Pedestrian Levels-of-Service tools: problems of conception, factor identification, measurement and usefulness

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Abstract

Streets are prominent parts of public space and reflect the livability of communities. Many streets are designed primarily for cars and neglect pedestrian requirements. Yet pedestrians are a major user group of streets, especially in activity centres and commercial areas. The concept of pedestrian level-of-service (PLOS) is often used to objectively quantify how well footpaths in streets accommodate pedestrians. There is significant dispute as to what should, or should not, be included when calculating PLOS. A wide range of measures and tools have been developed for different pedestrian environments. These aid designers and engineers in developing or retrofitting streets, crossings and paths. This paper has two aims: i) to review the past experience with PLOS measures and tools, in part to highlight the problems of existing approaches, and ii) to outline a more robust approach and methods to develop an improved PLOS tool and measures. A systematic literature review identified 58 papers on PLOS tools and measures for analysis. These are categorised as being focused on streets, intersections, mid-block crossings and footpaths per se. The measures used in these studies are identified, categorised and tabulated under the themes of geometric/physical, traffic, network/environmental, and user characteristics. The most common metrics include volume/capacity ratios but there is growing interest in built environment measures relating to the amenity of the streetscape. There is also significant tension identified between subjective and objective measures and uncertainty about how to conceive of and include streetscape items. Very few of these PLOS studies have been developed from primary research, either via revealed pedestrian perceptions or using groups of experts. Even fewer studies have used testing to ensure that their tools have strong inter-rater reliability. A proposed approach and methods to develop a more robust tool is outlined. This is scoped at PLOS on commercial streets only, given the importance of this particular type of facility in Australian cities. The full pathway to tool development and testing is outlined. The methods include a Delphi process (online survey and a walkshop) with a panel of experts specialised in pedestrian issues, and intercept surveys with pedestrians.[1]

1. Introduction

In recent years active transport, including walking and cycling, has been was given much more attention. Pedestrians have become an increasingly consideration in road design. Efforts have been made toward improving pedestrian facilities and operational characteristics in order to create appropriate environments for users and to promote walking. Objectives include reducing traffic, improving safety, economic development and creating a better environment. It is now recognised that streets must meet the needs of users and provide a convenient environment for pedestrians, while at the same time, discouraging dependence on vehicles (Sisiopiku and Akin, 2003, p. 250). Much of the effort towards improving public spaces has focused on streets given their importance to the public realm (Mehta, 2007, p. 166).

Studies on the relationship between the built environment and walking have led to the creation of numerous tools and methods for measuring walkability (Saelens and Handy, 2008, p. 8). Improving the built environment and street configuration, based on how pedestrians perceive these issues, is a priority to promote walking in urban precincts (Koohsari et al., 2013, 706). However, there may be many factors that influence pedestrian behaviour in the built environment that are yet to be discovered (Maghelal and Capp, 2011, 5).

[1] These activities are currently in-progress and though preliminary results cannot be included in the paper they should be available for presentation at the conference.

A sub-set of the research on built environments and walking is focused on the micro-scale of urban design. These studies consider how an individual link such as a section of footpath or an individual crossing provides for the pedestrian. It is at this scale that we most commonly use the concept of pedestrian level of service (PLOS). A level of service can be defined as an assessment of the quality of service or an overall measure of current conditions of streets including facilities, situations, equipment and infrastructures. More technically it can be described as “a quantitative stratification of a performance measure or measures that represent quality of service’’ (Kang et al., 2013, p. 11). Level of service (LOS) method can indicate existing conditions for street users or forecast possible conditions of hypothetical designs to be built in future. In this sense Gallon (2001, p. 48) defined pedestrian level of service as “an overall measure of walking condition on a route, path and facility”.

This paper has two aims: i) to review the past experience with PLOS measures and tools, in part to highlight the problems of existing approaches, and ii) to outline a more robust approach and methods to develop an improved PLOS tool and measures.

As will be shown, the present approaches have a number of limitations, including a lack of evidentiary support to justify the inclusion of many measures, and a lack of testing of PLOS audit tools to ensure inter-rater reliability for the measurement of subjective items. The contributions of this paper include the outcomes of systematic review which has for the first time identified, coded and themed the many measures used across 58 studies on PLOS reported in the literature, highlighting the most and least used measures in the field. An improved approach and methods to generate more appropriate measures and a more reliable tool are also provided.

The paper is structured as follows. In Section 2 the PLOS approach is outlined providing the key conceptual and theoretical framing for the paper. The first foundational research on PLOS is outlined, introducing Fruin’s (1971) perspective and how this approach was adopted in the most influential guidance to practitioners, especially in North America. How a similar approach has been adopted in Australia and New Zealand is then explained. In Section 3 the results of the systematic literature are provided including the full list of measures identified across the 58 studies, by theme. In Section 4 the proposed approach and method to develop an improved PLOS tool and measures is outlined and then summarised in a single figure. Section 5 describes the work in-progress and the expected timeline to completion.

