9.4 THE WUDAPT FRAMEWORK FOR GENERATING URBAN MORPHOLOGY, MATERIAL COMPOSITION AND ACTIVITY DATA FOR MODELING

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1. INTRODUCTION

The World Urban Database and Access Portal Tools or WUDAPT (www.WUDAPT.org) is a strategically designed, multi-level, universally consistent, and community-based approach that describes the physical geography of cities capturing information on urban form, material content and function (energy demand) for climate studies and model applications (Ching 2013 Ching et al., 2016, Mills 2015, 2017). They provide the bases for modeling the multiscale flows and structural aspects of the Urban Boundary Layer (Fig. 1a); examples of parameters used in models are shown in Fig. 1b.

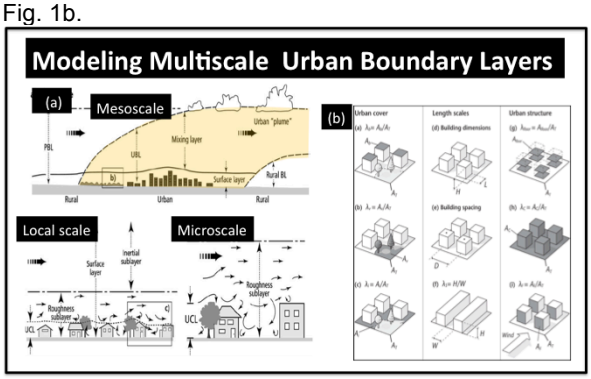

Fig 1: (a) Schematic of the multiscale urban boundary layer (Source: Oke 2006); (b) Common UCP that describe character of urban surfaces (Source: Oke 2017)

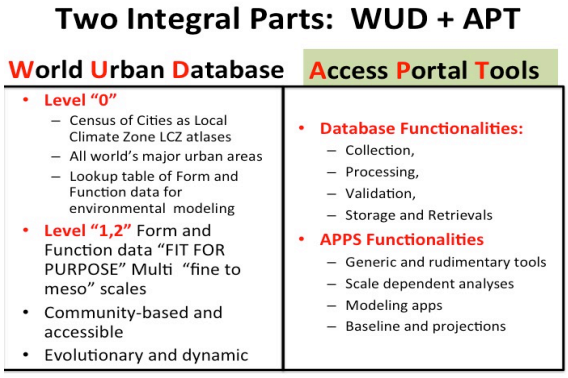

Figure 2: WUDAPT Components

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WUDAPT is designed as a database of information for all major cities throughout the world with a portal that provides a data repository and means to facilitate its utility for running urban modeling as tools to address societal issues associated with population growth, urbanization and climate changes (Fig. 2) (Ching 2013, Ching et al., 2016, Jackson et al., 2010). The WUDAPT design requirements are for timely generation of the database collected in a universally consistent manner, which utilizes publically available inputs and where the outcomes are unrestricted and fully accessible to the world community.

