristics. While Space Syntax research has developed a wide range of possible methods for investigating the built environment, the present paper is only concerned with one approach; the JPG.

The first step in the construction of a JPG is typically the production of a convex map or boundary map. A convex map is a way of partitioning an architectural plan into a diagram of defined spaces or nodes and the connections between them. There are a number of alternative variations of this stage, ranging from the highly proscribed to the very general [Hillier and Hanson 1984; Markus 1993].

The particular method chosen for producing the convex map has a direct impact on the JPG and its results. For example, it is possible for an irregular plan for a small house to require as many as 50 separate convex spaces to fulfil the requirements of the original convex map definition [Hillier and Hanson 1984]. The subsequent JPGs are typically over-convoluted and can be mathematically dominated by the influence of often quite small architectural features. For example, the convex map produced by Major and Sarris [1999] of Peter Eisenman's House 1, has 39 nodes or spaces, while Eisenman identifies only seven functional spaces in the house! By counting every alcove for a built-in bookcase, display stand or wardrobe, and by dividing every section of space visually occluded by, or separated from, another space by a change in corridor width, or location of a blade column or open stair, the number of spaces can increase sixfold. This process artificially inflates the program and alters the actual, inhabited and experienced structure of the house. The more recent methods, as discussed in the next section, are more inclined to associate spaces directly with functional zones, thus reducing the number of nodes and more clearly aligning the JPG with inhabitation patterns [Peponis et al. 1997; Bafna 2003].

Once the convex plan is constructed it is converted into a graph diagram that displays only nodes (rooms) and lines (connections between rooms). This graph is arrayed across a number of levels, starting with zero at the base, regardless of the actual orientation of space in the original building [Hillier and Hanson 1984]. Once completed, the JPG displays levels of connectivity and separation between the root or carrier space, at the bottom of the JPG, and all other spaces. Thereafter, there are three common ways to approach the JPG.

First, a JPG may be graphically or visually analysed to uncover a range of qualitative properties of the spatial structure, including relative asymmetry, spatial hierarchy (arborescent qualities) and permeability (rhizomorphous qualities). The majority of the examples of this approach to the JPG are concerned with "inhabitant-visitor relations" and they rely on the production of JPGs with the exterior as carrier [Marcus 1987, 1993; Dovey 1999, 2010]. Despite this, a small number of examples of visual analysis have used multiple carriers and visual archetypes to investigate the properties of space [Alexander 1966; Ostwald 1997].

Second, the JPG may be mathematically analysed as a complete system. The formulas for this process may be found in a range of places [Hillier and Hanson 1984; Osman and Suliman 1994; Hanson 1998] as well as in several software tools (Depthmap; AGraph). From this analysis it is possible to develop a set of values describing the JPG from the point of view of Total Depth (*TD*), Mean Depth (*MD*), Relative Asymmetry (*RA*), integration (i) and control value (*CV*). i values may be used in architectural analysis to develop an "inequality genotype", which is important in the present context because it formed the basis for the two major analytical precedents for the present paper [Major and Sarris 1999; Bafna 1999]. As Sonit Bafna [2001] explains,

> [t]he most common basis of comparison has been … the inequality genotype: the ranking of programmatic labeled spaces according to their mean depth (most often described in terms of *integration* values) of the nodes in the graph of the spatial configuration to which they correspond [Bafna 2001: 20.1].

In practice, an inequality genotype is a list of spaces in the JPG, arranged in order from highest to lowest i value. But in order to interpret what this list means, we have to leave behind the mathematics and start to consider wider social and cultural factors that are part of graph theory.

The visual and mathematical information derived from the JPG may be used to theorise some additional properties or qualities about a building. This, the third approach, is the most controversial [Dovey 1999] but it is also necessary for any attempt to use the JPG to assist in interpreting architecture. For example, returning to the inequality genotype, Zako argues that it is "one of the most general means by which culture is built into spatial layout" [2006: 67]. However, the inequality genotype is simply a hierarchical list, and to interpret further how deliberate it is, it must be interpreted with the assistance of the difference factor (H). Zako notes that the *difference factor* "was developed to quantify the degree of difference between the integration values of any three (or more with a modified formula) spaces or functions" [2006: 67]. Therefore, the difference factor, or H, can be used to determine how strong or weak certain inequalities are in the base JPG. Thus, an inequality genotype with "a low entropy [H] value will therefore be [a] 'strong' genotype, whereas one that exists, but tends to have a high entropy, will be a 'weak' genotype" [Zako 2006: 67]. This is a typical example of a reasonably accepted use of mathematics to hypothesize certain qualities about an architectural plan.

A less emphatic interpretation is offered by Hillier and Tzortzi, who propose that through the application of visual and mathematical processes, a JPG can be used to demonstrate how a "culture manifests itself in the layout of space by forming a spatial pattern in which activities are integrated and segregated to different degrees" [2006: 285]. This is possible because the spaces are not just multi-purpose voids awaiting appropriate furnishings and fittings, but they are also locked into a "certain configurational relation to the house as a whole" [2006: 285]. It is for this reason that the inequality genotype is used to uncover not only a set of social values or ideals responsible for shaping architecture, but also the recurring social values and principles in an individual architect's works.

Methodological precedents

Hanson's study of housing [1998], using a combination of JPG and axial graph methods, includes a qualitative review of the plans of several famous houses by Adolf Loos, John Hejduk, Mario Botta and Richard Meier. Without the support of a mathematical analysis, Hanson's review of these houses is largely restricted to identifying differences in the visual structure of the JPGs. While this is an important early example, it tends to be of limited practical use in the present context because it relies on a rigid formula for convex map construction (leading to over 60 defined nodes in several cases). The following year, Major and Sarris set out to use the JPG method to analyse eight houses by Peter Eisenman [1999]. In each case they produced a JPG for visual analysis and then used mathematics to develop an inequality genotype recording the order of integration of spaces from highest to lowest. One of the important issues in Major and Sarris's work which is relevant for the present research is that, by using the original method of convex plan generation, they produced JPGs for houses with up to 133 separate spaces. As a result of this process, their inequality genotypes did not display a high level of order until they had been stripped of all but the major functional zones.

Probably the best precedent for the present study is found in the work of Bafna [1999; 2001] who has published several JPG analyses of Mies van der Rohe courtyard houses. What is significant in Bafna's work is that he too has found that inequality genotypes are difficult to work with. Bafna's not unreasonable starting assumption was that there would be a "genotypical consistency in these houses" which could be used "as a basis upon which to study their phenotypical differences" [2001: 20.3]. This implies that the order of rooms in the inequality genotype would reflect the architect's ideal (itself a reflection of social conditions) and that small differences in the JPG would be the result of differences caused by particular, site, context of program conditions. Unfortunately, the inequality genotypes were more diverse than anticipated, and even simplifying the node set (as Major and Sarris were forced to do) did not produce a clear result. Upon reflection, this realisation lead Bafna [2001] to conclude that the genotype is "better defined, not as a given rank order of labeled spaces, but [as] a statistically stable pattern of variation of those" [2001: 20.9]. Thus, it is the broader pattern represented in the genotypes that is most important.

As described in the following section, the present paper adopts a variation of Bafna's [1999, 2001] convex map boundary generation rules and the inequality genotype method. Rather than copying Bafna's mathematical approach to the genotype analysis, the present paper uses a simplified statistical version to identify both genotype patterns and a stable archetype in Murcutt's early house designs.

