Improving Self-Help Housing in Texas Colonias Using Spatial Agents and Building Information Modeling (BIM)

Duygu Yenerim[1], Mark J.Clayton[2]

Abstract

By equipping field agents with knowledge of spatial design and advanced information technology, it may be possible to improve the affordability and sustainability of self-help housing in informal settlements. This paper presents a research design to investigate this proposition through qualitative research methods, model-based reasoning and a quasi-experiment. Informal settlements are comprised of low-cost self-built houses with deficiencies such as: substandard construction, higher energy costs per unit area due to poor construction methods, and inattention to best practices for sustainable community development due to low knowledge of residents. The introduction of increased knowledge of sustainable design practices may enable residents to make better decisions with respect to sustainability when undertaking self-help construction projects. The concept for delivering information about sustainability to residents is to equip 'spatial agents' with advanced information technology for architectural design. Spatial agency refers to providing professional services including design ideas and knowledge to people who do not have access to them. The agents can be facilitated by equipping them with Building Information Modelling (BIM) tools that aid designers in providing high performance design, visualization and analysis capabilities.

This study is a part of an on-going Ph.D dissertation. This paper proposes a mixed method research to devise a new model for aiding the residents to achieve greater sustainability in self-help housing through a test case of an informal settlement near Laredo, Texas, US, known as "*colonias*". We propose three steps: (1) collect information through interviews on two topics: best practices for sustainable home design and construction, and existing patterns of home design and construction, (2) incorporate the rules and patterns for home design revealed from the first step into BIM software to produce a tool kit for designing sustainable homes and additions, and (3) test the software using a quasi-experiment for spatial agents. The expectation is that the new model using trained spatial agents assisted with a BIM toolkit can produce home designs that are more affordable, more sustainable, and more quickly.

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1. Introduction

The aim of this paper is to explore a strategy to improve affordability and sustainability of self-help housing in informal settlements by fusing the concepts of spatial agency and Building Information Model (BIM). Spatial agents can assist residents in sustainable design and construction with advanced technology which may results in energy efficient and cost effective houses in informal settlements. Thus, the quality of housing and quality of life may be improved.

Informal settlements serve to provide shelter to low- and very-low income people who cannot afford to live in a formal house. These settlements are one of the major challenges for most cities owing to their lack of access to basic services and their unpredictable growth (UN-Habitat 2008). Global growth of population in informal settlements has an increasing impact on consumption of resources. Therefore, achieving sustainability and energy efficiency in these settlements is becoming an acute challenge.

This study focuses on informal settlement development north of the United States (U.S.)/Mexico border called ‘colonias’. The common practice in the colonias is self-help housing in which residents construct their houses incrementally with help of family members and friends to accommodate their changing needs and based on availability of money. Houses in colonias often have deficiencies such as substandard construction (Ward, Olmedo, et al. 2010), higher energy cost (Gharaibeh et al. 2009), and lack of sustainable community development due to low knowledge and awareness on the part of the residents (Rohe et al. 2002). The introduction of increased knowledge of sustainable design practices may enable residents to make better decisions with respect to sustainability when undertaking self-help construction projects.

We envisioned a new process of delivering design and construction knowledge on sustainable and cost-effective self-help housing in colonias from experts to residents. This process includes agency in architecture via spatial agents, assisted BIM tool. Spatial agency refers to providing/bringing professional services including design ideas and knowledge to people and communities who do not have access to them. The notions of agency and advocacy in architecture apply the concept to provide underserved populations with architectural knowledge. The spatial agents can be facilitated by equipping them with BIM tools that aid designers in providing high performance design, visualization and analysis capabilities.

This paper is structured in three sections: (1) background information on informal settlements and colonias in U.S., (2) conceptual framework of this study: Spatial agency and BIM, and (3) assisting residents with advanced technology.

2. Background

This section serves to define the universe of informal settlements and to identify where colonias fit in this framework.