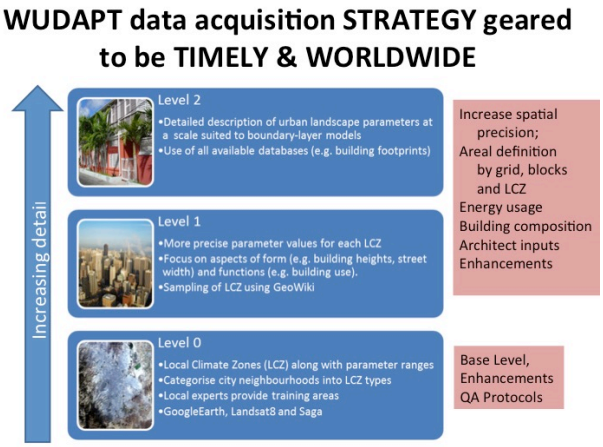

Fig 3: Implementation strategy for WUDAPT data acquisition

To achieve this, the WUDAPT implementation strategy is based on a three-tiered structure (Fig. 3) (Mills et al, 2015, See et al., 2015). At its first tier, or Level 0, (hereafter "L0") the basic structure of urban areas are characterized using the Local Climate Zone (LCZ) scheme of Stewart and Oke (2012) using an innovative methodology based on readily available Landsat imagery and the expertise of urban experts (Bechtel and Daneke, 2012 and Bechtel et al., 2015). For each LCZ there is an associated table providing nominal ranges and representative values of urban canopy parameters (UCP) that capture essential aspects of urban form and functions that regulate its microclimate. Refinements to the methodology have occurred since its inception in 2011 (Fig. 4). Recently, the Project has developed a protocol that establishes high quality criteria to be met before official acceptance of the LCZ maps into the

database. LCZ maps for more than 100 cities currently fulfill this level of acceptance. (Mills et al., 2017). This make possible the use of LCZs and selected values of urban canopy parameter from associated look-up tables towards calculating urban energy budgets (Alexander et al., 2015, 2016) and perform WRF mesoscale model simulations (Brousse et al., 2016).

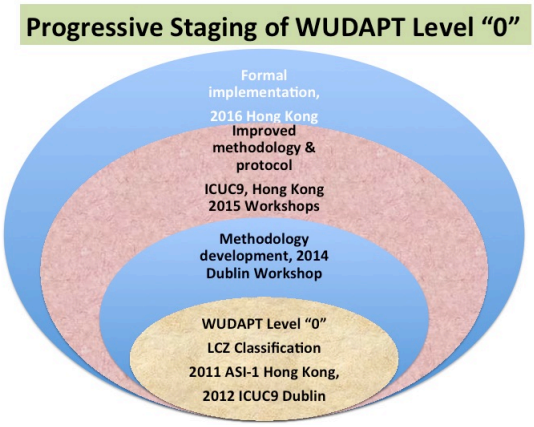

Fig 4: Progressive staging strategy towards WUDAPT Level "0" (L0)

2. WUDAPT LEVEL 1 AND 2 (L1&2)

2.1 Objectives

The objective of both Level 1 and 2 (hereinafter L1&2) is to generate geo-specific parameter values at increased spatial resolution and precision for running the suite of community-based environmental models that need morphological forms, material composition data and anthropogenic functions such as energy usage for each and all LCZs by using the LCZ framework to sample parameter values (Fig. 5).

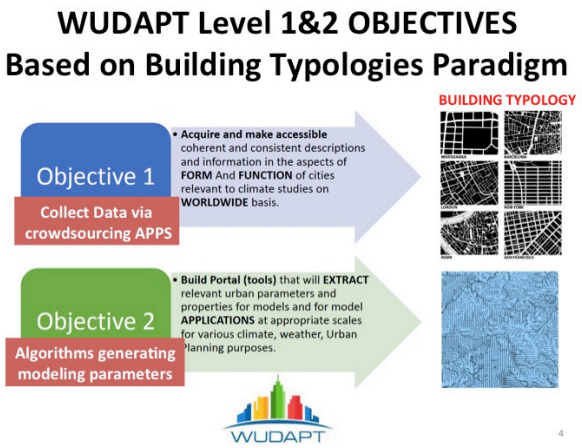

Fig. 5 Objectives of WUDAPT level 1 and 2 (L1&2)

A major advancement to L0 is minimizing model uncertainties associated with using the range of values from L0 parameter lookup tables. At level 1 (L1), information about building materials and building heating and cooling functions. Level 2 (L2) offers information for advanced modeling applications by providing spatially comprehensive data with high resolution and precision. At L2, the input data requirements, especially on form, may not be currently and readily available for all cities but, nevertheless, the methodology being developed satisfies WUDAPT's mandatory level of consistency. In concept and design, L1 and L2 and L1&2 require the methodology and protocol to adopt the principles established for L0, i.e., the utilization of publically available data and a methodology consistently applied to all the world's cities and implementable by a community of urban experts.

