PREDICTING SEBERANG PERAI HOUSING LAND PATTERN IN 2017

Rosmiyati Hasni* and Narimah Samat
Geography Section, School of Humanities, Universiti Sains Malaysia
*Corresponding author's e-mail: rosmiyati.hasni@gmail.com

ABSTRACT: Land use decision making is a complex process involving trade-offs among various land stakeholders due to the resource's scarcity. Pulau Pinang is the second most densely populated and also the fourth most urbanised state in Malaysia. Urbanisation is Penang state is partially translated as escalating housing land demand that poses threats to agricultural land especially around the peri urban areas. At present, Malaysia is still lacking in scientific tools to assist planners simulate current and future land use developmental patterns. Existing planning guidelines could not anticipate future development scenarios. Hence the need for a scientific tool based on dynamic spatial model to simulated development pattern using scenario approach. This study aims to develop a GIS-based, CA Markov Model that predicts housing land development in Seberang Perai region of Penang State up to 2017 using 2005 and 2011 land use data. The study first demarcated Seberang Perai based on the degree of suitability to accommodate all land use classifications. The degree of suitability is ranked according to development criteria scores, weightings and constraints, with the latter two quantified using Analytical Hierarchy Process (AHP) technique. CA Markov Model then simulates the dynamic interactions between cells under specific transition rules to predict land pattern in 2017. The study provides information on the potential locations and direction/pattern of growth in 2017. The simulation outcomes show that new or expanded housing lands are located in close proximity with the predicted growth centres and settlements identified in the Penang Structure Plan 2020 hence endorses compact urban development pattern. The CA Markov Model can assist relevant authorities in allocating suitable housing land sites sustainably.
Keywords: housing land pattern, geographical information system (GIS), multi criteria decision analysis (MCDA), analytical hierarchy process (AHP), CA Markov

INTRODUCTION

Depleting natural resources and population growth represent two of land use planning's supply and demand parameters that are to be balanced by resource allocation. Penang State is the third smallest state, constituting merely 0.3 per cent of Malaysia's total land area (Department of Survey and Mapping, 2005), and also second most densely populated and fourth most urbanised. These settings lead to immense pressure for new development land. Land allocation considers the suitability of current and potential new land use on the area of interest and its adjacent neighbours. Each land use has its own group of stakeholders that possess specific needs and preferences. Conflicting interests among stakeholders becomes more complex as sustainable land allocation needs to consider the impacts of various development scenarios. Therefore, trade-offs among development criteria become inevitable to accommodate the stakeholders' needs and preferences.

Population growth will both intensify the needs and varying demands for housing land. Physical land planning traditionally subscribes to top-down planning approach that is mainly influenced by generalised supply-side stakeholders' interests and priorities (der Merwe, 1997). According to Smit et al. (1987, as cited in der Merwe, 1997), the one-dimensional nature of land use decision focuses on the suitability of a particular land use rather than selecting the most suitable out of all land use options. The outcome of such planning nature merely provides short-term solution to the conflict. Challenges in current housing land planning include providing satisfactory and affordable sites, and establishing a more liveable environment to the population with various socio-economic backgrounds. Geographical Information System (GIS) is widely recognised as a powerful tool to manage conflicting interests in sustainable land management practices by providing scientific argument to support decision making recommendations. Wang et al. (2004) simulates various planning scenarios involving GIS-based analysis of temporal land use pattern and site suitability in the environmental planning of the Lake Erhai basin in China. Local authorities such as the Suffolk Coastal District Council launched a web-based GIS service (Suffolk Coastal District Council, 2015) to identify potential housing land supply through their Strategic Housing Land Availability Assessment.

Land suitability and site selection differ in term of their analysis output; the former ranks the suitability of the entire study while the latter identifies only selected sites Al-Shalabi et al. (2006). Anderson (1987) characterised seven land suitability analysis methods (pass/fall screening, graduated screening, weighted factors, penalty point assignment, composite rating, weighted composite rating, and direct assignment) that Banai-Kashani (1989) found to be lacking verification of expert judgement consistency, and are also influenced by the economic, demographic and political uncertainties. Banai-Kashani (1989) proposes Analytical Hierarchy Process (AHP) by Saaty (1980) due to the technique's capability to analyse both qualitative and quantitative development criteria through Multi Criteria Evaluation (MCE) analysis, and also capability to evaluate and rectify the consistency of expert judgements.