2. The pedestrian level of service approach

Many studies have been conducted to evaluate streets using LOS in relation to motorised vehicles. However, until the 1970s this conceptual approach was not taken across into the field of pedestrian studies. The needs of pedestrians were mostly neglected. Only recently has research accelerated in the field of PLOS with more attention been given to pedestrian design (Authors removed for refereeing, in-submission). The main approach to PLOS has changed over time. As will be shown in detail, initially the concept was very much about volume of pedestrians vs. capacity and the freedom of movement for pedestrians in a given environment. This conception of PLOS was narrow and engineering focused. As with LOS for motorised traffic, PLOS tools tended to use a six-level scale using the letters that suggested whether a facility offered good service or not. Facilities scored as an ‘A’ offered the best PLOS; facilities scoring an ‘F’ the worst (Kang et al., 2013, p. 11). This may be seen as providing both objectivity in measurement and an easy system for road managers to help prioritise investment. Over time the narrow conception of PLOS as being mostly about volume vs. capacity has been challenged. In a set of evolutionary steps, and despite much debate, the concept has been broadened and expanded to encompass a greater set of issues from a wider range of disciplines.

2.1. The beginnings of the PLOS approach

Fruin (1971) proposed the first PLOS model based on footpath capacity and pedestrian volume. He described the relationships between basic vehicle flow and pedestrian volumes, average speed, and density, using the reciprocal of density, and defined it in area modules of square feet per pedestrian (Landis et al., 2001, p. 6). Fruin's measures can therefore be described as being only about speed-density-flow linear relationships while broader built environment measures were ignored.

In the 1970s and 80s a number of studies adopted Fruin's approach with some additions or modifications in PLOS criteria or models (Pushkarev and Zupan, 1975; Polus et al., 1983; Tanaboriboon and Guyano, 1989; Lam et al., 1995; Davis and Braaksma, 1987). Fruin's approach was adopted in the Highway Capacity Manual (HCM) for evaluating PLOS on footpath (Singh and Jain, 2011, p. 117) which was defined in term of time delay on signalized/unsignalized intersections (Muraleetharan et al., 2005, p. 128). The HCM can be defined as a guide used to determine the quality and level of service and capacity for given roadway segments and facilities. The importance of the HCM lies in its capacity to provide appropriate methods for evaluating quality and level of service and to give the best and most effective results in specific conditions (Ensley, 2012, p. 11). Although HCM describes LOS methods for evaluating pedestrian at intersections and footpaths, these methods were criticized by many researchers for different reasons. The HCM method doesn't include a wide range of the factors affecting PLOS, for example crossing facilities or turning vehicles on intersections (Muraleetharan et al., 2005, p. 128) or the surface condition, comfort or safety of footpaths (Kang et al., 2013, p. 11). Moreover, it did not take into consideration other universal cultural contexts, but sat within American cultural views of the street (Singh and Jain, 2011, p. 119). The HCM methods also assumed that pedestrians have a similar behavior to vehicles in terms of movement such as traveling in a linear path, that faster speed indicates efficient flow and so on (Asadi-Shekari et al., 2012, p. 182). Therefore, Mateo-Babiano and Ieda (2007, p. 1916) deemed the HCM methodology to be partly inaccurate as a result of change and complexity of pedestrian movement patterns, such as avoidance of barriers, choice of alternative routes, or resting on a bench

Since the 1990s a number of studies have gone further and suggested a method of evaluating PLOS based on other aspects of trip quality (Jaskiewicz, 2000, pp. 1-14). Factors such as safety, comfort and convenience have been included (Sarkar, 1993; Henson, 2000; Khisty, 1994). These environmental, geometry and behavioural factors may be used alone or in combination with the capacity approach.

2.2. Australia/New Zealand adoption of PLOS

The concept of LOS was adopted by the *NZ Pedestrian Planning and Design Guide* for selecting appropriate crossing facilities (Croft et al., 2013, p. 28). A spreadsheet tool includes a wide range of factors affecting crossing facilities, based on research conducted in New Zealand. The NZ Guide included safety and delay issues and not only traffic and pedestrian flows. This Guide presents detailed and useful information about this approach (Croft et al., 2013, p. 17 & 28). The Austroads *Guide to Traffic Management* (GTM) has been used in Australia to provide further guidance for determining LOS. A review of PLOS by Austroads (2013) refers to the need for acknowledgement of the influence of other factors which significantly influence pedestrian perceptions of LOS as well the basic considerations of pedestrian flow. Further, the review identified the need for developing practical LOS criteria for pedestrian facilities with suitable methods for selecting and assessing those facilities in Australian and New Zealand environments. The review asserted the need to continue to develop a comprehensive tool further, integrating and adapting techniques for application in Australia and New Zealand (Croft et al., 2013, p. 31& 50).

