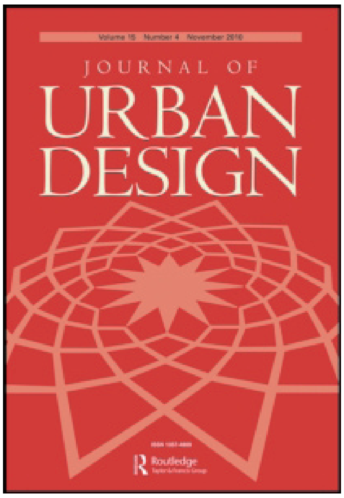

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Measuring the Unmeasurable: Urban Design Qualities Related to Walkability

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Measuring the Unmeasurable: Urban Design Qualities Related to Walkability

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ABSTRACT *This study attempts to comprehensively and objectively measure subjective qualities of the urban street environment. Using ratings from an expert panel, it was possible to measure five urban design qualities in terms of physical characteristics of streets and their edges: imageability, enclosure, human scale, transparency and complexity. The operational definitions do not always comport with the qualitative definitions, and provide new insights into the nature of these urban design qualities. The immediate purpose of this study is to arm researchers with operational definitions they can use to measure the street environment and test for significant associations with walking behaviour. A validation study is currently underway in New York City. Depending on the outcome of this and other follow-up research, the ultimate purpose would be to inform urban design practice.*

Introduction

During the past few years, the fields of urban design and public health have been drawn together by their common interest in walkable communities. Walking is by far the most common form of leisure-time physical activity among US adults, engaged in by 41% according to the Behavioural Risk Factor Surveillance System (BRFSS). By comparison, golf is played by less than 4%. The Centers for Disease Control and Prevention (CDC) have endorsed healthy community design (CDC, 2005). Similarly, the Active Living by Design programme, funded by the Robert Wood Johnson Foundation, promotes community design that incorporates walking and bicycling into daily life (ALbD undated).

Many tools for measuring the quality of the walking environment have emerged during the past few years. Generically called walking audit instruments, these are now widely used across the US by researchers, local governments, and community groups. Robert Wood Johnson's Active Living Research (ALR) website alone posts 13 walking audit instruments <http://www.activelivingresearch.org/alr/resourcesearch/toolsandmeasures>. At least five of these have been validated to some degree. They require the measurement of such physical features as building height, block length and street and sidewalk width.

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However, physical features individually may not tell us much about the experience of walking down a particular street. Specifically, they do not capture people's overall perceptions of the street environment, perceptions that may have complex or subtle relationships to physical features. The urban design literature points to numerous perceptual qualities that may affect the walking environment (Handy, 1992; Ewing, 1996). Other fields also contribute, including architecture, landscape architecture, park planning, environmental psychology, and the growing visual preference and visual assessment literature (Ewing, 2000; Ewing *et al.*, 2005a). A literature review produced a list of 51 perceptual qualities (Table 1).

With few exceptions, the urban design literature has not attempted to objectively measure these or other perceptual qualities (referred to below as 'urban design qualities'), and instead simply asserts their importance. This study sets out to objectively measure seemingly subjective qualities of the walking environment. The approach is to link specific physical features to urban design quality ratings by a panel of experts for a sample of commercial streets. Of the 51 perceptual qualities, eight were selected for further study based on the importance assigned to them in the literature: imageability, enclosure, human scale, transparency, complexity, legibility, linkage and coherence. The first five were successfully operationalized. The methodology is described in detail elsewhere (Ewing *et al.*, 2005b, 2006). It is the basis for an illustrated field survey manual posted on the ALR website (Clemente *et al.*, 2005). The paper here provides only a brief outline of the methodology and instead focuses on results.

The paper first discusses each urban design quality that was successfully operationalized as it is depicted in the literature and is characterized by the panel of experts. The qualitative discussion leans heavily on classic works in urban design. It ends with a 'consensus qualitative definition' from the expert panel formed to help with this project.

Second, previous attempts to operationalize these particular urban design qualities are described. These come from visual assessment studies, urban design guidelines and land development regulations. It will be apparent that previous attempts are limited in scope and not particularly applicable to the ultimate task at hand, measuring perceptual qualities that contribute to walkability.

Finally, operational definitions of the urban design qualities in the context of commercial streets are presented. These definitions are based on ratings by the same expert panel of video clips of 48 commercial streets from across the

Table 1. Perceptual qualities

adaptability	distinctiveness	intricacy	richness
ambiguity	diversity	legibility	sensuousness
centrality	dominance	linkage	singularity
Clarity	enclosure	meaning	spaciousness
coherence	expectancy	mystery	territoriality
compatibility	focality.	naturalness	texture
comfort	formality	novelty	transparency
complementarity	human scale	openness	unity
complexity	identifiability	ornateness	upkeep
continuity	imageability	prospect	variety
contrast	intelligibility	refuge	visibility
deflection	interest	regularity	vividness
Depth	intimacy	rhythm	

United States. The video clips were filmed following a consistent protocol that mimicked the experience of pedestrians.

The immediate purpose of this study is to arm researchers with operational definitions they can use to measure the street environment and test for significant associations with walking behaviour. Such research is currently underway in New York City, conducted by an interdisciplinary team at Columbia University (Health & Society News, 2006). Depending on the outcome of this and follow-up research, the ultimate purpose would be to inform urban design practice.