Approach

Despite completing several urban houses prior to 1975, the five houses being analysed in the present paper are widely regarded as the first of Murcutt's characteristic works. Drew describes the first four of these houses as a significant set; the "Marie Short, Nicholas, Carruthers and Fredericks farmhouses are really members of a series, … taken together, they represent a progressive development and refinement of the longitudinal house type" [1985: 92]. These four also directly prefigure a fifth house – an intermediate work in Murcutt's oeuvre –, the Ball-Eastaway House [Farrelly 1993; Fromonot 1995]. After the completion of the Ball-Eastaway house, Murcutt retained his linear planning style but he developed more elaborate sections, typically featuring curvilinear steel structures, as well as producing a series of larger houses. Significantly, all of the five houses considered in this paper have been altered or extended since being completed and many have been resold (Murcutt himself now owns the Marie Short House). In all cases, the version of the house analysed here is the original, and the original naming of each house has also been retained. Furthermore, several of the houses feature mezzanine levels that are rarely acknowledged in published plans or sections, and many of these are not even apparent in published photographs. In the present paper the mezzanine levels that were completed as part of the original construction phase are all included in the analysis.

As the first stage in the process, new plans for each house were prepared and annotated with a standard set of abbreviations and in accordance with Murcutt's original notations (table 1). The general principle adopted in this paper for the construction of a convex map or boundary map, is to try to keep the set as small or economical as possible. Thus, the method broadly follows Bafna's approach:

> [The JPGs are based] upon a modified version of the boundary map of the plans, rather than go with the more conventional minimum convex partition. One reason for this was that minimum convex partition generates spaces to which programmatic labels might be difficult to assign; another, that it is based upon a heuristic method which, given the free-plan arrangement of several houses, could be quite inconsistent. The boundary map, by contrast, is generated by recognizing programmatically defined boundaries between individual components [Bafna 1999: 01.7]

This approach is ideal for analyzing the work of Murcutt, an architect who often designs small alcoves to accommodate cupboard door swings or ledges to display artwork. None of these alcoves, ledges or indented walls are separately identified. Furthermore, many of Murcutt's houses, being rural in their settings, have small utility zones as their secondary connection to the exterior. Such zones typically feature storage cupboards, hanging rails (for coats) and racks for shoes. In this paper utility zones are typically identified, according to Murcutt's labels, as a single area even though a rigorous convex mapping exercise would divide them into as many as nine separate spaces. Similarly, bathrooms with internal, partial-height partitions separating bath, shower or toilet are counted as one space.

The issue of open plan space is more complex, with many of Murcutt's spaces being defined by a combination of the furniture in them and the label on a plan. If we follow Bafna [1999], then some of Murcutt's major spaces, which have no visible separation but are labelled dining room, living room or kitchen, would be divided along these lines. However, in the present paper, a larger set of threshold conditions has been required to break down an open plan space. For example, a change in floor texture alone is not enough to signal a new space, but in combination with a freestanding column or an island kitchen bench, it can identify a separate zone, even if it remains otherwise almost completely within an open-plan volume. Where no clear threshold marker combinations existed, even though multiple functions were labelled in the one space, the space was counted as a singular node. Because several of Murcutt's houses feature open-plan, multifunction areas with no clear thresholds, some combined space labels were used (for example, KDL, means an open plan, kitchen, dining and living space).

While not strictly relevant to the method, to assist the reader large open plan spaces have elongated oval nodes as opposed to circular ones in the JPG. With the exception of the exterior, if there are more than one of a particular room type they are numbered; thus if there are two bedrooms, they become B1 and B2. The exterior is represented in the JPG as a crossed circle and in text and tables as ⊕. Three additional graphic conventions were adopted to assist the reader. First, a double line in a JPG indicates a primary car access, next, a line in a JPG broken by a zigzag indicates a major change in level (typically stairs or a ladder) and third, a dashed and dotted line has been used for secondary or service access from the exterior. None of the graphic variations described in this paragraph have an impact on the mathematical results. Similarly, JPG theory uses curved lines to connect nodes when required by the visual complexity of the graph. Curved lines are effectively identical to straight lines in a graph as far as the mathematical analysis is concerned.

⊕	Exterior	L	Living Area	B	Bedroom
V	Veranda	F	Family Room	WIR	Walk in Robe
LBY	Lobby	D	Dining	b	Bathroom
C	Court	K	Kitchen	SH	Shower
H	Hall	ST	Studio	WC	Toilet
G	Garage	M	Music Room	A	Alcove
U	Utility Room	l	Laundry	S	Store

Table 1. General abbreviations for rooms used in the JPG

Five Houses

Marie Short House

The Marie Short House (1975) is sited on a raised floodplain, in the bend of a river, near Kempsey, in northern New South Wales, Australia. This is the first of Murcutt's famous regional houses; it was credited as heralding both a new Australian style [MacMahon 2001] as well as being a key Critical Regionalist work [Frampton 2006]. The house consists of two, similarly sized pavilions that are placed side-by-side and then slid apart along a centreline. One pavilion contains living spaces, the second, sleeping quarters, and a corridor both divides and connects the two (figs. 1, 2). Drew describes the house as featuring a pair of pavilions which merge "Mies van der Rohe's single storey glass pavilion type" with the "primitive hut archetype" [1985: 74]. Beck and Cooper note that the staggered plan of the Marie Short House "is reminiscent of the Farnsworth house with its staggered deck" and "layered zones of public and private" [2002: 48]. Frampton reiterates this canonical reading of the house as capturing the essence of the "Semperian primitive hut of 1852 with the tectonic refinement of Mies' Farnsworth House" [Frampton 2002: 1].

A visual analysis of the JPG for the Marie Short House (fig. 3) reveals an unexpectedly complex, two-part structure, with a "ring-like" circulation approach to the living pavilion and a "bush-like" structure, rooted in the hallway, to the more private pavilion, Between these two, the hall provides a constant point of connection and passage. While far more complex and "deep" than might be imagined from its simple exterior form, this spatial pattern is reasonable for two adjacent structures, one of which is more flexible for living and the other of which is compartmentalised for private activities (sleeping and bathing).

Fig. 1. Perspective, the Marie Short House (1975), Glenn Murcutt

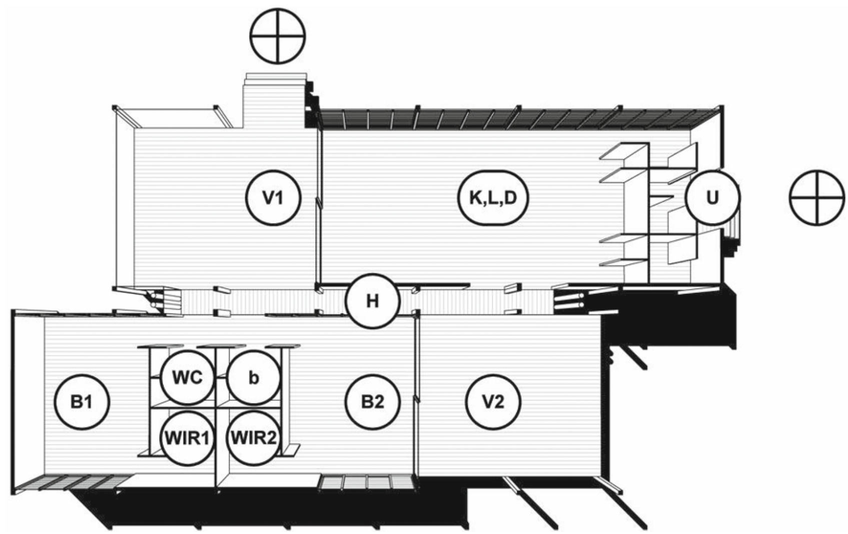

Fig. 2. Annotated Plan, the Marie Short House (refer to Table 1 for room abbreviations)

The mathematical results for the Marie Short JPG (table 2) show that the mean total depth (*TD*) of the house is 24.83. Conversely, the mean depth (*MD*) of rooms in the house is 2.25; this suggests that the most isolated spaces in the configuration are, in order, the two walk-in-wardrobes (*MD* = 3.00 and *MD* = 2.90), the utility area (*MD* = 2.63) and the exterior (*MD* = 2.63). Conversely, the most accessible are the hallway (*MD* = 1.36), veranda 1 (*MD* = 1.90) and the open plan kitchen dining and living areas (*MD* = 1.90). The integration (*i*) values confirm this, but provide advice on the relative magnitude of the integration or isolation. For example, the hallway (*i* = 13.75) is more than double the level of the next most integrated pair of spaces, veranda 1 and the kitchen, living and dining areas (both, *i* = 5.50). The remainder of the rooms, including the exterior, are all relatively isolated (ranging from 3.00 to 5.00) with only the two wardrobes being markedly isolated. Finally, and not surprisingly, the hall exerts the highest spatial influence (CV = 4.00) generally possessing more than four times the capacity to influence space of any of the other nodes. The only anomaly in the analysis is that bedroom two, with its access to a second private veranda, is also surprisingly highly integrated (i = 5.00), and exerts the second highest level of control in the house (CV= 1.64).