3. Systematic review

3.1. Study of literature

A systematic quantitative literature review was conducted. This involved systematically searching and categorising the relevant literature. Our review focused on studies related to quality of walking environment and explicitly to PLOS. We sought to categorise and tabulate what researchers have suggested are the most important factors in generating PLOS outputs. The list of factors was derived from a scoping review of the literature. The search terms used for identifying original research papers related to pedestrian level of service were ("Pedestrian Level of Service") as a Title AND ("Sidewalks* OR Footpaths* OR Pedestrian perceptions* OR Safety* OR Comfort* OR Quality of walking environment* OR Physical Characteristics* OR Obstructions* OR Aesthetics and Amenities* OR Pedestrian Traffic* OR Adjacent Traffic* OR PLOS Models*). We searched electronic databases including Google Scholar, Web of Science, TRID, SCOPUS and Science Direct. Only original research papers published in English language academic journals and conferences were progressively chosen in a research effort that stretched from January 2016 to November 2016. A total of 617 papers including many duplicates were initially obtained for possible inclusion during the preliminary database search process. We then excluded duplicate papers, book chapters, theses, and most grey literature. The second screening stage was to exclude all papers whose title indicated that they were irrelevant to our topic. The next stage was full-text papers assessed for eligibility focusing on their direct provision of input to PLOS tools and measures. 58 papers were finally identified as directly related to PLOS. The final set of research papers all assessed the concept of PLOS in different ways and in massive detail are shown in Table 1.

Table 1 the final set of research papers all assessed the concept of PLOS in different ways

Author of Study	Year	Country of Study	Data Collection	Target Area	Analysis Method	Model Type
Fruin	1971	U.S.A	Time lapse photography	Area	Linear relationship	Capacity based model
Polus et al.	1983	Israel	A videotape recorder and a digital clock	Sidewalk	linear speed-density regression	Capacity based model
Mori & Tsukaguchi	1987	Japan	Video	Sidewalk	Regression	Combination Model
Tanaboriboon & Guyano	1989	Thailand	Portable video camera	Walkway	Linear relationship	Capacity based model
Sarkar	1993	Munich & Rome	Observation	Street	Point system	Roadway Characteristics
Khisty	1994	U.S.A	Observation	Street	Point system	Roadway Characteristics
Mozer	1994	U.S.A	Worksheet	Street	Point system	Combination Model
Dixon	1996	U.S.A	Audit	Corridor Roadway	Point system	Roadway Characteristics
Milazzo et al.	1999	U.S.A	A videotape recorder	Signalized and unsignalized Intersection crossing	Linear relationship	Capacity based model
Miller et al.	2000	U.S.A	Survey	Intersection	Simulation and point system	Roadway Characteristics
Jaskiewicz	2000	U.S.A	Observation	Roadway	Point system	Roadway Characteristics
Gallin	2001	Australia	Audit	Roadway	Point system	Combination Model
Landis et al.	2001	U.S.A	Observation	Roadway	stepwise multi-variable regression analysis	Combination Model
Baltes & Chu	2002	U.S.A	Archived Inventory and video camera	Midblock	The ordinary least-squares statistical	Combination Model
Sarkar	2003	U.S.A	Audit	Walkway	Point system	Roadway Characteristics
Zhang & Prevedouros	2004	U.S.A	Video	Signalized Intersection	Regression	Roadway Characteristics
Steinman & Hines	2004	U.S.A	Survey	Signalized Intersection	Point system	Combination Model
Petritsch et al.	2005	U.S.A	Field Observation and a video simulation	Signalized Intersections	Stepwise regression	Combination Model
Muraleetharan et al.	2004	Japan	Field Survey	Sidewalk	Linear Relationship	Combination Model
Muraleetharan et al.	2005	Japan	Field Survey	Intersection	Stepwise multiple regression model	Combination Model
Petritsch et al.	2006	U.S.A	Field Observation	Sidewalk and Intersection	Stepwise regression	Combination Model
Kim et al.	2006	U.S.A	Field Observation	Sidewalk	Linear relationship	Combination Model l
Tan et al.	2007	China	Intercept survey	Sidewalk	Step-wise regression	Combination Model
Muraleetharan & Hagiwara	2007	Japan	Field survey	Sidewalk and Crosswalk	Stepwise multiple regression model	Combination Model
Jensen	2007	Denmark	Respondents, video, and Questionnaire	Roadway	Cumulative Logic Regression	Combination Model
Huang & Chiun	2007	Taiwan	Observation	Street	the step-wise regression	Combination Model
Daniel et al.	2007	Malaysia	Field survey	signalized intersections	Multiple linear regression	Combination Model
NCHRP	2008	U.S.A	Survey and video	Roadway and Intersection	Regression	Combination Model
Petritsch et al.	2008	U.S.A	Video simulation laboratories	Street	Linear regression	Combination Model
FDOT	2009	U.S.A	Observation	Roadway	Stepwise regression	Combination Model
Bian et al.	2009	China	Intercept survey	Intersection	Step-wise regression	Combination Model