Conceptual Framework

Perception is the process of attaining awareness or understanding of sensory information. What one perceives is a result of interplays between past experiences, one's culture and the interpretation of the perceived.

The conceptual framework underlying this study considers the role of perceptions as they intervene (or mediate) between the physical features of the environment and walking behaviour (Figure 1). Physical features influence the quality of the walking environment both directly and indirectly through the perceptions and sensitivities of individuals.

Urban design qualities are different from qualities such as sense of comfort, sense of safety and level of interest that reflect how an individual reacts to a place—how they assess the conditions there, given their own attitudes and preferences. Perceptions are just that, perceptions. They may produce different reactions in different people. They can be assessed with a degree of objectivity by outside observers; individual reactions cannot.

All of these factors—physical features, urban design qualities and individual reactions—may influence the way an individual feels about the environment as a place to walk. By measuring these intervening variables, researchers can better

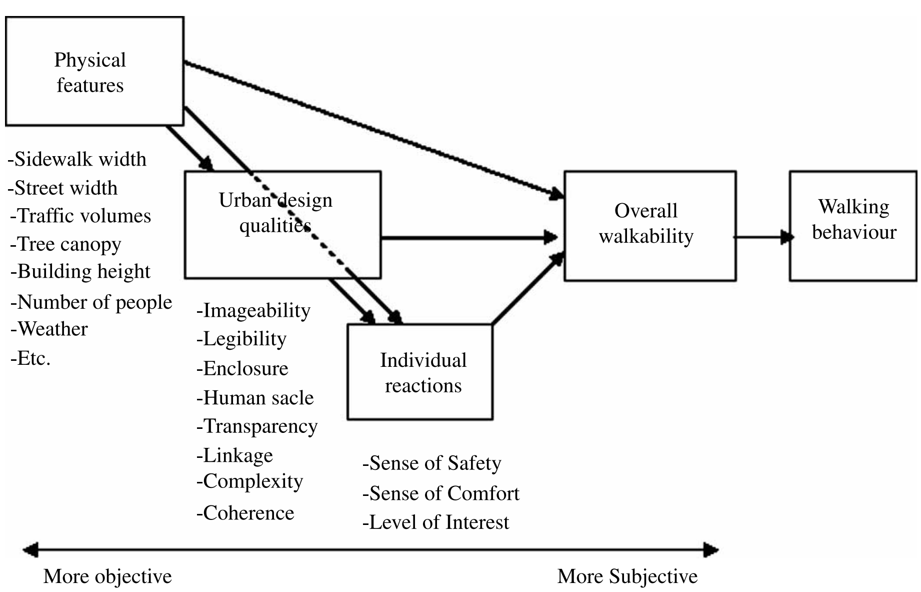

Figure 1. Conceptual framework.

articulate the relationship between physical features of the street environment and walking behaviour.

Expert Panel

This study employed a mixed qualitative and quantitative design. Because the concepts the study sought to operationalize are not familiar to the average person, it was not possible to simply ask a random sample of street users to rate streetscapes with regard to their 'legibility', 'coherence', and so on. Instead, the decision was made to consult experts who employ these constructs in their work.

A panel of 10 urban design and planning experts was assembled from professional practice as well as academia. The panel members helped to qualitatively define urban design qualities of streetscapes, rated different scenes with respect to these qualities, submitted to interviews as they assigned their ratings to provide the research team with qualitative insights into physical features that influenced their ratings, met to discuss ways of measuring urban design qualities, and reviewed and commented on the draft field survey manual that presented the measurement instrument in all its detail. The panelists' ratings of the urban design qualities for the sample of streetscapes were accepted as valid by virtue of their specialized expertise.

Obviously, the validity of the results is no better than the quality of ratings by the expert panel. The 10 panel members were recruited from different disciplines and have different orientations (for example, some were New Urbanist, others not). They are leaders in their respective fields, and have intimate knowledge of urban design concepts from their research, teaching, and/or practice. Because of the critical role they played in this study, brief affiliations are provided in the Acknowledgements.

Scenes

For practical reasons, video clips of streetscapes were used rather than field visits as the medium for rating urban design qualities. To ensure that reactions to street scenes were not biased by different filming techniques, a consistent filming protocol was developed. A great deal of experimentation and dialogue among the investigators went into the development of a protocol that would mimic the experience of pedestrians. Pedestrians are usually in motion, sway a bit as they walk, have peripheral vision and tend to scan their environments. The protocol specified the starting point on a street block, walking speed and panning motions; the distance covered and time length of the clips varied somewhat depending on actual walking and panning speeds but averaged between 1 and 1.25 minutes.

More than 200 clips were filmed in dozens of cities across the United States. Diversity of street scenes was ensured by the different regional locations of the investigators and the travels of the investigators on other business during the course of the study. While shooting clips the focus was on commercial streets in urban or 'main street' settings—all places with sidewalks and other pedestrian amenities such as landscaping, pedestrian lighting, street furniture and businesses or public spaces within view.

Scenes were shot and ultimately selected for the visual assessment study using a fractional factorial design. A factorial design was used to capture relevant combinations of the eight urban design qualities chosen for operationalization (tidiness was added later). Without variation across the qualities, it would have been impossible to tease out the contributions of individual physical features to urban design quality ratings. Factorial designs are common in experimental research in which the goal is to isolate the effect of each of multiple factors.