Projection of Penang state housing needs (PDTCP, 2007) did not specify the actual housing sites (Samat et al., 2011). During site selection process, housing developers generally prioritise topographical-related guidelines (Federal Department of Town and Country Planning, 2011a, 2009, 2011b) over actual needs and preferences of house buyers. Mismatched housing supply and demand will lead to property overhang, for instance unsold high-rise dwelling units in Southern Seberang Perai was attributed to buyer's preference for landed property (PSDTCP, 2007).

STUDY AREA AND DATA

Seberang Perai, formerly known as Province Wellesley, is a region of Penang State that is located at the mainland of Peninsular Malaysia (see Figure 1). Hosting three of the five state districts, namely Northern, Central and Southern, Seberang Perai constitutes 72 per cent of total state land with population density of 1,083 persons/km^2, as compared to Penang Island's 28 per cent and 2,485 persons/km^2 respectively (Department of Statistics, 2011).

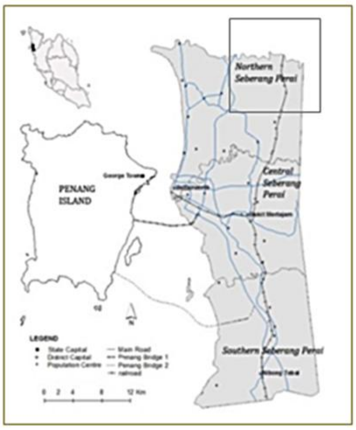


Figure 1: The study area

Land scarcity and socio-economic growth are two major influences that have pushed the island region's house pricing to more than 3.5 folds higher than Seberang Perai, therefore categorised as "severely unaffordable" by Khazanah Research Institute (2015). Penang state has very limited land stock due to its unique pattern of land ownership (MacDonald, 2011), forcing the state to rely heavily on private developers for housing supply and this causes the pricing to be dictated by the property market mechanism in spite of various governmental efforts to secure more affordable units (Quah, 2010).

Going by the House Buyers' Association's affordability threshold value of house-price-to-income-ratio of at most 3.0 (as cited in Khazanah Research Institute, 2015), and Penang State median monthly income of RM4,702 (Department of Statistics, 2015), the affordability threshold is at approximately

RM170,000. When the cheapest new landed housing unit on Penang Island costs RM550,000 (Valuation and Property Services Department, 2014), it forces the middle-income earners to either purchase subpar housing unit, reside on rented property or reside further away from the population centres (Quah, 2010).

Penang State Department of Town and Country Planning (PSDTCP) have adopted various measures to reduce the imbalanced population distribution and property pricing between the two regions (PSDTCP, 2007). Among others, the state is targeting for population distribution ratio of 60:40 for Seberang Perai and Penang Island respectively by 2020. Also by assigning sectoral development by district, the more balanced distribution of development is expected to support various state development corridors. PSDTCP also encourages landed housing development in Seberang Perai to accommodate the development spill over from Penang Island and also its endogenous demands.

The study relies on datasets obtained from PSDTCP, Northern Zone Project Office of DTCP, and DTCP Geoportal. They include land use data for 2005 and 2011, proposed land use for 2020, road network, administrative boundary, slope gradient, elevation, prime agricultural areas, development corridors, and flood-prone areas. Various topographical information were derived from Department of Survey and Mapping topographical maps (1987). Soil classification was derived from Penang State Hydrological Soil Group Map (at 1:75,000) (Department of Agriculture, n.d.). Housing site selection criteria were gathered via a series of interview with housing stakeholders in 2014 and literature review.

METHODOLOGY

To predict the region’s land use pattern, CA Markov Model relies on a two-part independent analysis: namely Multi Criteria Decision Analysis (MCDA) and Markov Chain Analysis (see Figure 2 below).