Asadi-Shekari and Zaly Shah	2011	Malaysia & Singapore	Observation	Roadway	Point system	Combination Model
Hidayat et al.	2011	Thailand & Indonesia	Interview & Questionnaire surveys with pedestrian	Sidewalk	A multiple linear regression	Roadway Characteristics Based Model
Vedagiri. & Anithottam	2012	India	The video-graphic and field survey	Sidewalk	Pearson correlation, factor analysis and Step-wise regression	Combination Model
Christopoulou	2012	Greece	Questionnaire Survey	Sidewalk	Point system	Combination Model
Bunevska & Malenkovska	2012	Macedonia	Video Simulation	Sidewalk	Simulation	Combination Model
Nagraj & Vedagiri	2013	India	Video graphic technique, Questionnaire survey and field measurement	Signalized Intersections	Stepwise regression	Roadway Characteristics
Ling et al.	2013	China	Contingent Field Survey & Extensive video data	Signalized Intersections	Stepwise regression	Combination Model
Kang et al.	2013	China	Video clips & field measurement	Sidewalk	Ordered probit	Combination Model
Jensen	2013	Denmark	Video clips & questionnaire & field measurement	Signalized & unsignalized intersections & Roundabouts	CLM stepwise regression	Combination Model
Kim et al.	2013	Korea	intercept survey, a field survey	Sidewalk	Step-wise regression	Combination Model
Bian, Zhao & Lu	2013	China	Questionnaire survey & Field Survey	unsignalized intersections	Stepwise regression	Roadway Characteristics
Asadi-Shekari et al.	2013	Singapore	Results of guidelines	Street	Point system	Roadway Characteristics
Zhao et al.	2014	China	Questionnaire survey & Field Survey.	Unsignalized Midblock Crossings	Stepwise regression	Combination Model
Meng et al.	2014	China	Questionnaire survey	Street	Pearson correlation, factor analysis and Step-wise regression	Combination Model
Kim et al.	2014	Korea	A pedestrian questionnaire survey and video recordings	sidewalk	Multiple linear regressions	Combination Model
Kadali & Vedagiri	2014	India	questionnaire survey & video	Mid-Block crossing	Ordered probit	Roadway Characteristics
Asadi-Shekari, Moeinaddini & Shah	2014	Malaysia	Results of guidelines	Street	Point system	Combination Model
Zhao et al.	2015	China	Observation & questionnaire survey	Sidewalk	The fuzzy mathematics method	Combination Model
Ye et al.	2015	China	Video technique & Questionnaire survey	Signalized intersection	Linear regression technique	Combination Model
Kadali & Vedagiri	2015	India	Questionnaire survey and video graphic	unsignalized mid-block	Ordered probit	Combination Model
Hasan et al	2015	Bangladesh	Questionnaire survey	Walkway	-	Combination Model
Archana	2015	India	Visual surveys and field surveys	Intersection	Multiple linear regressions	Combination Model
Lazou et al.	2015	Greece	Questionnaire survey,	Streets	Ordinal regression model (ordered logit)	Roadway Characteristics
Zhao et al.	2016	China	Questionnaire survey	Sidewalk	Fuzzy neural network method	Combination Model
Raghuwanshi & Tare	2016	India	Video graphic survey & field survey	Sidewalk	Multiple linear regression	Combination Model
Daniel et al.	2016	Malaysia	On-site measurement, video & visual walkthrough surveys	Sidewalk	Multiple linear regression	Combination Model
Chandana et al.	2016	India	Questionnaire survey	Street	Inverse variance method	Roadway Characteristics

3.2. Factors derived from relevant literature

The selected papers were analysed regarding basic data on PLOS research and methods from each paper. The selected papers were divided into four types: PLOS for streets (holistically), PLOS for footpaths only, PLOS for intersections, and PLOS for midblock crossings.

Each study was separately considered to obtain all factors used by the researchers to describe and measure PLOS. We took the set of factors used, catalogued and coded them, eventually producing as table of factors (see Table 2). Factors with the same meaning but using different terms were unified by selecting an appropriate synonym. For example, footpath width was presented in some studies under name sidewalk width while in other studies was path width or footpath width. The factors were themed and two groups of factors were identified: factors related to the pedestrian environment and factors related to the traffic system and users. The first group involves geometric/physical characteristics and network characteristics or (environmental characteristics) while the second group includes traffic characteristics and users' characteristics and behaviours. After completing an analysis of the literature, a list of potentially important factors was generated for different facilities and is presented within the framework in Table 2. The number of times a factor was included in a study gives some indication as to how, collectively, the field has viewed that particular factor.