To choose the samples, one investigator and a research assistant rated clips as 'high' or 'low' with respect to the eight urban design qualities. From the larger set, 48 clips were selected that best matched the combinations of high/low values in a 2^{8-4} fractional factorial design. Urban design qualities tend to co-vary (that is, appear in certain combinations of high and low values), making perfect matches unlikely starting with any practically sized set of clips. Some of the clips matched high/low patterns perfectly, while others matched on only seven, six, or even five of the qualities, rather than all eight. Although it was not possible to exactly match the fractional factorial design in all cases, following the design as closely as possible resulted in the selection of clips that were distinctly different. Where ratings for two or more clips matched factorial designs equally well, clips were selected to maximize geographic diversity.

Figures 2–5 are static images from four of the video clips, illustrating variation in urban design qualities. Clips were rated by the expert panel on a scale that represented low to high levels of each quality (1 to 5).

Figure 2. Scene rated high on all eight urban design qualities (Annapolis, MD).

Figure 3. Scene rated high on imageability, legibility and coherence (Washington, DC).

Figure 4. Scene rated high on enclosure, linkage, and complexity (San Francisco, CA).

Figure 5. Scene rated low on all eight urban design qualities (Rockville, MD).

Measures

To measure physical features of streetscapes, all 48 video clips were analyzed for content. In total, more than 100 features were measured in this manner for each scene. The process typically required more than an hour for each video clip, and much more for the more complex scenes. Detailed operational rules for measuring each physical feature were developed to ensure consistency.

The physical features measured in this manner were derived from the urban design literature, from earlier visual assessment studies, and most importantly, from interviews with the expert panel. As panelists rated scenes, they also commented on the physical features that caused ratings to be high or low with respect to each urban design quality. Interviews, which had been taped, were reviewed to identify promising features.

One of the investigators and a research assistant measured each physical feature for all 48 clips using a process that might be best described as one of forced consensus. The two independently measured each feature, discussed differences and finally reached agreement on a single value for each physical feature of each video clip. To assess inter-rater reliability of measured physical features, a random sample of video clips was assigned to three other members of the research team. The sample consisted of 12 clips in total, or four per team member. Sample size was limited by the time required to evaluate more than 100 features of each clip.

For most features, there was almost perfect agreement (ICCs $\geq$ 0.8) or substantial agreement (0.8 $>$ ICCs $\geq$ 0.6) among the team members. The ICC (intra-class correlation coefficient) is a measure of inter-rater reliability. It is relatively easy to count objects and measure widths, and ICC values were accordingly high.

However, several features had low or even negative ICC values. Of these, features such as the number of landscape elements probably could be rated more consistently with better operational definitions. Other features, such as landscape condition, involve a high degree of judgement and might require training and/or photographic examples to achieve reasonable inter-rater reliability.

Physical features also vary in their degree of constancy, which complicates their measurement, validation, and use in research and design. Some features vary by the hour or day (number of people and parked cars), others vary by the season (presence of outdoor dining and debris), and still others vary only as redevelopment occurs (average building setback and height). The inconstant features may be treated as control variables, and ignored in the scoring of streets. Or they may be averaged over reasonable time periods and included as scoring factors. Even the most variable features, such as pedestrian volume, may be predictable in terms of gross attributes of an area such as density and land use mix, qualities that can be influenced by planners and designers.

Model Estimation

Expert panel ratings were used as dependent variables in the estimation of statistical models. The physical characteristics of the street environment were the independent variables. The models provided several important bits of information: which physical characteristics are statistically associated with each perceptual quality; the direction of the association, whether positive or negative;

the share of variation in ratings of each perceptual quality across the scenes explained by the physical characteristics in the model; and the share of total variation in ratings (including variation across video clips, expert panelists, and measurement error) explained by the model.

Through the course of the study, it became clear that not all urban design qualities could be defined operationally. Some are more amenable to measurement than are others. To decide which urban design qualities could be defined operationally in a field survey instrument, five criteria were established. By these criteria, it was possible to operationalize five of the eight urban design qualities with a degree of validity and reliability deemed adequate for future active living research. The five are: imageability, enclosure, human scale, transparency and complexity. The following discussion focuses on these five urban design qualities. The operational definitions do not always comport with the qualitative definitions, and thus provide new insights into the nature of these urban design qualities.

Of more than 130 physical features tested, 38 proved significant in one or more models (including models of legibility, linkage and coherence). Six features were significant in two models: long sight lines, number of buildings with identifiers, proportion first floor façade with windows, proportion street wall, and number of pieces of public art. Two features were significant in three models: number of people in a scene and presence of outdoor dining. For operational definitions of these and other physical features of commercial streets, see the Final Report for the project (Ewing *et al.*, 2005b). In the discussion that follows, and in the model summaries in Table 2, physical features are listed as contributors to each quality in order of descending significance.

Qualitative and Operational Definitions

Imageability

Kevin Lynch (1960, p. 9) defines imageability as a quality of a physical environment that evokes a strong image in an observer: "It is that shape, color, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment". A highly imageable city is well formed, contains distinct parts, and is instantly recognizable to anyone who has visited or lived there. It plays to the innate human ability to detect and remember patterns. It is one whose elements are easily identifiable and grouped into an overall pattern.