2.1 Informal Settlements: A Global Challenge

Informal settlements are unplanned residential areas in which houses are built by people who are unable to pay for legal houses. Unauthorized occupation of land usually with no land use and building regulations initiates the informal settlement formation process. These houses are mostly constructed without building codes and regulations. UN-Habitat (2003) defines informal settlements as the areas comprised of houses with one or two of the following universal features: (1) inadequate access to basic services such as clean water and sanitation, (2) substandard housing or illegal and inadequate building structure, (3) overcrowding and high density settlements, (4) unhealthy living conditions and locating hazardous locations, (5) insecure residents, (6) irregularly developed settlements, (7) poverty and social exclusion, and (8) minimum settlement size. Therefore, not only do they often provide deplorable living conditions with inadequate living space and poor access to basic facilities and services, but growth is unpredictable and often at a rate that overwhelms resources (UN-Habitat 2003).

2.2 Type of Informal Settlements

Informal settlements are found not only in developing countries but also in developed ones: Brazil, South Africa, Turkey, China, India, Nigeria, Pakistan, Bangladesh, Indonesia, Iran, Philippines, Mexico, South Korea, Peru, USA, Egypt, Argentina, Tanzania, Ethiopia, Sudan, and Vietnam (UN-Habitat 2003). No matter social, economic and political dynamics of the nations, 'pirate urbanism' and 'traditional squatting' are the two formation processes observed all over the world (Davis 2006). 'Pirate urbanism' refers to the abandoned inner city residential structures accommodated by low income families such as; *inquilinatos* in Buenos Aires, *chawls* in Mumbai, and *Callejones* in Lima. On the other hand, the second type, 'traditional squatting' includes a self-help process of construction by invasion of land illegally. This process often ends up with a formation of widespread communities such as *barrios, tugurios*, *favelas, bidonvilles, gecekondus, kampongs, and* ***colonias. Colonias*** is the focus of this study.

2.3 Colonias: An example of informal settlements in U.S.

Colonias are examples of informal settlements development north of the U.S.-Mexico border in the states of Texas (1,800 *colonias*), New Mexico (142 *colonias*), Arizona (86 *colonias*), and California (15 *colonias*) (HUD 2003). *Colonias* share many of the same features of the informal settlements in other parts of the world such as: (1) being developed on mostly unincorporated towns and cities, (2) being built by using improper materials and construction methods, (3) with inadequate regulation, (4) with lack of access to services such as running water, sewage system, public safety, and a proper electricity installation, (5) with attached water tanks on many units, (6) being composed of mixture of trailer and self-built houses and

(7) inattention on the part of economy and political authority (Ward 1999). However, the major differences are (1) being mostly constructed on legal lands, and (2) being multiple housing located on larger lots which leads to lower density than the other informal settlements (Arizmendi et al. 2010).

When considering colonias in U.S. context, the characteristics of colonia residents differ from the rest of U.S. in terms of (a) having mostly Hispanic population, (b) having larger family size than the average in U.S., and (c) having median household income$14,458 less than the U.S. average (Martinez 2010) (Table 1). In terms of population, 7 million people live in the 24 border counties with a 67.1% of Hispanic population. Texas and California have higher population than Arizona and New Mexico; Texas has the highest Hispanic population ratio. On the other hand, Texas and New Mexico house the counties that have lower median household income. In terms of poverty, the highest percentage belongs to Texas (24%). However, it is mostly observed in border counties (Martinez 2010).

Table 1: Socio-Economic Conditions in U.S.-Mexico Border States (Adopted from Martinez 2010)

State	# counties (having colonias)	Total Population (2007)	% Hispanic Population (2006)	Median Household Income (2004)	% Population in poverty (2004)	Percent Annual Unemployment Rate (2007)
Arizona	4	1,328,357	50.2	35,601	17.6	7.2
California	2	3,136,726	52.9	42,807	14.7	10.5
New Mexico	3	230,732	60.6	25,777	22.8	5.3
Texas*	15	2,269,778	74.9	27,446*	24.0	6.0
TOTAL/AVE	24	6,965,593	67.1	29,876	22.0	6.5
USA		301,621,157	14.8	44,334	12.7	4.6

The economic patterns on the north of U.S.-Mexico border has transformed from a basic agriculture related production system to a more diversified commercial, industrial and service related system providing low-cost labour (Martinez 2010). Today, counties on the border region offer low-paying jobs, usually temporary, in agriculture, construction, and manufacturing.