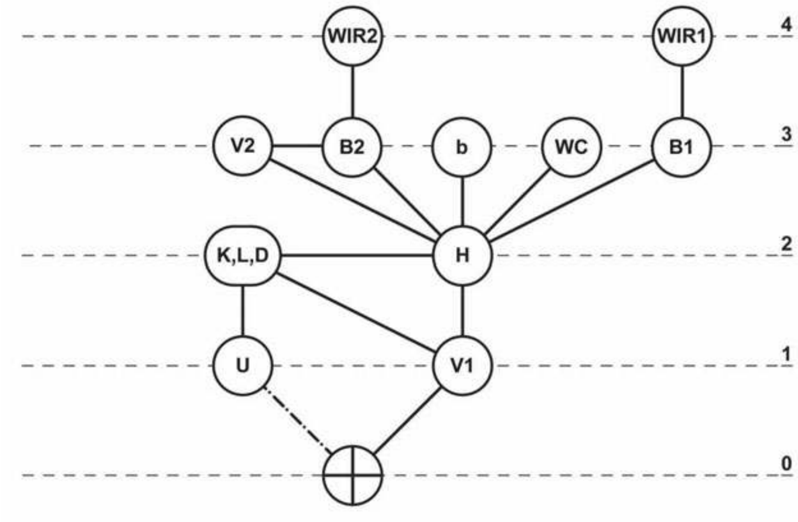

Fig. 3. JPG, with exterior as carrier, for the Marie Short House

#	Space	TD_n	MD_n	*RA*	*i*	*CV*
0	⊕	29	2.63	0.32	3.05	0.83
1	V1	21	1.90	0.18	5.50	0.97
2	K,L,D	21	1.90	0.18	5.50	0.97
3	H	15	1.36	0.07	13.75	4.00
4	U	29	2.63	0.32	3.05	0.83
5	V2	23	2.09	0.21	4.58	0.47
6	B2	22	2.00	0.20	5.00	1.64
7	B	25	2.27	0.25	3.92	0.14
8	WC	25	2.27	0.25	3.92	0.14
9	B1	23	2.09	0.21	4.58	1.14
10	WIR2	32	2.90	0.38	2.61	0.33
11	WIR1	33	3.00	0.40	2.50	0.50

Minimum	15.00	1.36	*0.07*	2.50	0.14
Mean	*24.83*	*2.25*	*0.25*	*4.83*	1.00
Maximum	33.00	3.00	*0.40*	13.75	4.00

H	0.92	**H***	0.56

Table 2. Summary of JPG results for the Marie Short House

Nicholas House

Located in the Blue Mountains, west of Sydney, the Nicholas House (1980) and the Carruthers House (1980) – discussed in the next section – were built on adjacent sites as country retreats for the families of two lawyers. While the Nicholas House, like the Marie Short house, has a two-pavilion *parti*, it is the first of Murcutt's houses where the pavilions are unequally sized to accommodate living spaces in the larger one and services in the smaller (fig. 4).

Fig. 4. Perspective, the Nicholas House (1980), Glenn Murcutt

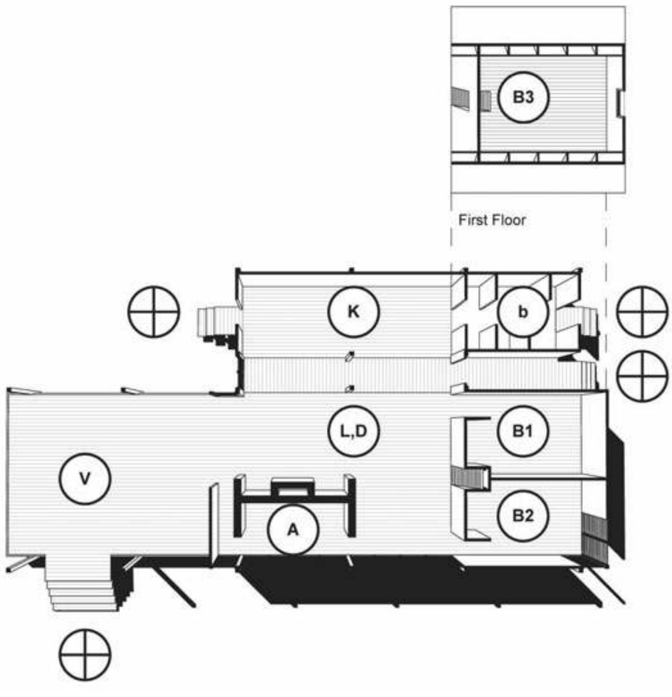

Fig. 5. Annotated Plan for the Nicholas House

The larger north pavilion of the Nicholas house is dominated by semi-open plan living and eating areas as well as two ground floor bedrooms. A loft space, accessed by a narrow ladder, is created for the third bedroom. This main pavilion, which like most of Murcutt's houses is slightly raised above the ground, is clad in timber boards and lined with glass louvers and cedar external blinds. In contrast, the south edge of the house has a distinctive solid wall clad in corrugated iron and with a curved roof above. The service zones, including the kitchen, bathroom and storage, are located in this smaller pavilion (fig. 5).

A visual review of the JPG for the Nicholas house reveals a shallow structure that is three levels deep for the exterior carrier (the Marie Short house was four levels deep for the same carrier), with a "ring-like" entry configuration encompassing the exterior, veranda, living and dining and kitchen. The living and dining spaces are the starting point for a "bush-like" structure extending beyond that for the more private areas (fig. 6). Though of a slightly smaller scale than the Marie Short House (eight spaces as opposed to eleven), and lacking an explicit hallway connection, the configurational strategy is unexpectedly similar.

The mathematical analysis of the Nicholas house reveals that while it is only marginally smaller in program than the Marie Short House, it is much simpler in its configuration (table 3). The average total depth of the Nicholas house plan is 15.55, which is around 60% less than the result for the Marie Short House. The most integrated space in the Nicholas house is the combined living and dining room, which connects the majority of the plan. For the remainder of the spaces, the next most integrated is the kitchen (i = 5.60), closely followed by the veranda (i = 4.66) and a range of spaces thereafter with equal integration vales (i = 3.11).

The open plan living and dining area exerts the greatest degree of control, with a *CV* value of 4.83; a result which is almost five times higher than the nearest spatial competitor – the kitchen – and more than ten times higher than for the majority of the rooms. This not only confirms the intuitive reading that the open plan living and dining area is the most important in the house, it quantifies the level of importance of that space.