Landmarks are believed to be a key component of imageability. The term 'landmark' does not necessarily denote a grandiose civic structure or even a large object. In the words of Lynch, it can be a doorknob or a dome. What is essential is its singularity and location, in relationship to its context, background and the city at large. Landmarks are a principle of urban design because they act as visual termination points, orientation points and points of contrast in the urban setting. Tunnard & Pushkarev (1963, p. 140) attribute great importance to landmarks, stating: "A landmark lifts a considerable area around itself out of anonymity, giving it identity and visual structure".

Distinctive buildings are the most common type of landmarks. Memorable buildings are characterized by complex shapes, large sizes, and high use (Appleyard, 1969; Evans *et al.*, 1982). Additional elements that may enhance

Table 2. Summary of models[a]

Urban design quality	Significant physical features	Coefficients	*p*-values
Imageability	people (#)	0.0239	0.000
	proportion of historic buildings	0.970	0.000
	courtyards/plazas/parks (#)	0.414	0.000
	outdoor dining (y/n)	0.644	0.000
	buildings with non-rectangular silhouettes (#)	0.0795	0.036
	noise level (rating)	− 0.183	0.045
	major landscape features (#)	0.722	0.049
	buildings with identifiers (#)	0.111	0.083
Enclosure	proportion street wall—same side	0.716	0.001
	proportion street wall—opposite side	0.940	0.002
	proportion sky across	− 2.193	0.021
	long sight lines (#)	− 0.308	0.035
	proportion sky ahead	− 1.418	0.055
Human scale	long sight lines (#)	− 0.744	0.000
	all street furniture and other street items (#)	0.0364	0.000
	proportion first floor with windows	1.099	0.000
	building height—same side	− 0.00304	0.033
	small planters (#)	0.0496	0.047
	urban designer (y/n)	0.382	0.066
Transparency	proportion first floor with windows	1.219	0.002
	proportion active uses	0.533	0.004
	proportion street wall—same side	0.666	0.011
Complexity	people (#)	0.0268	0.000
	buildings (#)	0.0510	0.008
	dominant building colours (#)	0.177	0.031
	accent colours (#)	0.108	0.043
	outdoor dining (y/n)	0.367	0.045
	public art (#)	0.272	0.066

Notes: [a]Models of imageability, human scale and complexity were re-estimated since the publication of the final report (Ewing *et al.*, 2005b), which accounts for the minor differences in variables and coefficient values.

building recall are natural features around them, ease of pedestrian access, and uniqueness of architectural style.

Imageability is related to ‘sense of place’. Jan Gehl (1987, p. 183) explains this phenomena using the example of famous Italian city squares, where “life in the space, the climate, and the architectural quality support and complement each other to create an unforgettable total impression”. When all factors manage to work together to such pleasing ends, a feeling of physical and psychological well-being results: the feeling that a space is a thoroughly pleasant place in which to be.

Imageability is related to many other urban design qualities—legibility, enclosure, human scale, transparency, linkage, complexity and coherence—and is in some way the net effect of these qualities. Places that rate high on these qualities are likely to rate high on imageability as well—the neighbourhoods of Paris or San Francisco, for example. However, places that rate low on these qualities may also evoke strong images, and are ones that people may prefer to forget. Although the strength of the image a place evokes, whether positive or negative, is itself of interest, urban designers focus on the strength of positive images in discussing imageability and sense of place.

The expert panel most often mentioned vernacular architecture as a contributor to imageability. Other influences mentioned were striking views, unusual topography, and marquee signage.

Consensus qualitative definition. Imageability is the quality of a place that makes it distinct, recognizable and memorable. A place has high imageability when specific physical elements and their arrangement capture attention, evoke feelings and create a lasting impression.

Previous attempts to operationalize. Beyond Kevin Lynch's detailed qualitative characterizations, and the two quantitative studies of building recall, the study could find no attempts to operationalize imageability either in visual assessment studies or design guidelines.

Operational definition. The imageability model is summarized in Table 2. The model differs slightly from that reported previously (Ewing *et al.*, 2005b). Based on the field experience, the number of people visible in a scene, including those standing and sitting, was substituted for the number of moving pedestrians. Features contributing significantly to imageability are (in order of significance):

- number of people—same side of street;
- proportion of historic buildings—both sides of street;
- number of courtyards, plazas, and parks—both sides of street;
- presence of outdoor dining—same side of street;
- number of buildings with non-rectangular silhouettes—both sides of street;
- noise level—same side of street;
- number of major landscape features—both sides of street;
- number of buildings with identifiers—both sides of street.

All have positive relationships to perceptions of imageability except noise level, which detracts. The best-fit model explains 72% of the variation across scenes, and 36% of the overall variation in imageability scores (including variation across viewers and measurement errors). The significance of the number of people and outdoor dining points to the importance of human activity in creating imageable places. The lack of significance of landmarks, distinctive architecture and public art forces us to rethink just what makes a place memorable. This model is strong with respect to validity and reliability (see Ewing *et al.*, 2005b, 2006).

Enclosure

Outdoor spaces are defined and shaped by vertical elements, which interrupt viewers' lines of sight. As numerous urban design theorists have articulated, a sense of enclosure results when lines of sight are so decisively blocked as to make outdoor spaces seem room-like. Gordon Cullen (1961, p. 29) states that "Enclosure, or the outdoor room, is, perhaps, the most powerful, the most obvious, of all the devices to instill a sense of position, of identity with the surroundings … it embodies the idea of hereness …" Christopher Alexander *et al.* (1977, p. 106) say that "An outdoor space is positive when it has a distinct and definite shape, as definite as the shape of a room, and when its shape is as important as the shapes of the buildings which surround it". Similarly, Allan

Jacobs (1993) says that people react favourably to fixed boundaries as something safe, defined and even memorable—an invitation to enter a place special enough to warrant boundaries. Jacobs & Appleyard (1987, p. 118) speak of the need for buildings to "define or even enclose space—rather than sit in space". Richard Hedman (1984) refers to certain arrangements of buildings as creating intensely three-dimensional spaces.