2.2 *Conceptual framework: WUDAPT Level 1 and 2* (L1&2)

For L1, WUDAPT is focused on creating a database with detailed descriptions of building materials, critically important to determining and modeling the thermodynamic properties of urban areas in terms of its radiative properties, canopy heat storage and modulation of energy usage in urban areas. Rather than applying a bottom-up approach that would involve gathering and assimilating such details for each building in a city, which is deemed impractical to implement in WUDAPT, we choose rather to consider, explore and devise an innovative methodology incorporating properties associated with the use of building typology (BT) archetypes, and crowdsourcing facilitation with appropriate Geo-Wiki tools. For L2, the desired goal is more specific and provides precise 3-D georeferenced information on urban form, i.e., features such as building footprints and the surrounding geometries. These would include features such as that shown in Fig. 1b. This requires high-resolution stereo and or SAR satellite, lidar and stereo-photogrammetric data, which are typically expensive and or not available universally or openly accessible.

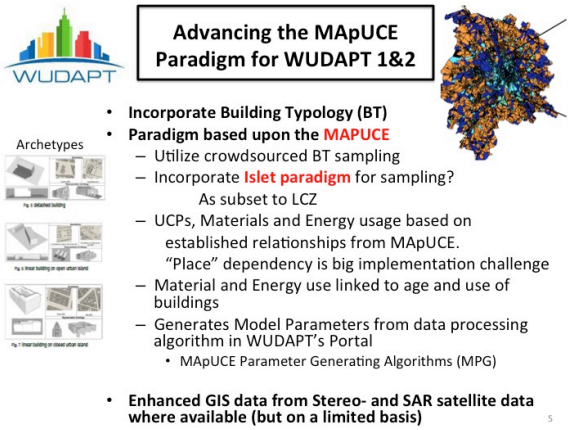

Fig 6: Applying MApUCE paradigm to WUDAPT

Albeit, while the availability of SAR type data is currently limited, the methodology for generating highly accurate building form data such as the building coverage ratio or building fractional area λb, building volume density (BVD), frontal area index λf, sky view factor (SVF), and roughness length, Z_0 at L2 is underway (Xu et al., 2015a,b). Alternatively, Wang and Dai (2015) have utilized an approach based on using parallax imagery of buildings using dual satellite data with different orbital parameters yielding the desired fields of UCPs. These are optional approaches, and candidates for consideration.

With respect to L1, the paradigm adopted and used in the MApUCE project (Masson et al., 2015; 2017) provides a framework to generating L1 information on building material and functions. The MApUCE project has information on every building in France and thus has been able to organize and classify BTs accordingly. Comparable data will typically not be available on a worldwide base, so modifications to the MApUCE methodology will be required to reflect and be applicable to cultural, historical, and climatological contexts of architectural archetypes and BTs, differing from those for France (Fig 6). For this, we intend to extend the MApUCE paradigm illustrated in Figs 7-9. At issue are the city-to-city, and regional (between country differences) and variations in BTs and their properties that will be exhibited between different cities around the world. Fundamentally, this modification will consist of two major components, a crowdsourcing data gathering deployment strategy and a data processing system based on algorithms and tools designed to generate the desired building parameter fields. Different applications for crowdsourcing level 1 data (referred to here has APPS) are available. These include desktop-based applications (which utilize Google Earth and Bing imagery as well as OpenStreetMap layers) to sample area-based parameters or examine photographs from Google StreetView for individual building parameters or BTs, as well as mobile applications based on smart phone technology that provide sampling on the ground. The latter can be used to provide geotagged photographs that provide specific details of individual buildings (Fig 8) and groups of buildings (Fig 9) according to their use, age, HVAC, materials, color, number of floors, roof type, wall type, landscaping (Fig 7) or BTs of interest determined from prior desktop queries. While clearly in an early stage of development, we envision organizing this effort with workgroups and various interested participants with skills and knowledge in modeling, urban architecture and climate experts. We have begun by establishing three loosely confederated Workgroups (Fig 10) with interested members from the international urban climate, architectural and modeling communities