Table 2 factors and variable affecting PLOS on different facilities

PLOS for Streets		PLOS for Footpaths		PLOS for Intersections		PLOS for Midblock Crossings	
Factors detail	No.	Factors detail	No.	Factors detail	No.	Factors detail	No.
1.Factors related to the pedestrian environment							
a. Geometric/Physical characteristics							
Awnings	1	Adequate footpath	1	Corner space	1	Crosswalk dummy	1
Crossing facilities	1	Benches	1	Crosswalk width	1	Farside crossing width	1
Crossing opportunities	1	Bicycle- vehicle separation	1	handicapped access	1	Farside cycle length	1
Disabled facilities	1	Crossing facilities	1	Median openings	1	Median presence	1
Enclosure	1	Disabled guiding	1	Refuge island presence	1	Mid-block crosswalk type	1
Elevator	1	Driveway frequency	1	Turn island presence	1	Nearside crossing width	1
Public health facility	1	Lateral streets	1	two-step crossing presence	1	Nearside cycle length	1
Recreational facilities	1	Marking	1	Warning signs	1	Pedestrian crossing time	1
Surface quality	1	Ramp	1	Corner radius	2	Pedestrian waiting time	1
Toilet presence	1	Shading	1	Crossing distance	2	Pedestrian-signal dummy	1
Transportation facilities	1	Support facilities	1	Crosswalk marking	2	Signal Spacing	1
Trash receptacles	1	Transportation facilities	1	Crosswalk surface condition	2	Width of Painted Median	1
Advance stop bar	2	Tree	1	Pedestrian signal	2	Width of Restricted Median	1
Benches	2	Vehicle lane width	1	Traffic lanes' number	2	Land-use type	1
Bollard	2	Road facility conditions	1	Vehicle lane width	2	Traffic lanes' number	2
Buffer barrier	2	Buffer width	2	-		Median opening width	2
Crossing distance	2	Pedestrian-vehicle separation	2	-		Median width	2
Disabled drinking fountain	2	Buffer presence	3	-		Crosswalk distance	3
Disabled guiding	2	Surface quality	3	-		-	
Disabled warning	2	On-street parking	4	-		-	
Dummy	2	Shoulder width	4	-		-	
Facility type	2	Footpath width	10	-		-	
Fire hydrant	2	-		-		-	
Garbage facilities	2	-		-		-	
Grade	2	-		-		-	
Median	2	-		-		-	
Mid-block crossing	2	-		-		-	
Pedestrian-vehicle separation	2	-		-		-	
Signals	2	-		-		-	
Slope	2	-		-		-	
Trees	2	-		-		-	
Corner island	3	-		-		-	
Curb ramp	3	-		-		-	
Shading	3	-		-		-	
Support facilities	3	-		-		-	
Buffer	4	-		-		-	
Buffer width	4	-		-		-	
Driveway frequency	4	-		-		-	
Lighting	4	-		-		-	
Marking	4	-		-		-	
Vehicle lane width	4	-		-		-	
On-street parking	5	-		-		-	
Shoulder width	5	-		-		-	
Traffic lane's number	5	-		-		-	
Footpath width	12	-		-		-	
b. Network Characteristics or (Environmental characteristics)							
Accessibility	1	Businesses' presence	1	Crosswalk presence	1	-	
Amenities	1	Aesthetics	1	Safety	1	-	

Table 1 Continued

Building articulation	1	Footpath performance	1	Security	1	-	
Connectivity	1	Pollution	1	Crossing area type	2	-	
Footpath performance	1	Social space	1	Crossing facilities type	2	-	
Maintenance	1	Footpath continuity	2	Maintenance	2	-	
Transparency	1	Movement easiness	2	One-way street crossing	2	-	
Transportation facilities	1	Noise	2	-		-	
Social space	1	Comfort	3	-		-	
System coherence	1	Footpath condition	3	-		-	
Weather conditions	1	Safety	3	-		-	
Complexity	2	Security	3	-		-	
Continuity	2	Weather conditions	3	-		-	
Convenience	2	Obstructions	7	-		-	
Attractiveness	3	-		-		-	
Footpath presence	3	-		-		-	
Comfort	4	-		-		-	
Landscape development	4	-		-		-	
Safety	4	-		-		-	
Security	4	-		-		-	
Footpath condition	5	-		-		-	
Obstructions	6	-		-		-	
2. Factors related to the traffic system and users							
a. Traffic Characteristics							
Adjacent roadway volume	1	Adjacent roadway volume	1	Bicycle flow	1	Farside total volume	1
Bicycle volume	1	Bicycle speed	1	Bicycle speed	1	Farside turning movements	1
Heavy vehicle volumes	1	Electronic bike volume	1	Opposite bicycle flow	1	Nearside total volume	1
Motor vehicle mix	1	Mix of path users	1	Pedestrian space	1	Nearside turning movements	1
Pedestrian space	1	Pedestrian crossing time	1	Pedestrian speed	1	Pedestrian speed	1
Turning vehicles	1	Vehicle conflict points	1	Vehicle flow	1	Vehicle volume	2
Vehicle LOS	1	Vehicle flow	1	Vehicles speed	1	-	
Traffic flow	2	Bicycle flow	2	Vehicle-vehicle Conflict	1	-	
Vehicle conflict points	3	Bicycle volume	2	Pedestrian flow	2	-	
Pedestrian flow	4	Pedestrian volume	2	Pedestrian volume	3	-	
Delay	5	Traffic conditions	2	Turning bicycle	3	-	
Pedestrian volume	6	Pedestrian density	3	Bicycle volume	4	-	
Vehicle volume	6	Pedestrian space	3	Pedestrian crossing time	4	-	
Vehicle speed	9	Vehicle speed	3	Vehicle volume	4	-	
-		Vehicle volume	4	Turn conflicts	5	-	
-		Pedestrian speed	5	Delay	9	-	
-		Pedestrian flow	11	Turning vehicle	10	-	
b. Users' Characteristics & Behaviours							
Encroachment	1	Day time trip	1	Noncompliance	1	Frequency of using crosswalk	2
Mix of path users	1	Economical	1	pedestrian-bicycle interaction	1	Pedestrian gender	2
-		Mix of path users	1	-		Trip purpose	2
-		Pedestrian age	1	-		Pedestrian perceived difficulty	2
-		Pedestrian conflicts points	1	-		Pedestrian perceived Safety	2
-		Encroachment	1	-		Pedestrian age	3
-		Horizontal manoeuvers	1	-		-	
-		Vendors attraction	1	-		-	
-		Vertical manoeuvers	1	-		-	