In an urban setting, enclosure is formed by lining the street or plaza with unbroken building fronts of roughly equal height. The buildings become the 'walls' of the outdoor room, the street and sidewalks become the 'floor', and if the buildings are roughly equal height, the sky projects as an invisible ceiling. Buildings lined up that way are often referred to as 'street walls'. Alexander *et al.* (1977, pp. 489–491) state that the total width of the street, building-to-building, should not exceed the building heights in order to maintain a comfortable feeling of enclosure. Allan Jacobs (1993) is more lenient in this regard, suggesting that the proportion of building heights to street width should be at least 1:2. Other designers have recommended proportions as high as 3:2 and as low as 1:6 for a sense of enclosure.

At low suburban densities, building masses become less important in defining space, and street trees assume the dominant role. Rows of trees on both sides of a street can humanize the height-to-width ratio. Henry Arnold (1993) explains that trees define space both horizontally and vertically. Horizontally they do so by visually enclosing or completing an area of open space. Vertically they define space by creating an airy ceiling of branches and leaves. Unlike the solid enclosure of buildings, tree lines depend on visual suggestion and illusion. Street space will seem enclosed only if trees are closely spaced. Properly scaled, walls and fences can also provide spatial definition in urban and suburban settings. Lynch recommended walls and fences that are either low or over 6 feet tall.

Visual termination points may also contribute to a sense of enclosure. Andres Duany and other New Urbanists advocate closing vistas at street ends with prominent buildings, monuments, fountains or other architectural elements as a way of achieving enclosure in all directions (Duany & Plater-Zyberk, 1992). When a street is not strongly defined by buildings, focal points at its ends can maintain the visual linearity of the arrangement. Similarly, the layout of the street network can influence the sense of enclosure. A rectilinear grid with continuous streets creates long sight lines. These may undermine the sense of enclosure created by the buildings and trees that line the street. Irregular grids may create visual termination points that help to enclose a space; cul-de-sacs, for example, tend to create more sense of enclosure than through streets.

Enclosure is eroded by breaks in the continuity of the street wall, that is, breaks in the vertical elements such as buildings or tree rows that line the street. Breaks in continuity that are occupied by inactive uses create dead spaces that further erode enclosure; vacant lots, parking lots, driveways and other uses that do not generate human presence are all considered dead spaces. Large building setbacks are another source of dead space. Alexander *et al.* (1977, p. 593) say "building setbacks from the street, originally invented to protect the public welfare by giving every building light and air, have actually helped greatly to destroy the street as social space".

The expert panel suggested on-street parking, planted medians, and even traffic itself contribute to visual enclosure. They opined that the required building height to enclose street space varies with context, specifically, between a big city and small town.

Consensus qualitative definition. Enclosure refers to the degree to which streets and other public spaces are visually defined by buildings, walls, trees and other vertical elements. Spaces where the height of vertical elements is proportionally related to the width of the space between them have a room-like quality.

Previous attempts to operationalize. The visual assessment literature suggests that enclosure is an important factor in human responses to environments, and that solid surfaces are the important variable in impressions of enclosure. Using photographs of Paris, Stamps & Smith (2002) found that the perception of enclosure is positively related to the proportion of a scene covered by walls, and negatively related to the proportion of a scene consisting of ground, the depth of view, and the number of sides open at the front. These results were confirmed in later visual simulations (Stamps, 2005).

Enclosure is defined both qualitatively and quantitatively in many urban design guidelines and several land development codes. The qualitative definitions sometimes capture the multi-faceted nature of the concept, for example, Denver, CO's:

> Building facades should closely align and create a continuous facade, punctuated by store entrances and windows. This produces a comfortable sense of enclosure for the pedestrian and a continuous storefront that attracts and encourages the pedestrian to continue along the street. (City of Denver, 1993)

However, when it comes to operationalizing the concept of enclosure, urban design guidelines tend to limit themselves to one aspect of enclosure, the relationship between street width and abutting building heights. Guidelines from the Raleigh, NC, illustrate this limited approach:

> The condition of enclosure generated by the height-width ratio of the space is related to the physiology of the human eye. If the width of a public space is such that the cone of vision encompasses less street walls than the opening to the sky, then the degree of spatial enclosure is slight. A 1:6 height-to-width ratio is the minimum for appropriate urban spatial definition. An appropriate average ratio is 1:3. As a general rule, the tighter the ratio, the stronger the sense of place. (City of Raleigh, 2002)

Maximum setback limitations in certain zoning districts of progressive jurisdictions (for example, New York, Seattle and San Francisco) seem aimed in part at creating a sense of street enclosure. Similarly, required building lines (build-to requirements) in the new form-based codes may have this purpose (Arlington, VA; Woodford County, VA; Pleasant Hill BART Station Property Code).