Poverty causes most colonia developments. In Texas, residents with wages from $12 to $14 can afford at most a $60,000 to $70,000 house constructed by homebuilders (TDCHA 2011). However, considering the additional land acquisition and development costs, it is difficult to build low price homes. Since Colonia residents mostly work seasonal and low-wage jobs, lending/financial institutions do not regard them as credit worthy. Therefore, they do not have access to credit or financing methods (Giusti and Estevez 2011). They tend to purchase small lots and build their houses incrementally with help of family members and friends to accommodate their changing needs and based on availability of money (Giusti and Estevez 2011). This situation causes Contract for Deed arrangements which mean that lots and dwellings are sold to residents through non formal financial arrangements and the title is transformed to the purchaser after he/she finishes all the payments. Considering the income

level of residents in Texas Border counties, colonia type housing is the only feasible way of home ownership (Ward et al. 2011).

Houses in the colonias often have substandard construction that does not meet building standards for safety (Ward, Olmedo, et al. 2010). The major house types in colonias on the U.S./Mexico border are (a) classic self-help border houses with additions added over an extended period of time, (b) manufactured homes (single or double wide trailers), and (c) modular housing structures (Sullivan and Ward 2012). Although there are only three types of houses, they demonstrate a great variety in terms of form, materials and construction. They vary from $500 dilapidated trailers, to half constructed houses, to middle class houses that are seen in urban areas (Coronado 2003). This variety is based on incremental self-building process according to individual needs and availability of their money (Figure 1).

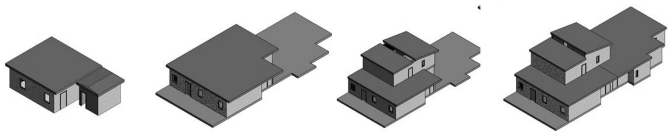
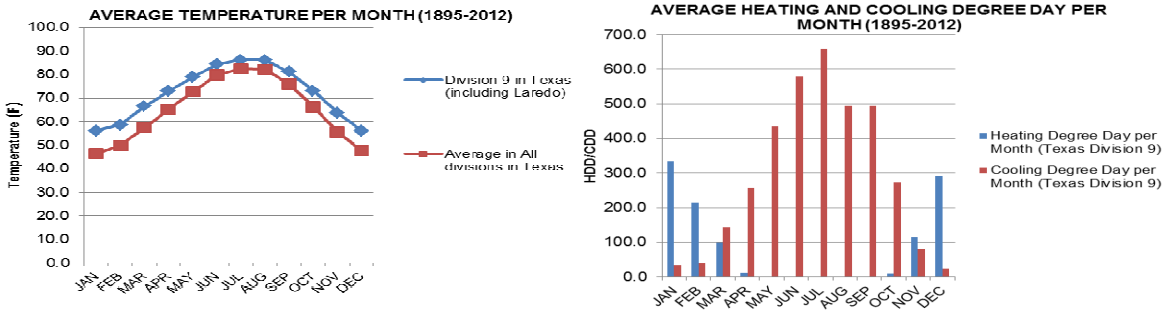


Figure 1: An example of an Incremental Growth/Improvements of colonia self-help house (Adopted from Reimers, 2009, modelled in BIM by author)

As colonias have a growing population, there is an increasing demand for cost-effective housing. Due to poor construction methods and inadequate access to infrastructure systems, the colonia residents pay higher energy costs per unit area (Gharaibeh et al. 2009). Electricity, natural gas, and bottled, tank or liquid propane or butane are the energy sources used by colonia residents for lighting, heating, cooling, and cooking (Machado 2006). According to the results of the study performed in El Paso county colonias in Texas (climate division 5), the average electricity bill in colonias (82.5 $/mo) is 40% more than the average in El Paso (59.7 $/mo) (Machado 2006). As illustrated in Table 2, Laredo in Texas has (climate division 9) more cooling degree days (3509.6) than heating degree days (1076). Therefore, the electricity for cooling is one of the major expenses for colonia residents in Laredo.

Table 2: Climate data for Texas Climate division 9 including Laredo, TX.