In reviewing the paper dataset, two general approaches are identifiable for evaluating PLOS, which are often used in combination. The first is a capacity-based modelling approach, which analyses the volume and flow of pedestrians in urban spaces, and came out of earlier work on volume/capacity studies of vehicular movement. Capacity-based modelling has been criticised in that the acceptability by pedestrians of modelling outputs has at times been insignificant. The second is a street characteristics approach, which analyses other features of the pedestrian environment beyond just volume and capacity. But, as will be shown, there is significant contention about what characteristics should be included, and how transferable these are given urban contexts differ so greatly around the world. Many studies used a combination of the two approaches, attempting to gain the best of both approaches. In our proposed model, a combination of the two approaches will initially be adopted, with a Delphi process with expert informants used to further refine it (as will be discussed shortly).

Footpath width is the most used factor in PLOS for streets and PLOS for footpaths. Turning vehicles and delay are the most used factors in PLOS for intersections. Crosswalk distance and pedestrian age are the most used factors in PLOS for mid-block crossings, albeit this type has a much lower number of studies. Pedestrian perceptions are considered essential in these methods, however, few if any of the studies reported any comprehensive pedestrian survey to obtain pedestrian perceptions in real situations.

3.3. The methods for collecting and analysing PLOS data

Modeling of pedestrian LOS at various facilities can provide an insight on pedestrian facility designs that better and more safely accommodate pedestrian mobility. The review of the literature explains data collection and data analysis methods and identifying a wide variety of factors needed to be considered for adequately capturing the pedestrian walking experience and thus calculating PLOS. It is apparent from the existing studies that the majority of studies have used different types of survey, observation, video, and audits to collect data and measure factors for LOS models. Analysis methods were categorised into four groups based on the methods used in calculating the PLOS. These include regression, simulation and fuzzy neural networks (mostly for capacity-based approaches) and a basic points system (for street characteristics approaches).

Calculating the PLOS is no easy issue and is influenced by complex factors. Some of these factors, especially qualitative factors, need complex methods of measurement, analysis and interpretation. For example, a qualitative model was developed by Sarkar (1993, p. 35) in order to evaluate PLOS which included safety, security, convenience and comfort, continuity, system coherence, and attractiveness. These are qualitatively defined rather than quantified which are makes it difficult to interpret results or compare across different environments. It is also difficult to measure each factor separately when there is significant interaction and overlap between the factors.

In contrast, a quantitative method was suggested by Khisty to evaluate PLOS in streets. Khisty's relied on the same factors proposed by Sarker. The survey responses have been used to determine the most significant factors effecting PLOS (Khisty, 1994, p. 45). Although Khisty's method has a key limitation as a result of using a point scale system which may not represent pedestrian perceptions, absent of systematic user inputs. Gallin (2001, pp. 47-55) developed a unique model for evaluating PLOS based on several factors that affected LOS. The factors in Gallin's model were classified into three categories including physical characteristics, location factors and user's factors. A point system method was used to calculate PLOS (Gallin, 2001, p. 48). The drawback of Gallin's model is that the weighting of factors affecting PLOS is based on personal decisions. In addition, the factors included in this model do not represent all aspects affecting the pedestrian environment. Sarkar (2003, p. 2) suggested a model based only on the key attributes of physical, psychological and physiological comfort levels on walkways. Sarkar's model involved two separate evaluations, including service levels, which give standards for the overall desirable and undesirable comfort conditions at the macro level, as well as the micro level finer details of comfort of pedestrians. Although this model has limitations in drawing on only a small number of factors.

Indeed, most current evaluation methods have drawbacks. They may lack rigour, be over complicated and time-consuming, or cover a narrow range of street conditions. Very little of the literature appears based on revealed pedestrian perceptions and the needs of different users are not commonly included.