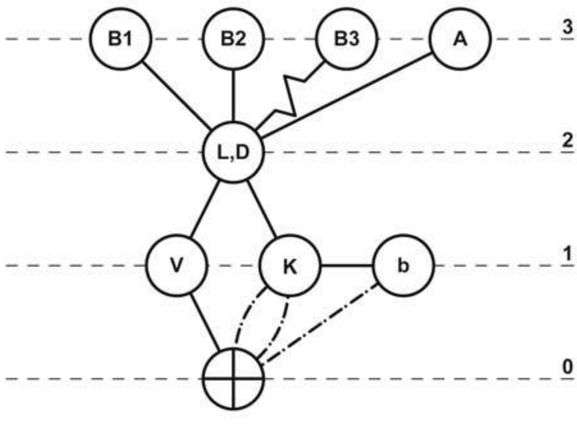

Fig. 6: JPG, with exterior as carrier, for the Nicholas House

#	Space	TD_n	MD_n	*RA*	*i*	*CV*
0	⊕	17	2.12	0.32	3.11	1.33
1	V	14	1.75	0.21	4.66	0.50
2	K	13	1.62	0.17	5.60	1.00
3	b	18	2.25	0.35	2.80	0.66
4	LD	10	1.25	0.07	14.00	4.83
5	B1	17	2.12	0.32	3.11	0.16
6	B2	17	2.12	0.32	3.11	0.16
7	B3	17	2.12	0.32	3.11	0.16
8	A	17	2.12	0.32	3.11	0.16
Minimum		10.00	1.25	0.07	2.80	0.16
Mean		*15.55*	*1.94*	*0.26*	4.73	1.00
Maximum		18.00	2.25	0.35	14.00	4.83
H		0.94		**H***	0.61	

Table 3: Summary of JPG results for the Nicholas House

Carruthers House

Located on the site adjacent to the Nicholas House, the Carruthers House (1980) is, at first glance, even more straightforward in its form and design. Fromonot describes it as a "simple timber barn roofed with corrugated iron" [2003: 112]. With the exception of the chimney, the single pavilion sits lightly on posts above the ground plane. Internally it is divided into two sections, the north edge that contains the main circulation space and a sitting room open to the landscape and the south edge where bedrooms, a bathroom and a kitchen are located. At one end of the pavilion there is a loft bedroom, while at the other the living area has a large, double height space. Externally, the south wall is almost fully enclosed protecting the inhabitants from winter winds. The actual building contains four elevated water collection tanks, which change its character, but otherwise have no impact on the present study (fig. 7).

A visual analysis of the JPG for the Carruthers House reveals a shallow structure (three levels of depth), with a dense, nested 'bush-like" structure with primary "root" in the hallway and secondary "root" in the dining room (really an extension of the hallway spatially, but because of the placement of furniture and the mezzanine above, a distinct and separate spatial zone) (fig. 9).

The mathematical analysis of the JPG (table 4) identifies the mean depth of the structure as 16.88; slightly more than the Nicholas House but still less complex than the Marie Short House. Not surprisingly the most integrated space is the hallway (i = 9.33), closely following by the dining room (i = 7.00) which is, as previously stated, an extension of the hallway, then a tight cluster of spaces (the exterior, bedroom 1, bedroom 2 and the bathroom) all with the same level of spatial integration (i = 2.80). The least integrated spaces are the kitchen, living and mezzanine levels (all i = 2.54); an unexpectedly isolated result for the major living space. The control value results mostly reflect the integration results, although they place the living area in the middle group of results.

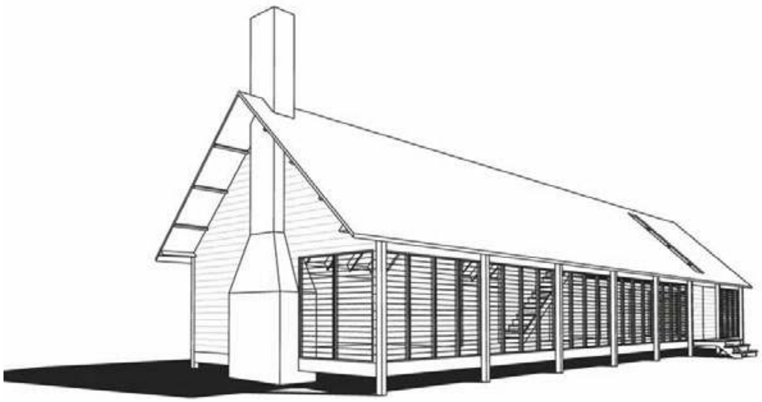

Fig. 7. Perspective, the Carruthers House (1980), Glenn Murcutt

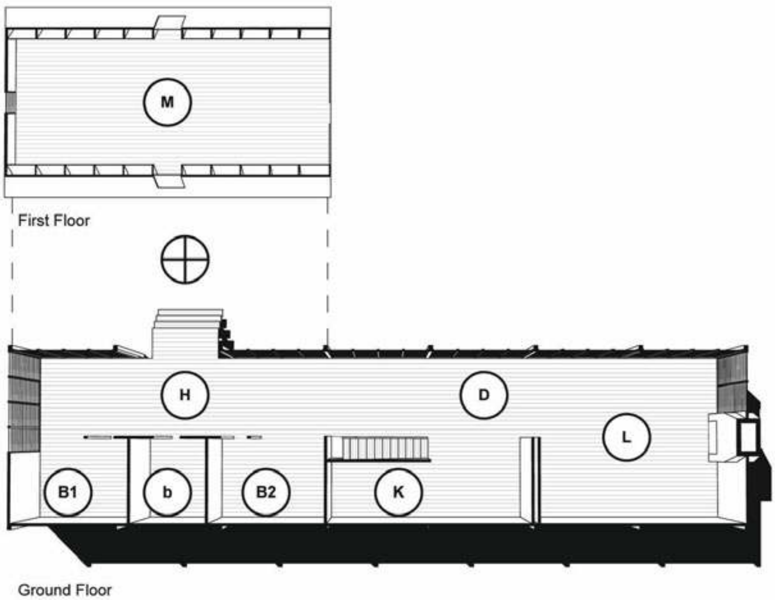

Fig. 8. Annotated Plan for the Carruthers House

There is an isolated phenomenal account of visiting this house that reflects some of these mathematical results. Drew argues that upon entry into the house the visitor is drawn into the "the pine tube" of the primary volume which is interrupted by three inserted planes: "one which separates the living room from the kitchen … one on the left of the stair, and another, below the left floor deck in line with the bedrooms, run parallel with the axis of the pavilion" [1985: 96]. The impact of these three spatial dividers is to lead the visitor to the sense that the space is "surge[ing] back and forth like a stream encountering boulders in its course" [1985: 96]. The two control values for the hallway and the dining room suggest a strong linear "pull" along the façade of the building that is interrupted by a series of side rooms, some irregularly placed, with lower control values.

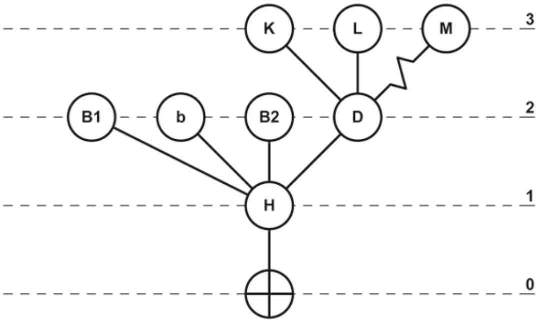

Fig. 9. JPG, with exterior as carrier, for the Carruthers House

#	Space	TD_n	MD_n	*RA*	*i*	*CV*
0	⊕	18	2.25	0.35	2.80	0.20
1	H	11	1.37	0.10	9.33	4.25
2	B1	18	2.25	0.35	2.80	0.20
3	b	18	2.25	0.35	2.80	0.20
4	B2	18	2.25	0.35	2.80	0.20
5	D	12	1.50	0.14	7.00	3.20
6	K	19	2.37	0.39	2.54	0.25
7	L	19	2.37	0.39	2.54	0.25
8	M	19	2.37	0.39	2.54	0.25
Minimum		11.00	1.37	0.10	2.54	0.20
Mean		*16.88*	*2.11*	*0.31*	*3.90*	1.00
Maximum		19.00	2.37	0.39	9.33	4.25
H		0.978		**H***	0.703	