Operational definition. With just five variables, the model for enclosure explains 73% of the scene variance and 43% of the total variance in enclosure ratings. Features contributing significantly to the perception of enclosure are (in order of significance):

- proportion street wall—same side of street;
- proportion street wall—opposite side of street;
- proportion sky—across street;
- number of long sight lines—ahead and to either side;
- proportion sky—straight ahead.

The signs of the coefficients in the model are as expected, with long sight lines, proportion of the view ahead that is sky and proportion of the view across the street that is sky detracting from the perception of enclosure (see Table 2). A more continuous 'street wall' of building facades, on each side of the street, adds to the perception of enclosure. This model suggests that enclosure is influenced not just by the near side of the street but also by views ahead and across the street. Surprisingly, the average street width, average building setback, average building height and relationship between the width of the street and building height were not significant. This model is strong with respect to validity and reliability (see Ewing *et al.*, 2005b, 2006).

Human Scale

Urban designers offer differing definitions of human scale. Alexander *et al.* (1977) state that any buildings over four storeys tall are out of human scale. Lennard & Lennard (1987) set the limit at six storeys. Hans Blumenfeld (1953) sets it at three storeys. In taller buildings, Roger Trancik (1986) says that lower floors should spread out and upper floors step back before they ascend, giving human-scale definition to streets and plazas. Richard Hedman (1984) emphasizes the importance of articulated architecture and belt courses and cornices on large buildings to help moderate scale.

Several authors suggest that the width of buildings, not just the height, defines human scale. For human scale, building widths should not be out of proportion with building heights, as are so many buildings in the suburbs.

Human scale can also be defined by human speed. Jane Holtz Kay (1997) argues that today, far too many things are built to accommodate the bulk and rapid speed of the automobile; we are 'designing for 60 mph'. When approached by foot, these things overwhelm the senses, creating disorientation. For example, large signs with large lettering are designed to be read by high-speed motorists. For pedestrians, small signs with small lettering are much more comfortable. Personal interaction distances play a role in designing for the human scale. Jan Gehl (1987) designates these distances as:

- Intimate distance 0–1.5 feet
- Personal distance 1.5–4.5 feet
- Social distance 4.5–12 feet
- Public distance >12 feet

According to Alexander *et al.* (1977), a person's face is just recognizable at 70 feet, a loud voice can just be heard at 70 feet, and a person's face is recognizable in portrait-like detail up to about 48 feet. These set the limits of human scale for social interaction.

Street trees can moderate the scale of tall buildings and wide streets. According to Henry Arnold (1993), where tall buildings or wide streets would intimidate pedestrians, a canopy of leaves and branches allows for a simultaneous experience of the smaller space within the larger volume. He posits that where streets are over 40 feet wide, additional rows of trees are needed to achieve human scale. Hedman (1984) recommends the use of other small-scale elements such as clock towers to moderate the scale of buildings and streets.

In addition to the above elements, the expert panel related human scale to the intricacy of paving patterns, amount of street furniture, depth of setbacks on tall buildings, presence of parked cars, ornamentation of buildings and spacing of windows and doors. Interestingly, high-rise Rockefeller Center and Times Square were both perceived as human scaled due to compensating elements at street level.

Consensus qualitative definition. Human scale refers to a size, texture, and articulation of physical elements that match the size and proportions of humans and, equally important, correspond to the speed at which humans walk. Building details, pavement texture, street trees, and street furniture are all physical elements contributing to human scale.

Previous attempts to operationalize. Land development ordinances and urban design guidelines occasionally make reference to human scale as a desirable quality. Davis CA's define human scale in qualitative terms:

> The size or proportion of a building element or space relative to the structural or functional dimensions of the human body. Used generally to refer to building elements that are smaller in scale, more proportional to the human body, rather than monumental (or larger scale). (City of Davis, undated)

A few ordinances get more specific, for example, Placer County, CA's:

> The relationship of a building, or portions of a building, to a human being is called its relationship to 'human scale'. The spectrum of relationships to human scale ranges from intimate to monumental. Intimate usually refers to small spaces or detail which is very much in keeping with the human scale, usually areas around eight to ten feet in size. These spaces feel intimate because of the relationship of a human being to the space . . . The components of a building with an intimate scale are often small and include details which break those components into smaller units. At the other end of the spectrum, monumental scale is used to present a feeling of grandeur, security, timelessness, or spiritual well being. Building types which commonly use the monumental scale to express these feelings are banks, churches, and civic buildings. The components of this scale also reflect this grandness, with oversized double door entries, 18-foot glass storefronts, or two-story columns. (Placer County, 2003)

To the authors' knowledge, there has been only one previous attempt to operationalize human scale via a visual assessment survey, and this strictly with respect of architectural massing (Stamps, 1998). The most important determinant was the cross-sectional area of buildings, second was the amount of fenestration, and third was the amount of façade articulation and partitioning.

Operational definition. The human scale model is summarized in Table 2. It differs slightly from that reported previously (Ewing *et al.*, 2005b). Based on the field experience here, the number of pieces of street furniture and other miscellaneous items was substituted for a more limited set of street items. Features contributing significantly to human scale are (in order of significance):

- number of long sight lines;
- number of pieces of street furniture and other miscellaneous items—same side of street;

- proportion first floor with windows—same side of street;
- building height—same side of street;
- number of small planters—same side of street.