3.4. Audit tools

Audit tools were used by researchers to collect key data on physical features (e.g., street trees, sidewalk width) that could not be obtained through other methods such as GIS databases or aerial photos (Brownson et al., 2009, p. 106). Many of the tools assessing route quality at the segment scale seek to establish a measure of LOS. Audit tools are considered a systematic approach for observation of the physical environment including the factors affecting physical activity (e.g., street pattern, number and quality of public spaces, sidewalk quality). Some proposed audit tools were not only established for research purposes, but they have also been used to support local decision making by community members. These tools have been designed with less detail than those designed for research purposes and they probably have not been tested for reliability (Moudon and Lee, 2003, p. 29).

There is agreement that factors affecting pedestrians' perceptions of safety and comfort on roadway environment are based on various complex factors (Landis et al., 2001, p. 4). Although several attempts to develop walkability audits have been undertaken by planners and engineers by including number of features that affect the entire roadway corridor environment, there has been no consensus on the degree of importance to pedestrians for each feature, using statistically reliable methods.

Of the audit studies in the literature we did not find any that explicitly showed testing for inter-rater reliability, defined as the agreement between two or more raters/observers using the tool in measuring PLOS. This is essential to understand the degree of reliability for a new model, as well as a test of usability. More robust approaches will be needed if we are to create tools that can help engineers and planners produce better pedestrian environments.

4. A proposed approach and method

If a new approach and method is needed, the challenge is to develop an assessment model that uses reliable methods to identify and measure factors affecting the PLOS for the full range of pedestrians. In this paper we look only at developing a new audit tool to evaluate PLOS on footpaths in commercial streets. The section below briefly shows the systematic approach and method being followed by the research team.

Task 1: a study of the literature and context

As we earlier shown in this paper a systematic quantitative literature review was conducted. Based on this literature review, a summary table was created, which involves factors that were either empirically studied or received prominent attention in the previous studies, as shown in Table 1.

Task 2: identifying factors appropriate for Australian cities

There are two stages in this task. The first stage involves a Delphi process with a panel of experts. Potential factors affecting PLOS are to be identified using two rounds. In the initial round a sample of experts from the professional association PedBikeTrans will complete an online survey that uses inputs from the quantitative literature review to refine a list of factors. In the next round the list of factors will be screened, filtered off, organised and then classified. They will then be used in a walking workshop (a 'walkshop') with the panel of experts. Participants will be asked to visit commercial streets and consider the revised list in the field. Upon returning to the workshop venue, the group will then attempt to obtain a more meaningful group consensus about what should be used to measure PLOS in commercial streets and to rate them in terms of their significance.

The second stage involves pedestrian users of commercial streets in Brisbane. Outputs from the Delphi process will be used to help design an intercept questionnaire for pedestrians. Sites and the timing of surveys will be carefully selected to get a range of users and environments. Questions will include users' perceptions of the quality of the footpath environment depending on their walking experience, and the factors that contribute to that feeling. Sampling will seek different ages, gender, disabled and mobile, and across other socio-demographics to be representative of the current user-base of these streets.

The key advantage of this stage is that perceptions which will be based on walking experiences in real situations. The scores provides by the pedestrians will be the basis to produce a new model for PLOS, helping to develop a weighted assessment sheet for calculating pedestrian level of service.

Task 3: development of a draft PLOS audit tool

In this step the PLOS audit tool will be designed based on the results of the focus group and pedestrian survey. It will consist of two components including the main categories which represent general footpath environment aspects and the items embedded under these categories which represent the detailed factors affecting PLOS. A simple guidance manual will also be prepared to aid raters in scoring key factors.