Data Source: http://www.ncdc.noaa.gov

Another deficiency in the colonias is lack of sustainable community development due to low knowledge and awareness on the part of the residents (Rohe et al. 2002). The growing population in the colonias has an escalating impact on consumption of resources. Therefore,

delivering sustainable and energy efficient solutions becomes a serious challenge. However, in order to eliminate the barrier of acceptability of proposed strategies in housing by colonia residents, it is crucial to comprehend and document the existing housing design and construction patterns.

This study was built on three existing studies: (a) Reimers's (2009) study on colonia houses and their expansion patterns according to residents' satisfaction over time, (b) Ward, and others' study (2010) on investigation of self-help housing conditions, and construction techniques in Central Texas colonias, and (c) Sullivan and Ward (2012) on sustainable housing applications and policies for low-income and self-built housing rehab. However, the significance of this study is making use of technology and methods from advanced architectural practice to assist in data collection of housing forms, materials, construction techniques, energy consumption and cost analyses, and resident profile.

3. A New Conceptual Framework for Improving Informal Settlements / Colonias

We propose a new model for delivering sustainable cost-effective architecture and construction knowledge from experts to residents in self-help housing in colonias Texas through fusing the concepts of spatial agency and BIM technology (Figure 2).

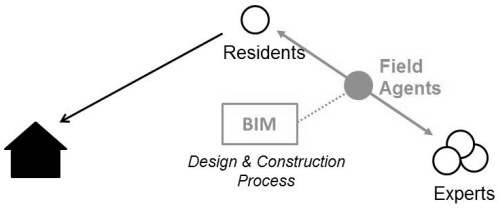


Figure 2: Conceptual Model for Spatial Agents and BIM in the colonias

3.1 Agency in Architecture via Field Agents: Two Models of Agency

The concept of agency in architecture relies on the notion of "advocacy" in architecture. In literature, the term "advocacy" was first referred in the context of urban planning which means empowering poor and unrepresentative population; scholars assert that planners must behave as an advocate for poor and unrepresented group (Heskin 1980). Similarly, 'advocacy' in architecture has been established as a new approach on spatial production that is different from the traditional concerns in architecture. Hence, the role of architects has been questioned. Architecture for Humanity (AFH) (2006) defines the essence of advocacy in architecture as architects delivering service to underrepresented and disadvantaged populations through using information technology and tools and empower people to participate in the design process.

Awan, Schneider and Till (2011) use the term *'Spatial Agency'* which means architects sharing their knowledge and design ideas with non-professional and self-builders to guide them. They ground on the term 'spatial" from Henri Lefebvre's book entitled *The Production of Space* (1974) and 'agency' and 'agent' from Anthony Giddens's *Theory of Structuration*

(1984). In other words, they use ‘spatial’ to extend the term architecture by encompassing social, economic, environmental and political notions. Therefore, spatial agency triggers self-help architecture process through empowering residents and encouraging residents to participate in the process of spatial design and production. To sum up, field agency refers to providing/bringing professional services including design ideas and knowledge to people and communities who do not have access to them.

Informal settlements are the product of bottom-up process of designing, building and managing the houses proceeded by residents. Agents are not only individual advocacy architects, but also organizations, advocacy groups, which act with and on behalf of self-builders. American agriculture has long used governmental representatives in the role of “field agents” to provide knowledge of best practices to farmers and the general public. United States Agency for International Development (USAID) and World Bank have developed and funded Farming System Research and Extension projects (FSR/E) (Kerry J. Byrnes 1989). The main idea of FSR/E is based on a training and field experience to deliver knowledge from researchers to cultivators in developing countries from 1970s to 1980s. These are funded by Federal Government, State Government and World Bank (Ugwu 2007).

In colonias, community organization has been established to overcome the challenges in housing and living conditions. These organizations set up a platform for collaboration between residents and authorities, which is advocated under the concept of spatial agency. Colonias Self-Help Center (SHC) program developed by Texas Department of Housing and Community Affairs (TDHCA) is a prominent on-going example established in several counties of Texas such as Cameron/Willacy, Hidalgo, Starr, Webb and El Paso. The aim of this program is to offer technical assistance to residents in housing improvements, new construction, infrastructure access, and capital access for mortgages (THDCA 2012).Texas A&M University Colonias Program, which was funded by counties and federal government, private sector and Texas Legislature, has developed Promotoras Program to link between the residents and the authorities in health care area. Promotoras are indigenous mostly women colonia residents who are specially trained by experts in Department of State Health Services to serve as agents in community organizations (Arizmendi and Ortiz 2004).