3. SUMMARY AND PATH FORWARD

WUDAPT is an ambitious ongoing community-based initiative designed to provide and fulfill the need for science-based infrastructure supporting tools for addressing issues in this Anthropocene epoch, heretofore, unavailable, and on a worldwide basis. In a short time, it has already developed and implemented an initial methodology (L0) that makes possible a universally consistent information base of the world's cities for running surface energy budget and urban weather models to address climate driven issues, which impact population growth, urbanization and energy in our urban centers. The effort addressed here is to fulfill the overall objective to provide a full expression of "fit for purpose" modeling as infrastructure tools in this Epoch. L1&2 is strategically designed to acquire enhanced details beyond L0 information but at finer spatial resolutions and includes additional types of data not available at L0. We are now positioned to undertake this effort; we have now identified and outlined an innovative, reasonable and pragmatic (bootstrapping) approach and also enlisted the support and commitment of many experts from urban communities around the world to this task.

We will explore generating L1&2 for LCZs and other optional spatial delimiters such as city blocks and grid meshes of different sizes to support the needs of a variety of models. As with L0, implementing L1&2 will engage the urban community. The methodology and approach will be developed by APPS, Testbed and Algorithm workgroups (Fig 10). The APPS WG will develop crowdsourcing apps (CSAPP) designed to collect representative samples of BTs in the LCZs from L0, both with individual photos and for selected areas such as Islets (Fig 9). The Testbed Group will be responsible for developing sampling strategies that are appropriately representative of each LCZ and/or Islets, and the Algorithm group will be responsible for developing the algorithms and processing procedures for generating the UCP parameters, building parameters and energy usage outputs generated from the CSAPPs and data collection. The specific subtasks of each workgroup are listed below:

Portal Algorithm Development (PAD) WorkGroup:

- Identify critical FMF modeling parameters to be generated
- Establish criteria for Representativeness and Completeness (RC) of data gathering
- Deploy CSAPP sampling
- Formulate processing algorithms based upon data collected using the CSAPPS
- Implement the portal functionality

APPS Method Development WorkGroup (AMD)

- Develop CSAPPS based on BTs
- Recommend sampling and devise deployment data gathering approaches towards RC criteria
- Customize as needed for target cities

APPS Test Deployment WorkGroup (ATD)

- Assemble crowdsourcing team
- Test recommended deployment strategies and provide feedback to AMD
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Coordination WorkGroup

- Review prototype sampling (AMD) and deployment (ATD) plans
- Recommend revisions to progress and results.