Table 4. Summary of JPG results for the Carruthers House

Fredericks Farmhouse

Drew describes the Fredericks Farmhouse (1982) as “the finest of Murcutt’s series of long houses” [1985:121]. For Drew, this house achieves a relationship between the landscape and the form of the building that is reminiscent of a temple: “Classical without sacrificing any of its richness to oversimplification, light in appearance, it is the best kind of essentialist minimalist architecture, every bit as impressive as the landscape” [Drew 1985, 121]. The Fredericks house is located in Jambaroo, south of Sydney and slightly inland from the coast. Superficially, it appears to have a cross-section that is reminiscent of the Marie Short House, but in this case, while the two pavilions might have similar sections, they are very different in floor area (fig. 10). Both pavilions are timber, post and beam structures, with external western red cedar cladding. Murcutt describes the house as having “a very ordinary plan […] like a railway carriage” [in Beck and Cooper 2002: 77]. An existing chimney structure anchors one side of the plan, with its central kitchen, dining and living spaces, while at each of the two ends of the pavilion there are bedroom, bathroom and services (fig. 11). Furthermore, this house has two loft-bedrooms which are rarely depicted in images or plans; Beck and Cooper argue that Murcutt’s reluctance to introduce a loft space may be due to the “dynamic spatial condition that disturbs the serenity” of the rest of the house [2002: 76].

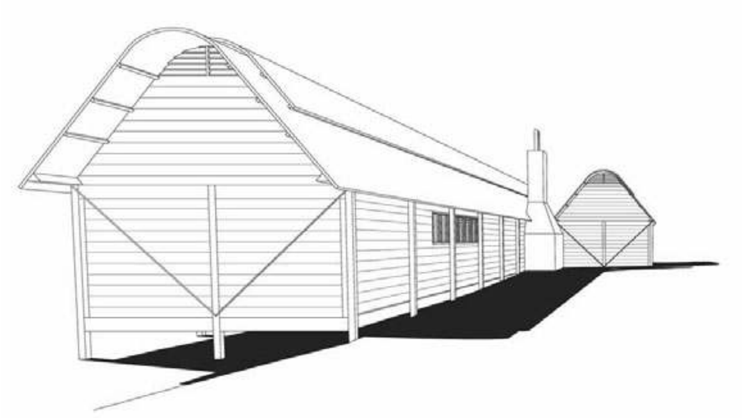

Fig. 10. Perspective, the Fredericks House (1980), Glenn Murcutt

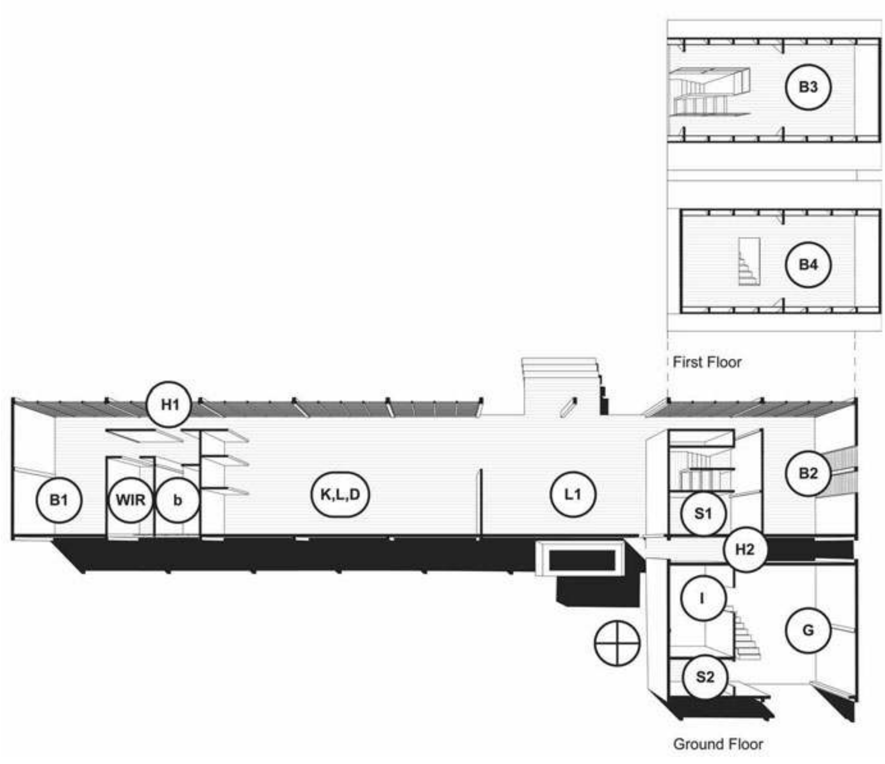

Fig. 11. Annotated Plan for the Fredericks House

A visual inspection of the JPG of the Fredericks House reveals a "ring-like" entry structure, leading to a primary "bush-like" private zone and a secondary "bush-like" private zone, along with some isolated service rooms (fig 12). This is the third of Murcutt's houses to feature a combination of "ring-like" and "bush-like" configurations, the second "bush-like" growth appears to be in response to the need to increase the number of spaces in the plan.

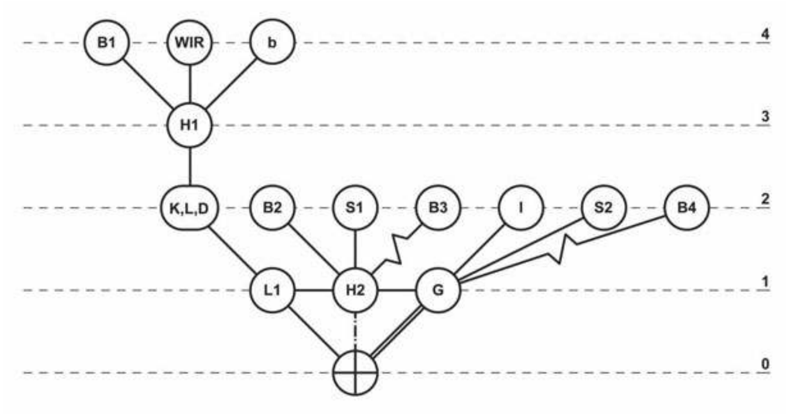

Fig. 12. JPG, with exterior as carrier, for the Fredericks House

#	Space	TD_n	MD_n	*RA*	*i*	*CV*
0	⊕	32	2.28	0.19	5.05	0.70
1	L1	31	2.21	0.18	5.35	1.00
2	H2	29	2.07	0.16	6.06	3.86
3	G	35	2.50	0.23	4.33	3.50
4	K,L,D	36	2.57	0.24	4.13	0.58
5	B2	42	3.00	0.30	3.25	0.16
6	B3	42	3.00	0.30	3.25	0.16
7	S1	42	3.00	0.30	3.25	0.16
8	l	48	3.42	0.37	2.67	0.20
9	S2	48	3.42	0.37	2.67	0.20
10	B4	48	3.42	0.37	2.67	0.20
11	H1	43	3.07	0.31	3.13	3.50
12	B1	56	4.00	0.46	2.16	0.25
13	WIR	56	4.00	0.46	2.16	0.25
14	b	56	4.00	0.46	2.16	0.25
Minimum		29.00	2.07	0.16	2.16	0.16
Mean		*42.93*	*3.06*	*0.31*	*3.49*	1.00
Maximum		56.00	4.00	0.46	6.06	3.86
H		1.017		**H***	0.799	

Table 5. Summary of JPG results for the Fredericks House

The mathematics of the JPG (table 5) confirms that the Fredericks House is the largest and most complex of the five early houses covered in this paper. Its mean Total Depth (mean *TD* = 42.93) is roughly double the number of possible connections in the structure as the Marie Short House. This is significant, given that there are only three more spaces in the Fredericks House than in the Marie Short House. Paradoxically, the most integrated space is hallway 2 (*i* = 6.06), followed by the living room (*i* = 5.35), the exterior (*i* = 5.05) and the garage (*i* = 4.33); this is a mixed result with a service hallway and the garage featuring unusually strongly in the configuration. The least integrated spaces are more consistent with Murcutt's other works. These include bedroom 1, bathroom and the walk-in wardrobe (*i* = 2.16). The control value results further crystallise this unexpected structure, with the most significant spaces being hallway 2 (*CV* = 3.86), hallway 1 (*CV* = 3.50) and the garage (*CV* = 3.50)! The mathematical analysis suggests that the more complex the house, the more likely it is to rely on secondary circulation and spaces to achieve connectivity, and that this type of planning draws the user or visitor away from the major spaces in the house.