This paper suggests a similar model of spatial agents for sustainable architectural service delivery model from experts to residents that can be established under Texas A&M University Colonias Program***.*** By following a similar path with both promotoras and field agents in agriculture, spatial agents can be trained by undergraduate interns from Department of Architecture at Texas A&M University. The equipment and the funding can be provided by counties and federal government, private sector. In sustainable design and construction, there are several experts whose knowledge can be very useful to *colonias* residents. Therefore, this study is to employ ‘spatial agency’ in architecture by extending the concept of the self-help centers to share knowledge of experts with residents.

3.2 Methods for Sustainable and Affordable Housing Design

The introduction of increased knowledge of sustainable design practices may enable residents to make better decisions with respect to sustainability when undertaking self-help

construction projects. Even though the existing literature on sustainable construction and design practices often focuses on middle and high income houses, the studies focused on low-income houses are related to rehabilitation of existing houses for low-income settlements and infrastructure systems of informal settlements.

Several studies have identified the sustainable and cost-effective housing interventions to colonias according to ease of application and maintenance, cost savings, initial cost and human capital (Ward, Olmedo, et al. 2010; Ward, Sullivan, et al. 2010). There are very limited number of studies focuses on quantitative documentation of cost and energy savings of different applications that can be used by low-income residents (Bradshaw et al. 2005).

3.3 BIM Technology

This study suggests applying advanced digital tools for architectural design to architectural service delivery model of spatial agents to guide residents on sustainable and affordable housing design and construction in informal settlements. BIM is a recent advanced technology in the Architecture, Engineering and Construction Industry (AEC) that is enabling designers to produce high performance buildings more quickly and at a lower cost. Being an object-oriented modeling tool is the major feature of BIM that makes it distinguished from other conventional design tools such as; Computer Aided Design (CAD). The object-oriented modeling feature of BIM enables designers to determine geometric and non-geometric features through setting up parameters and rules for objects (Eastman et al. 2008).

In the context of modeling informal settlements, Geographic Information Systems (GIS) software is currently used for integrating spatial and non-spatial data. In colonias, it has been utilized in several researches to manage, monitor and predict health of dwellers, the growth of communities and resources. GIS is a tool to visualize the data. To allow quick visualization, there are several design software developed to support visualization and design process such as Project Galileo and Autodesk Civil by Autodesk, Bentley Map by Bentley Systems, CityCad by Holistic City Software and CommunityViz® by Placeways LLC (Gil et al. 2010). However, these tools lack in parametric modeling and integrating comprehensive information on design patterns, materials, construction and parameters of individual buildings.

Application of BIM holds significant capabilities in the informal settlement context *(Figure 3).* (1) BIM technology supports *3-dimensional modeling of a building*, parametric form generation and object-oriented modeling that represents real-time design changes of it (Eastman et al. 2008). (2) BIM allows *documenting and collecting large amounts of data* (design, construction and operation) on both existing and newly designed individual houses such as (a) designer data, (b) legal data, (c) geospatial data, (d) financial data, (e) specifier data, (e) environmentalist data, (f) sustainers data, and (g) owner/occupier data (Bazjanac 2008). (3) BIM design tools have an *embedded library of components* that are frequently used for conventional buildings (Eastman et al. 2008) which enable users to develop new library that *supports modeling buildings in the colonias* with additional parameters. (4) The idea of *parametric modeling* refers to creating models which are clearly defined by parameters mainly to establish variation of geometrical components of objects (Woodbury

2010). (5) To examine the risk of a proposed building, a number of *simulation tools* may be used. However, one of the major challenges of these tools is that they are mainly dependent on user input of building components, loads and so on (Hand et al. 2008). In literature, several researches have been focused on linking the 3D rich visual BIMs of buildings and the computational tools. This integration enables designers in earlier stages of design to test the proposed building by changing the form or material (Clayton, Warden, and Parker 2002).