These five variables explain 63% of the scene variance and 36% of the total variance in human scale ratings. The signs of the coefficients are as expected: the number of long sight lines and building height on the same side of the street detract from the perception of human scale, while the presence of first floor windows, small planters and street furniture increase the perception of human scale. Human scale is the only quality for which characteristics of viewers proved significant in the expert panel ratings: urban designers tended to rate scenes higher than did other panel members. This model is strong with respect to validity and reliability (see Ewing *et al.*, 2005b, 2006).

Transparency

Taken literally, transparency is a material condition that is pervious to light and/or air, an inherent quality of substance as in a glass wall. A classic example of transparency is a shopping street with display windows that invite passers-by to look in and then come in to shop. Blank walls and reflective glass buildings are classic examples of design elements that reduce transparency.

But transparency can be subtler than this. What lies behind the street edge need only be imagined, not actually seen. Allan Jacobs (1993) says that streets with many entryways contribute to the perception of human activity beyond the street, while those with blank walls and garages suggest that people are far away. Even blank walls may exhibit some transparency if overhung by trees or bushes, providing signs of habitation. Henry Arnold (1993) tells us that trees with high canopies create ‘partially transparent tents’, affording awareness of the space beyond while still conferring a sense of enclosure. By contrast, small trees in most urban settings work against transparency (Arnold, 1993).

Transparency is most critical at the street level, because this is where the greatest interaction occurs between indoors and outdoors. William H. Whyte (1988) suggested that if a blank wall index were ever computed, as the percentage of blockfront up to 35-foot height, it would show that blank walls have become the dominant feature of cityscapes. The ultimate in transparency is when internal activities are ‘externalized’ or brought out to the sidewalk (Llewelyn-Davies, 2000). Outdoor dining and outdoor merchandising are examples.

The expert panel suggested that courtyards, signs and buildings that convey specific uses (schools and churches) add to transparency. Reflective glass, arcades and large building setbacks were thought to detract from transparency. Interior lighting, shadows and reflections were also thought to have a role in the perception of transparency.

Consensus qualitative definition. Transparency refers to the degree to which people can see or perceive what lies beyond the edge of a street and, more specifically, the degree to which people can see or perceive human activity beyond the edge of a street. Physical elements that influence transparency include walls, windows, doors, fences, landscaping and openings into mid-block spaces.

Previous attempts to operationalize. Transparency is the urban design quality most frequently defined in urban design guidelines and land development codes. Some definitions of transparency are strictly qualitative. Others are quantitative. The concept is operationalized almost always in limited terms of windows as a percentage of ground floor façade. San Jose's operational definition is typical:

> Transparency: A street level development standard that defines a requirement for clear or lightly tinted glass in terms of a percentage of the façade area between an area falling within 2 feet and 20 feet above the adjacent sidewalk or walkway. (City of San Jose, 2004)

Operational definition. Only three variables explain 62% of the scene variance and 32% of the total variance in the perception of transparency. The three (in order of significance) are:

- the proportion first floor with windows—same side of street;
- the proportion active uses—same side of street;
- the proportion street wall—same side of street.

The model confirms but expands the standard approach to operationalizing transparency. It suggests that both being able to see into buildings and having human activity along the street contribute to the perception of transparency. Note that windows above ground-level do not increase the perception of transparency (after controlling for other variables). This model is strong with respect to validity and reliability (see Ewing *et al.*, 2005b, 2006).

Complexity

Amos Rapoport (1990) explains the fundamental properties of complexity. Complexity is related to the number noticeable differences to which a viewer is exposed per unit time. Human beings are most comfortable receiving information at usable rates. Too little information produces sensory deprivation, too much creates sensory overload.

Rapoport & Hawkes (1970) contrast the complexity requirements of pedestrians and motorists. Pedestrians moving 3 mph require a high level of complexity to hold their interest. Motorists traveling 60 mph will find the same environment chaotic. The commercial strip is too complex and chaotic at driving speeds, yet due to scale, yields few noticeable differences at pedestrian speeds.

The environment can provide low levels of usable information in three ways: elements may be too few or too similar; elements, although numerous and varied, may be too predictable for surprise or novelty; or elements, although numerous and varied, may be too unordered for comprehension.

Streets high in complexity provide many interesting things to look at: building details, signs, people, surfaces, changing light patterns and movement, signs of habitation. As Jan Gehl (1987, p. 143) notes in his classic *Life Between Buildings*, an interesting walking network will have the "psychological effect of making the walking distance seem shorter," by virtue that the trip is "divided naturally, into manageable stages".

Complexity results from varying building shapes, sizes, materials, colours, architecture and ornamentation. According to Jacobs & Appleyard (1987), narrow buildings in varying arrangements add to complexity, while wide buildings subtract. Tony Nelessen (1994, p. 224) asserts that "Variations on basic patterns must be encouraged in order to prevent a dull sameness. If a particular building or up to three buildings are merely repeated, the result will be boring and mass produced". Variation can be incorporated into the building orientation plan or building set-back line, allowing for varied building frontage instead of monotonous, straight building frontage. Numerous doors and windows produce complexity as well as transparency.

Other elements of the built environment also contribute to complexity. According to Henry Arnold (1993), one function of trees is to restore the rich textural detail missing from modern architecture. Light filtered through trees gives life to space. Manipulation of light and shade transforms stone, asphalt and concrete into tapestries of sunlight and shadow. Allan Jacobs (1993) similarly values the constant movement of branches and leaves, and ever-changing light that play on, through and around them.