Figure 7: Aspects of MApUCE relevant to L 1&2

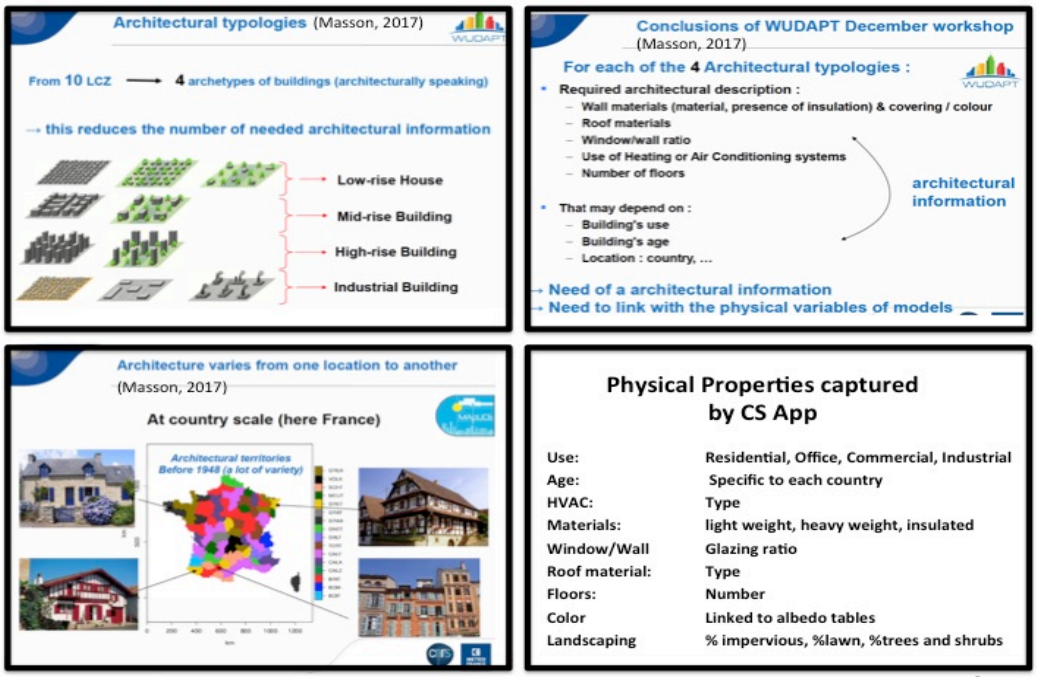

Fig 7: Aspects of MApUCE relevant to L1&2

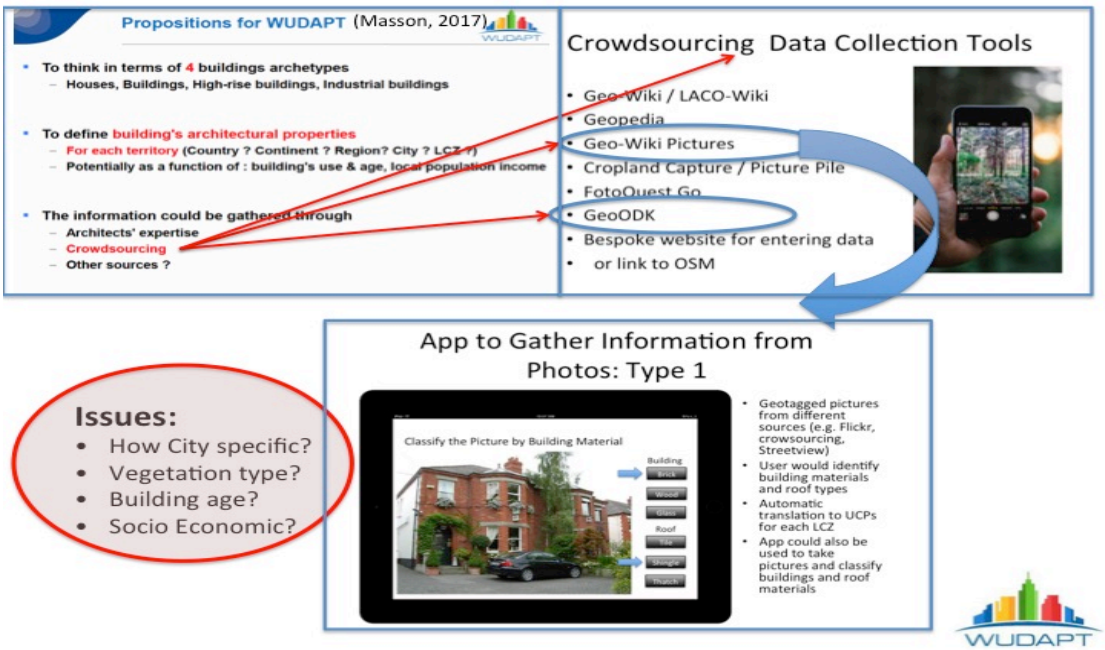

Fig 8: City (or regional) specific Crowdsourcing APP for gathering specific building data per typology