Ball-Eastaway House

Designed as a house and private gallery for the artists Syd Ball and Lyn Eastaway, the Ball-Eastaway House (1982) is sited in top of a series of sandstone ledges near a wooded reserve to the northwest of Sydney. The Ball-Eastaway House has a "train carriage" plan with "a simple arrangement of rooms located beneath the gentle barrel-vaulted ceiling" [MacMahon 2001: 122]. The train carriage feeling is exaggerated externally with the building sitting above the ground, as if raised on wheels, and being clad in corrugated steel, with exposed downpipes and vents (fig. 13). Elizabeth Farrelly describes the carriage or pavilion form as being "[o]pen at both ends" leading the house to "became an extruded form [and] emphatically directional" [1993, 21]. Whereas the first four houses in the present set are clad largely in timber, and with exposed timber detailing, the Ball-Eastaway house has metal cladding, a more industrial feel, and is lined internally in white plasterboard.

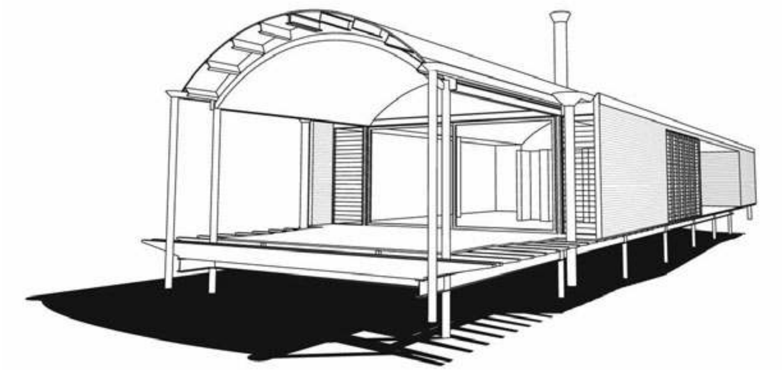

Fig. 13. Perspective, the Ball-Eastaway (1980), Glenn Murcutt

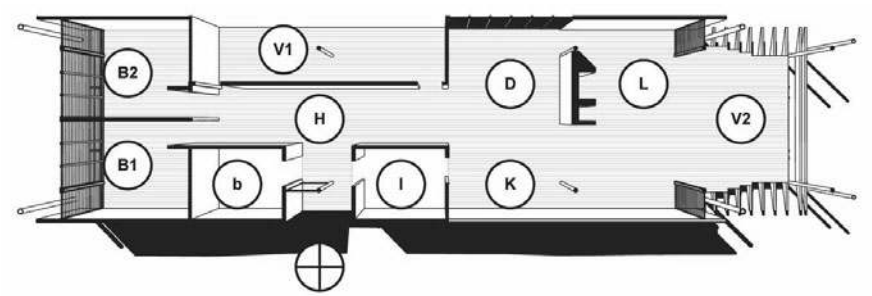

Fig. 14. Annotated Plan for the Ball-Eastaway

While this building appears to be a departure from Murcutt's previous aesthetic and tectonic practices, in planning terms it is closely associated with the previous four designs (fig. 14). Furthermore, despite often being left out of recent publications on Murcutt's work [Gusheh et al. 2008] – perhaps because it is not a clear example of critical regionalism – Fromonot describes the Ball-Eastaway house as "one of Murcutt's most successful buildings. It epitomises the lightweight, linear, economical and elegant pavilion, minimal in its environmental impact" [1995: 84].

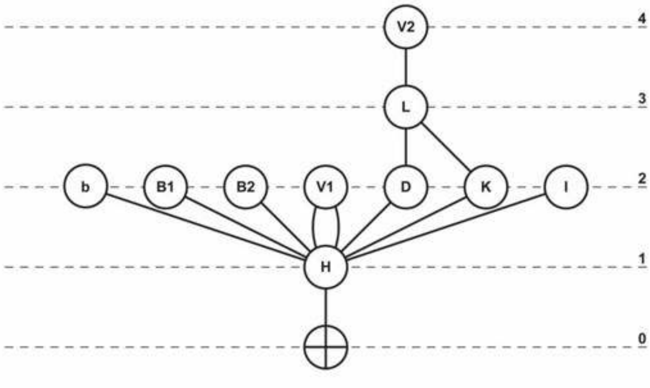

Fig. 15. JPG, with exterior as carrier, for the Ball-Eastaway

#	Space	TD_n	MD_n	*RA*	*i*	*CV*
0	⊕	22	2.20	0.26	3.75	0.12
1	H	13	1.30	0.06	15.00	7.50
2	b	22	2.20	0.26	3.75	0.12
3	B1	22	2.20	0.26	3.75	0.12
4	B2	22	2.20	0.26	3.75	0.12
5	V1	22	2.20	0.26	3.75	0.12
6	D	18	1.80	0.17	5.62	0.62
7	K	22	2.20	0.26	3.75	0.12
8	l	22	2.20	0.26	3.75	0.12
9	L	25	2.50	0.33	3.00	1.50
10	V2	34	3.40	0.53	1.87	0.50
Minimum		13.00	1.30	0.06	1.87	0.12
Mean		*22.18*	*2.21*	*0.27*	*4.70*	1.00
Maximum		34.00	3.40	0.53	15.00	7.50
H		0.848		**H***	0.382	

Table 6. Summary of JPG results for the Ball-Eastaway House

A visual analysis of the JPG for the Ball-Eastaway House shows a spatial configuration which is partway between that of the Carruthers House (a simple "bush-like" structure) and the other three; the Marie Short House, the Nicholas House and the Fredericks House all have a compound ring and then bush" structure. In the Ball-Eastaway House the ring (hall, living, dining, kitchen) is nested one level deep within the greater arborescent structure; a partial inversion of the fine grained pattern so far, but also a reinforcement of the general planning principles already identified (fig. 15).

The Ball-Eastaway House has a mean structural depth of 22.18 which is similar to that of the Marie Short House; both also have a similar number of rooms (table 6). Just as the JPG diagram for the exterior carrier implies, the hall is the most important room on the spatial configuration. It has an integration value of 15 and a control value of 7.50. This single hall, more than any individual room (or compartment) is the most important space in the everyday use of the house. Beyond the hall, veranda 1, the kitchen and the dining area, the remainder of the spaces are isolated and controlled by the hallway/room structure.

Discussion

As the first step in attempting to identify the primary spatial patterns in Murcutt's early houses the inequality genotypes for each are recorded. These are as follows:

- Marie Short House:
  H (13.75) > V1 (5.50) = KLD (5.50) > B2 (5.00) > V2 (4.58) = B1 (4.58) > b (3.92) = WC (3.92) > ⊕ (3.05) = U (3.05) > WIR2 (2.61) > WIR1 (2.50).

- Nicholas House:
  LD (14) > K(5.60) > V (4.66) > ⊕ (3.11) = B1 (3.11) = B2 (3.11) = B3 (3.11) = A (3.11) > b (2.80).

- Carruthers House:
  H (9.33) > D (7.00) > ⊕ (2.80) = B1 (2.80) = B2 (2.80) = b (2.80) > K (2.54) = L (2.54) = M (2.54).