Figure 3: BIMs of houses in Larga Vista colonias (Yenerim, and Clayton 2011)

To sum up, BIM can aid spatial agents to design, visualize and analyse the houses in 3-dimensions, and to create affordable high performance buildings that meet building standards*.*

4. Assisting Residents with Advanced Technology

This study is a part of an on-going Ph.D dissertation at Texas A&M University. This section shows the research development stage which employs a mixed-method research to devise a new model for aiding residents of informal settlements to achieve greater sustainability in self-help housing.

4.1 Study Area in Texas Colonias

The study area of this research is Texas since it has the largest number of colonia residents in U.S. The criteria of sample selection are (1) having varied ages and types of self-help houses, (2) accessibility and field work support, (3) data richness, and (4) manageable size. The city of Laredo in Webb County is the sample population; Laredo has Webb County Self-help Center, Texas A&M University Colonias Program and Promotoras Program Center which makes it convenient in terms of accessibility and field work support. In order to represent the varied characteristics of houses and households, we pick Larga Vista, San Carlos 1 and 2. Larga Vista is the smallest colonia with higher population located within the city limits, whereas San Carlos 1 & 2 are also denser colonias than the rest and are located outside the city limits.

4.2 Research Plan

This research relies upon both qualitative and quantitative research methods to explore the relationship between human beings and technology. This study involves three phases after the literature review.

4.2.1 Data Collection

Data collection includes interviews, focus groups and field survey. Data collection is required in two subjects: (1) best practices for sustainable cost effective home design and construction (completed), and (2) preferences and patterns of construction and lifestyle of colonia residents. First, we convened a focus group between eight experts who are experienced in sustainable and affordable home construction and design from government agencies, private practice, non-profit research centers, and academic research centers. The participants were selected from either Texas or Louisiana, since regional climate and industrial patterns are important determinants of construction practice. The outcome was a report that recommends specific sustainable design and construction practices for the colonia residents. Second, the interviews with residents and the field survey will serve to document size/volume/aspect ratio, orientation, form complexity, ratio of fenestration on façade, construction materials and methods, and shading of houses and characteristics of household. The Colonias Program and Promotoras Program of Texas A&M University are the gatekeepers of this study.

4.2.2 BIM Toolkit: Creating BIM Library and Parametric Models

The next stage will be to incorporate the rules and patterns for home design revealed from the first step into BIM software to produce a tool kit for designing sustainable homes, and home additions in the colonias. Autodesk Revit 2013 will be utilized as a BIM tool. First, based on the input from the first step, we will create two libraries including parametric families of building components and system families; one for existing houses, and other for sustainable cost effective solutions. We will add several parameters such as parameters such as cost, size and materials to be incorporated into a framework of simulation and analysis tools. The outcome will be two BIM libraries and a prototypical house that can be easily composed and manipulated to represent a variety of designs and rapidly analysed with respect to sustainability performance.

4.2.3 Usability Test of the Toolkit

The third step will be to test the software using a quasi-experiment with architecture design students who are stand-ins for spatial agents. The quasi-experiment will determine the ease of use, rapidity of design, satisfaction of the users, and sustainability of resulting designs in comparison to benchmark designs produced with more conventional methods.

5. Conclusion

Colonias are example of informal settlements in U.S. that provide shelter for low- and very-low income people who cannot afford formal ones. In colonias, residents often build their houses by themselves with help of families and friends based on their needs and availability of money. Due to lack of knowledge in sustainable cost-effective strategies in design and construction, people live in substandard houses, and pay more for energy. To overcome these challenges, it is important to first understand their culture and pattern of construction and then deliver these residents knowledge of sustainable architecture from experts.

This study proposed a new model for sustainable and affordable interventions to informal settlement through aiding trained spatial agents with BIM tool. Thus, Colonias Program of Texas A&M University can act as spatial agents after a training process with BIM toolkit. By utilizing BIM toolkit, they can empower residents and can guide residents to produce home designs that are more affordable, more sustainable, and more quickly. Since colonias share many of the same characteristics of “traditional squatting” formation typology, this model can be applied to other informal settlements.

The possible difficulties can be the training process which might be longer than other agency models. The tools can be expensive to purchase whereas the software is free for students and faculty in the university. The IT tools, experts and agents can be funded by federal government, county government and private agencies like the Colonias Program.

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