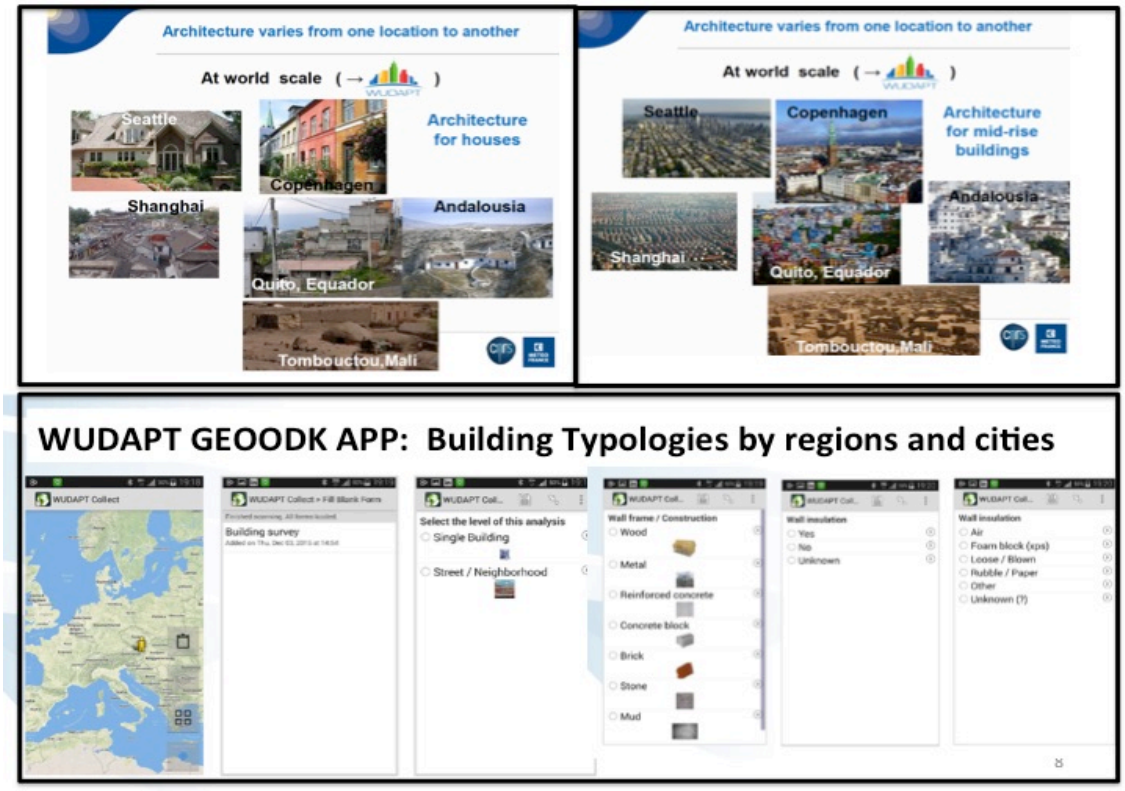

Fig 9: City (regional) specific Crowdsourcing data collection APP for building and neighborhoods for Building Typologies

Finally, the success of the L1&2 protocol will be judged by comparing results and applying the methodology to independently obtained high quality data sets for urban areas, including those from Toulouse, Hong Kong, Guangzhou New York, Houston and elsewhere. At this stage, the urban community will be challenged to produce L1&2, armed with this acceptable methodology as was accomplished with L0.

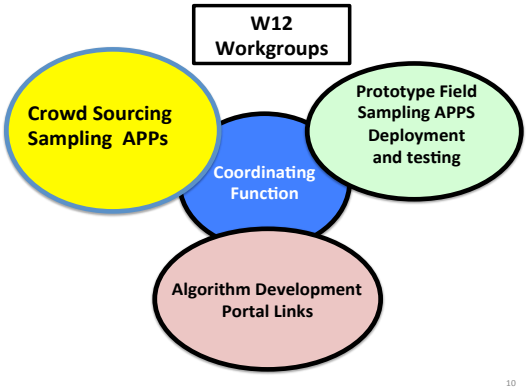

Fig 10: Workgroups to develop L1&2 methodology

PATH FORWARD plans to generating Form, Materials and Function parameters

Developing initial prototype methodology

- Plans for operational testing of prototype **LCZ maps from Level 0 (and optional Islets displays) as geo-referenced sampling template for CSAPPS LCZ**
- **Devise and deploy *crowdsourced sampling methodology* to generate BT data *fulfilling TBD representiveness and coverage criteria***
- **Develop and implement into Portal, algorithms to generate model parameters of Form, Materials and Function from BT data**
- **Test and evaluate $L_{1\&2}$ methodology against baselines (MApUCE and other comprehensive "standards")**

Working Group Teams, Community collaborations

Fig 11: Summary of plans to develop the L1&2 prototype methodology.

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