Task 4: reliability and usability tests

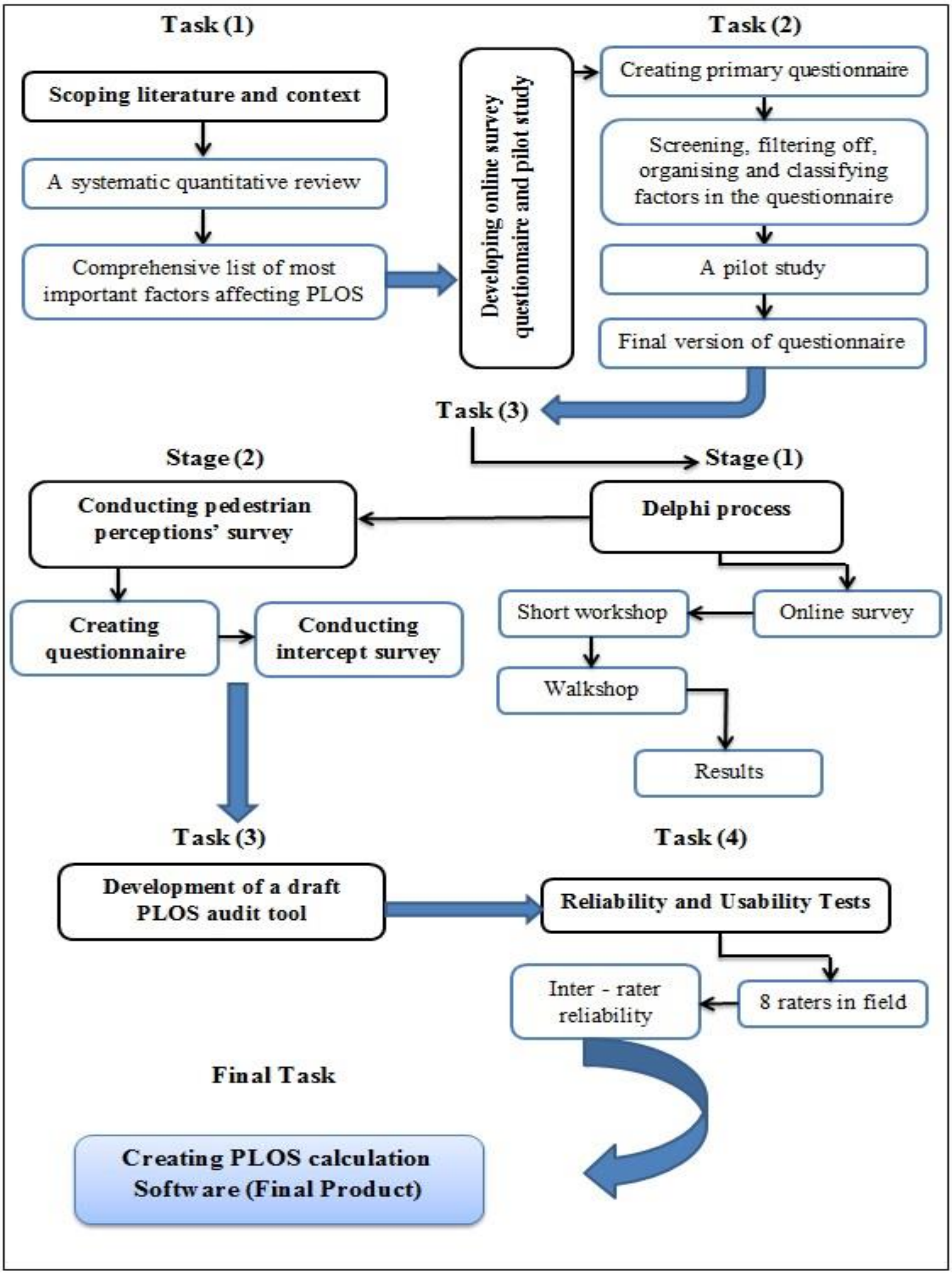
This task includes reliability and usability test for the new audit tool. Reliability or validity of the new audit tool will be assessed using inter and intra- rater reliability testing. Previous studies of inter-rater reliability using walkability tools (though, not PLOS measures, per se) have demonstrated high reliability from a sample of as few as 6 raters (Brownson et al., 2004, p. 194). We propose to use at least 8 raters to test the proposed audit tool, across multiple selected street segments, to ascertain the reliability of the instrument. A measure of agreement between raters will lead to measuring degree of reliability of the proposed audit tool. kappa (κ) statistics will be used to overcome level of agreement that could be occurring by chance (Viera and Garrett, 2005, p. 360). Raters will also be asked to record their rating about how easy it is to use the audit tool in the field as well as to record the required duration of measurement in each segment. This will provide insight into how much homogeneity, or consensus, there is in the ratings given by raters in order to assess the degree of reliability of the new tool, as well as its usability.

Task 5: creating PLOS calculation software

Finally, PLOS calculation software will be developed in order to get accurate results in a speedy manner. The Java programming language will be used to produce new PLOS software by taking advantage from both the electronic PLOS audit tool and the weighted assessment sheet. This task also includes testing applications of PLOS software to calculate

PLOS within various sites on footpaths in the study area. A point system method will be used to calculate PLOS within proposed software.

Figure 1 the proposed methodology of PLOS model on footpaths in commercial areas



5. Work in-progress

Work is underway for producing the PLOS audit tool using the proposed methodology. Currently, the first stage has been completed and all potential factors affecting PLOS have been derived from literature review. A workshop is prepared with a panel of transport experts in Brisbane. The research team seek to complete the focus group workshops and intercept pedestrian perceptions survey by the end of 2017. The objective remains that the footpath pedestrian audit tool will be designed to help practitioners to make informed decisions when designing the cross section for footpaths at any given roadway and provide more appropriate footpath environments in commercial streets.

This is only one piece of the puzzle that shapes the pedestrian environment but we hope it will make a significant contribution. Our approach is limited in that it solely looks at commercial streets, and only uses commercial streets in one Australian city. While the approach and method may prove transferable, the final audit tool may not be so applicable in other nations with distinct urban environments. Further work will be required for the development of tools for assessing all possible types of pedestrian facilities.

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