Street furniture also contributes to the complexity of street scenes. Jacobs (1993) states that pedestrian-scaled streetlights, fountains, carefully thought out benches, special paving, even public art, combine to make regal, special places.

Signage is a major source of complexity in urban and suburban areas. If well done, signs can add visual interest, make public spaces more inviting and help create a sense of place. Gordon Cullen (1961, p. 151) calls signs "the most characteristic, and, potentially, the most valuable, contribution of the twentieth century to urban scenery". When these signs are lit up at night, the result can be spectacular. However, signage must not be allowed to become chaotic and unfriendly to pedestrian traffic. Nasar (1987) reports that people prefer signage with moderate rather than high complexity—measured by the amount of variation among signs in location, shape, colour, direction and lettering style. Allan Jacobs (1993) uses Hong Kong signage as an example of complexity to the point of chaos.

The presence and activity of people add greatly to the complexity of a scene. This is true not only because people appear as discrete 'objects', but because they are in constant motion. Allan Jacobs, in the course of his worldwide travels, found that the most popular streets were ones that contained "sidewalks fairly cluttered with humans and life," calling them "attractive obstacle courses" that never failed to entertain (Jacobs, 1993, p. 59).

Complexity can also arise at a larger scale from the pattern of development. According to Christopher Alexander (1965), organically developed older cities have complex 'semi-lattice' structures, while new planned developments have simple 'tree-like structures'. Integration of land uses, housing types, activities, transportation modes and people creates diversity, and that in turn adds to complexity (Gehl, 1987). Jane Jacobs (1961, p. 161) describes diversity as a mixture of commercial, residential and civic uses in close proximity to each other, creating human traffic throughout day and night, and subsequently benefiting the safety, economic functioning and appeal of a place.

The expert panel here related complexity to:

- layering at the edge of streets, from sidewalk to arcade to courtyard to building;
- diversity of building ages;
- diversity of social settings;
- diversity of uses over the course of a day (something our videotapes couldn't capture).

Two panelists referred to the loss of complexity as design becomes more controlled and predictable (as in development projects under unified ownership).

Consensus qualitative definition. Complexity refers to the visual richness of a place. The complexity of a place depends on the variety of the physical environment, specifically the numbers and types of buildings, architectural diversity and ornamentation, landscape elements, street furniture, signage and human activity.

Previous attempts to operationalize. Complexity is one perceptual quality that has been measured extensively in visual assessment studies. It has been related to changes in texture, width, height and setback of buildings (Elshestaway, 1997; Stamps *et al.*, 2005). It has been related to building shapes, articulation, and ornamentation (Stamps, 1999; Heath *et al.*, 2000).

Operational definition. Six variables explain 73% of scene variance and 38% of total variance in the perception of complexity. In order of significance, they are (see Table 3):

- number of people—same side of street;
- number of dominant building colours—both sides of street;
- number of buildings—both sides of street;
- presence of outdoor dining—same side of street;
- number of accent colours—both sides of street;
- number of pieces of public art—both sides of street.

The signs of the coefficients are in the expected direction. The significance of people and outdoor dining suggests that human activity may contribute as much to the perception of complexity as do physical elements. The lack of significance of several other variables is notable: number of building materials, number of building projections, textured sidewalk surfaces, number of streets lights and other types of street furniture, among others. This model is strong with respect to validity and reliability (see Ewing *et al.*, 2005b, 2006).

Validation

Researchers associated with the Built Environment and Health (BEH) project at Columbia University recently implemented the urban design measurement protocol in a stratified sample of 588 block faces in New York City. The block face sample included residential as well as commercial and mixed-use neighbourhoods, and both low- and high-density areas. Results show that the urban design measures do not always mirror commonly-used indicators of urban form such as population density or land-use mix. Although the Bronx is much more densely settled than Queens or Staten Island, for example, the borough ranked the lowest on three out of five measures (Imageability, Human Scale and Complexity). Because urban design is not simply a function of population density and land-use mix, it has the potential to explain variation in walking behaviour that urban form cannot explain. To realize this potential, BEH researchers are using these observational measures as a ‘gold standard’ to validate digital measures of the five urban design dimensions. These digital measures will make it possible to study the relationship between urban design and physical activity at the city scale—something that would not have been possible without systematic measures of urban design.

Conclusions

The study here offers important insights into the physical characteristics of the street environment that contribute to more abstract urban design qualities. Although many characteristics that it was thought would be associated with perceptions proved statistically insignificant, the characteristics that were significant had the expected relationships to expert panel ratings. The models explained substantial variation in the ratings across the different scenes in the sample. The results of this study can be used in a variety of ways:

- Research: Researchers can objectively and consistently measure these qualities as independent variables in efforts to explain walking, use of public space and other potential outcomes. This was the ultimate purpose of this study.
- Planning: Planners can inventory physical characteristics to assess these qualities in an evaluation of public spaces in order to identify problems and develop strategies for improving public spaces.
- Design: Urban designers can give attention to physical characteristics shown to be associated with each urban design quality in designing public spaces.

The scope of this study was limited to commercial streets, from small town main streets to big city downtown streets, and the results might not apply to other settings. The viewers were experts in urban design and related fields, and a small group at that. It seems unlikely that users of street space would react in exactly the same way as experts. The scenes were displayed on videotapes in a laboratory setting, and only limited validation was performed in the field. These limitations can be addressed in future studies to shed further light on factors contributing to urban design qualities and their importance in explaining walking behaviour and ultimately quality of life.

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