- Fredericks Farmhouse:
  H2 (6.06) > L1 (5.35) > ⊕ (5.05) > G (4.33) > KLD (4.13) > B2 (3.25) = B3 (3.25) = S1 (3.25) > H1 (3.13) > l (2.67) = S2 (2.67) = B4 (2.67) > B1 (2.16) = b (2.16) = WIR (2.16).

- Ball-Eastaway House:
  H (15) > D (5.62) > ⊕ (3.75) = b (3.75) = B1 (3.75) = B2 (3.75) = V1(3.75) = K (3.75) = l (3.75) > L (3.0) > V2 (1.87).

In four of these cases hallways dominate the genotype as the most integrated spaces, and in three of these cases bedrooms, bathrooms and walk-in-robes are the least integrated. As Bafna records, "[i]t is natural that the circulation areas and lobby will be more integrated and that the bedrooms and the services will occupy the other pole along the integration-segregation axis" [2001: 20.8]. But beyond these general tendencies, there is also unexpected variation in the inequality genotypes and particularly in regard to the more 'public' spaces, like the living areas, dining room or kitchen. For example, in the Carruthers House and the Ball-Eastaway House, the living areas are the second most isolated. In the other three houses, the living areas are amongst the most integrated.

In order to seek a clear pattern in the work, both Bafna [1999] and Major and Sarris [1999] simplified their inequality genotypes by removing singular room types and combining other similar sets of rooms so that the focus was on a smaller set of rooms which were present in all cases. In the present paper the following steps have been taken to achieve this:

1. Room types with less then three instances have been removed; that is, across the five houses, one alcove, one utility room, one mezzanine, a second veranda, two storerooms and two third bedrooms have been removed;
2. Hallways and verandas that function as circulation are grouped into one category and counted as the higher *i* value of the pair;
3. Bathrooms and toilets are grouped into one category and counted as the higher *i* value of the pair.

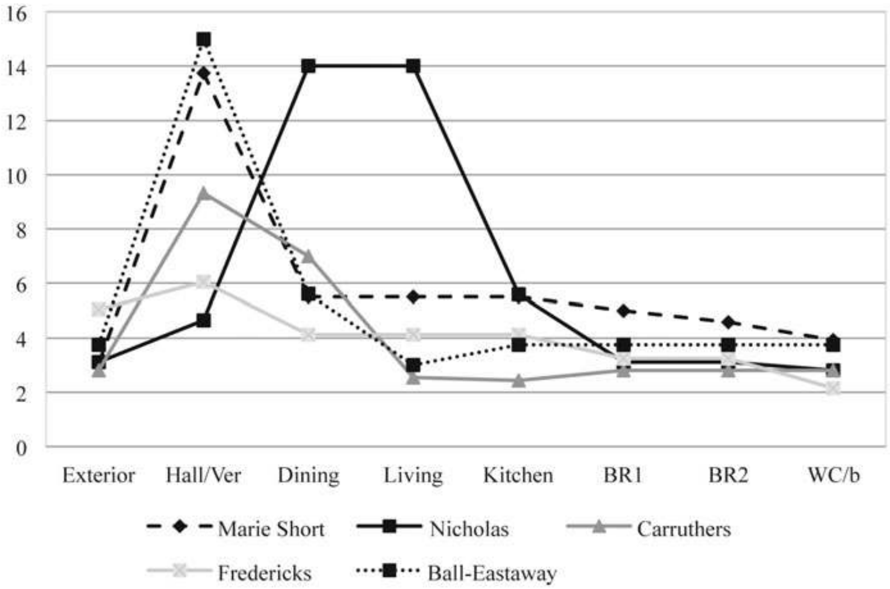

Fig. 16. Chart of inequality genotype data; divided by house

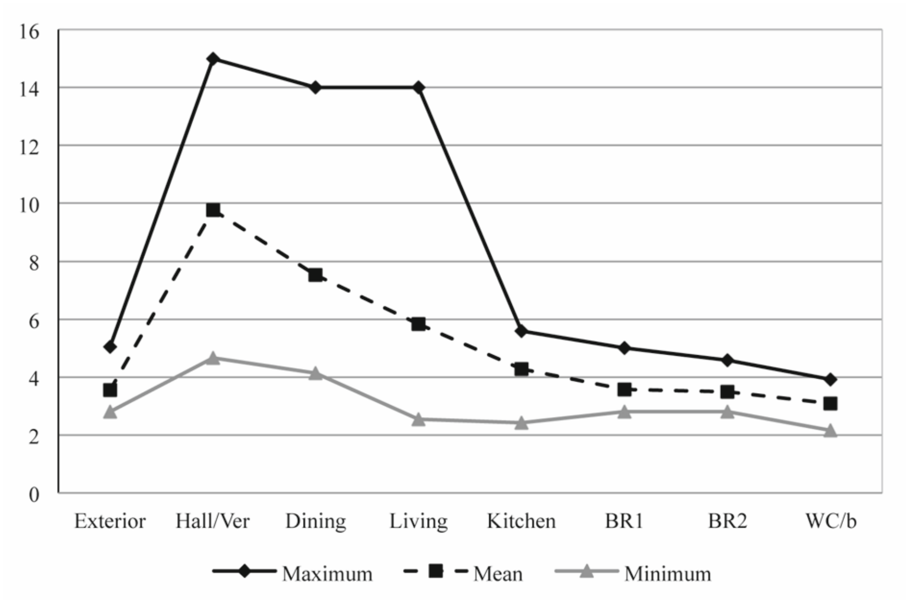

Fig. 17. Chart of inequality genotype data; divided by maximum, minimum and mean

Once these changes have been made, a simple pattern begins to emerge from the inequality genotypes, although there are still inconsistencies. In the comparative chart (fig. 16) the functional spaces are arranged along the *x*-axis broadly in accordance with the principal of "intimacy gradients" [Alexander et al. 1977]; that is, with the most public to the left and the least public to the right. The *y*-axis simply records the integration value. An intuitive reading of the relationship between integration and privacy might anticipate a line that commences at its highest level to the left of the *x*-axis and then drops to a low level at the right side. That is, the more public the space, the more integrated it is; the more private the space, the less integrated. The results of the graph are not quite this straightforward although, with the exception of the exterior, there is a broad trend down across the results from left to right, albeit typically across a series of plateaus. When the data is re-sorted to identify mean values, maximum and minimum, the pattern in Murcutt's inequality genotype becomes more visible (fig. 17).

In the next stage of the analytical process a "statistical archetype" is constructed. However, in the present context a set of five houses, with a total of fifty defined nodes, is not sufficiently large to derive a meaningful mathematical trend. While the past precedents for this method have had, on occasion, data sets of similar size, the more compelling results using this method tend to come from sets with at least double the number of nodes. While acknowledging this weakness, the present paper uses broad trends to construct a visual analysis diagram. This diagram is still called, for methodological consistency, a "statistical archetype" but the reader should remember that its construction is less robust than would otherwise be desired.

Within the visual analysis stage of this paper a range of observations recorded the relative frequency, in a set of five designs, where certain permeability and hierarchical patterns were identified. This information is used to construct a table of tendencies for structural and programmatic properties to occur in a project. The percentage probabilities were determined directly from the designs, thus if four of the five designs featured a particular pattern, then that is described as an 80% chance. The patterns identified through visual analysis in this paper are as follows:

1. There is a 80% chance that there will be an entry "ring" configuration founded on the exterior carrier, which encompasses, in order of probability, a hallway, a veranda and a dining room, or dining, kitchen and living area combination;
2. There is an 80% chance that the hallway will be the starting point for an arborescent branching structure leading to two bedrooms and a bathroom;
3. There is a 60% chance that there will be a mezzanine structure and a 40% chance that it will be for the third bedroom and will be accessed from a ground floor open plan dining/living area;
4. Given the above observations, the depth of the JPG, with exterior as carrier, is likely to be three layers (0-3);
5. While larger plans are a minority condition (40%), if they are required, a second hall will be added as the starting point for an additional branching structure, which may encompass either a garage wing, or a guest bedroom wing.

Taking all of these rules into account, it is possible to construct a partial "statistical archetype", or more correctly a trend diagram, for an early Murcutt house (fig. 18). Note, in this graph, the recurrent theme of the entry ring structure for the public parts of the house, which includes a hall, the starting point for a secondary arborescent structure that governs access to the more private zones in the house.

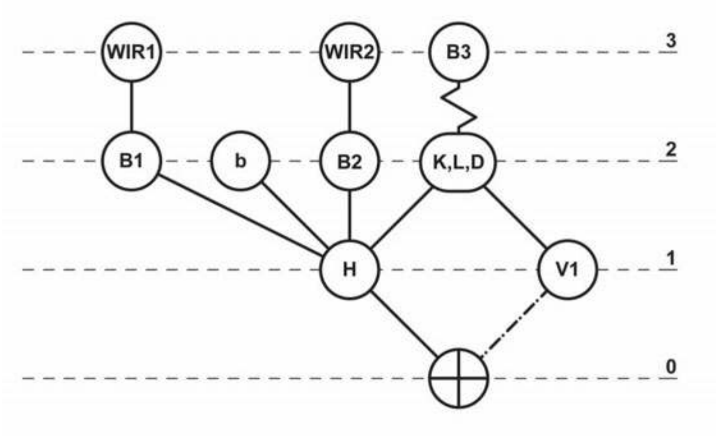

Fig. 18. JPG Statistical Archetype, with exterior as carrier, for an early Murcutt house

It is possible to interpret the Statistical Archetype graph visually from two divergent points of view, those of the stranger, and of the inhabitant [Hillier and Hanson 1984]. For example, the stranger entering this house has, by virtue of the entry ring, immediate access to the entire domestic core. In contrast, the inhabitant has their privacy (bedrooms, bathrooms, walk-in-robes) strongly protected through certain control zones (the origin points of the bush-like structure), but once within the body of the house they may take advantage of its open structure. This might seem to be an inversion of the anticipated social structure of a house, that is, a configuration that provides limited entry and access for the stranger and a more open interior for the inhabitant. But before accepting this conclusion, it must be remembered that the five houses are all on isolated rural properties where strangers are extremely rare. Indeed, it is more common for these houses to have guest spaces for people who have been invited to stay with the owners for a few nights. This explains both the strongly hierarchal nature of the private spaces (separating owners from guests) and the relative lack of concern about the programmatic depth afforded to strangers.

Leaving aside the comparative visual analysis, the five houses may be compared, mathematically, through a review and comparison of their relative difference factors, $H*$, which provides a measure of the degree of differentiation between spaces in terms of integration. It is also useful for comparative purposes because it normalises results. Once the $H*$ figure is determined, then it is interpreted as follows:

> The closer to 0 the difference factor, the more differentiated and structured the spaces …; the closer to 1, the more homogenised the spaces …, to a point where all have equal integration values and hence no configurational differences exist between them [Hanson 1998: 30-31].

The H^* results for the five houses are as follows: the Marie Short House H^*=0.56; Nicholas House H^*=0.61; Carruthers House H^*=0.703; Fredericks Farmhouse H^*=0.799; and Ball-Eastaway house H^*=0.382. Only the Ball-Eastaway house has a spatial configuration (H^* value) that falls into the category of "differentiated", "deliberative" or "strong" genotypes, but even that result is much closer to the middle range. The remaining four houses could more accurately be described as "homogenised", "loose" of "weak" genotypes with little structural differentiation between the spaces (which suggests that they could equally be bedrooms, bathrooms, kitchens or garages).

Conclusion

It was Philip Drew who noted that while the Marie Short, Nicholas, Carruthers and Fredericks houses share a number of external formal similarities, they are also quite different "in the arrangement of their spaces" [1985: 92]. Equally diplomatically, Beck and Cooper observe that the "Murcutt hallmark, the long plan" is seemingly able to be adapted "to any given programme" [2002:11]. These are rare instances where a critic implies that perhaps there is a lack of connection between the rigorous formal or geometric strategy that dominates the exterior and the somewhat loose planning strategy, or topology, of the interior. Farrelly is slightly more forthright than most when she argues that while Murcutt's "forms are universal [and] rationalist", the configuration of his plans "is particular, empirical and contingent" [1993: 21]. The JPG analysis in the present paper uncovered many examples of what Farrelly describes as "particular" or "contingent" spatial planning. Indeed, hallways dominate many of the plans and several secondary spaces, including garages and bedrooms, are also more critical to the plan and its circulation than the living or dining spaces. Similarly, almost all of Murcutt's loft spaces are accessed from unusual places (living rooms, utility hallways), a factor which consistently generated unlikely permeability results.

Murcutt himself notes that a simple form does not necessarily imply the presence of a simple interior. "The house [may be] very simple. But remember simplicity is the other face of complexity" [2007: 26]. In this statement Murcutt suggests that the apparent simplicity of the exterior form of a building may mask a more complex interior. This is certainly the case with the interiors of the five houses investigated in this paper. With the possible exception of the Ball-Eastaway, "train carriage" hierarchical plan, all of the rest of the spatial configurations were both more complex and less predictable than the canonical literature suggests. Certainly Pallasmaa's claim, cited early in this paper, that the form and spatiality of the houses are perfect reflections of each other, is impossible to maintain in light of the present research. Murcutt's spatial planning, while generally neatly zoned into served and servant spaces, is clearly not the primary or even the secondary driver of his design approach.

From a Space Syntax perspective this result echoes Bafna's observations about the domestic architecture of Mies van der Rohe, an architect Murcutt has often been favourably compared with. In both cases, rather than the geometry of the building being subservient to the internal genotype, geometry is the starting point for formulating the limits and constraints of a design, within which a program is forced to fit. As Bafna notes, one of the key anomalies in the early use of the JPG as that it assumed that "spatial organization has generally been seen as happening decisively within an entirely topological space, with geometry providing an opportunity for embellishments" [2001: 20.15]. Instead, Bafna suggests, it may be better to imagine that design progresses from a geometrical starting point which "permits, and indeed makes possible, a great deal of topological variation within certain restrictions" [2001: 20.15]. Thus, in the architecture of Mies van der Rohe and Glenn Murcutt, form does not follow programmatic function at least. Indeed, as many analysts have noted, the more "functional" a space, the less capacity it has to adapt to changing social and cultural conditions [Blake 1974; Brolin 1976].

A good example of this can be seen in the way in which Murcutt uses narrow slivers of space to connect parallel pavilion forms (something that occurs in three of the houses considered in this paper). In two of the cases (the Marie Short House and the Fredericks House) the space becomes a corridor, whereas in the third (the Nicolas House) it is largely merged with the rest of the open plan. Similarly, the steeply pitched roofs of these houses conceal mezzanine rooms on some occasions but not on others. In each of these examples – the connecting sliver and the inhabited roof – a review of the external form alone cannot be used to predict the relative depth, or social structure, of the interior.

Ultimately, because of the similarities between the architecture of Murcutt and Mies, it is not surprising that the present paper has reinforced the findings of Bafna [1999]. Both architects' minimalist aesthetic compositions clearly require some compromise. What would be more interesting for future researchers to test would be the inequality genotypes produced for houses designed by architects who have openly expressed a primary concern with program; Charles Moore, Christopher Alexander and Patkau Architects all fit into this category. Finally, an alternative research direction would be to expand the present paper to include new, larger and more complex rural houses by Murcutt. The larger programs of these houses provide further opportunities for considering the relationship between form and planning, or geometry and topology.

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