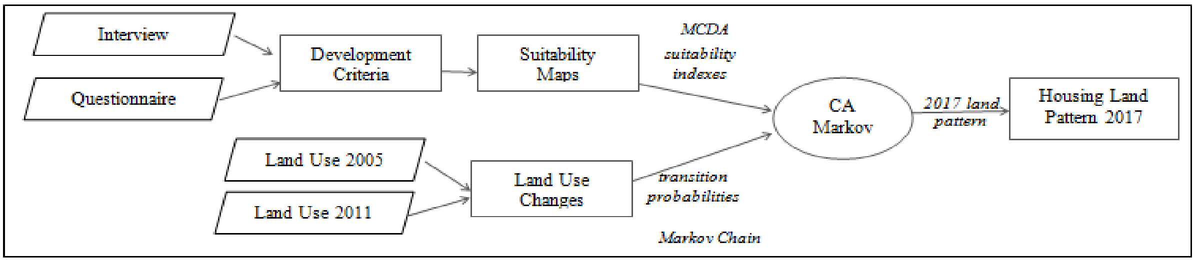


Figure 2: The Proposed Model

The first step in MCDA is to identify housing stakeholders who represent conclusive perspective of interests in housing land. Stakeholders here are defined as Buyers, Developers and Decision Makers. Site selection criteria, consisting of factors and constraints, were derived from a series of semi-structured interviews with house buyers and housing developer officers conducted in 2014. Decision maker’s criteria were derived from various planning guidelines and policies (Federal Department of Town and Country Planning, 2011a, 2009, 2011b) to demonstrate the roles of developmental control.
The study classifies land use activities into four categories: Housing, Other Built-Up Area, Agriculture and Other Non Built-Up Area. Weighting for each development factor per land use category (excluding Other Non Built-Up Area) is quantified using AHP technique. Other Non Built-Up Area is considered as developmental constraint. GIS is used to incorporate spatial dimension to the criteria weightings in order to derive site suitability indexes.

Cellular Automata-based Markov Chain Analysis utilises GIS to map the distribution of land use activities and monitor changes in activities’ land use pattern. Seberang Perai is represented as a lattice of two-dimensional rectangular grid of square cells with 30 meter resolution. By assigning a landed property plot size of 125 square meter[4], two adjacent 30x30 meter cells are estimated to cater for ten terrace housing units and land loss for the provision of facilities and utilities.

Markov Chain analyses the successive changes of cell states, $S = (s_1, s_2, \ldots, s_r)$ within a specific time-frame (step) with a certain probability (Grinstead and Snell, 1997). *Cell state* depicts the land use activity at a specific location and particular time-step. P_{ab} or *transition probabilities* (see Equation 1) is derived from the initial state value of all cells. P_{ab} value at s_b is not influenced by s_a. The array of transition probability values, known as transition matrix, contains either changed or unchanged stochastic value of the (s_a ,s_b) pairing.

$$^{t}P_{a,b,i,j} = P\{X_t=s_b|X_{t-1}=s_a\} \qquad [1]$$

where

$^{t}P_{a,b,i,j}$ represents the probability of a cell state at location i,j and step $t-1$, transforming from the current state s_a into s_b at the following time-step.

Cellular Automata (CA) contains four basic elements that are lattice, cell state, neighbourhood, and transition rules (Batty, 1997). Here, *lattice* represents Seberang Perai region; *cell state* land use activity at a location i,j and at step t (see Equation 2) ; *neighbourhood* radius of land use activities that influences the centre cell; and *transition rule* dictates the temporal behaviour of central cells based on their reaction to the respective neighbourhood cells. Extended Moore Neighbourhood (5x5 cell) is selected as a two-dimensional lattice is the most relevant dimension to depict urbanisation (Batty, 1997).

$$u_{i,j}^{t} = \begin{cases} 1 = Housing \\ 2 = Other\ Built-Up \\ 3 = Agricultural \\ 4 = Other\ Non\ Built-Up \end{cases} \qquad [2]$$

The transition rule is made up of criteria suitability indexes (see Equation 3), transition probabilities (see Equation 1) and neighbourhood indexes. Criteria suitability scores are standardised using Fuzzy Classification to rank the degree of membership of each factor cell to each land use activity, with value 225 reflecting most likely suitability. The scores are next multiplied with the corresponding weightings that had been derived using AHP technique shown in Equation 3. AHP Consistency Ratio at or less than 0.10 is deemed a reasonable level of consistency (Malczewski, 1999). The classification methods and approaches used in this study are available in IDRISI GIS software (Eastman, 2003). From here, the transition rule is defined (see Equation 4). Assessment is next carried out to verify the accuracy of the model prediction.

$$^{t}S_{i,j} = \sum_{m=1}^{M} {}^{t}x_{i,j} . w_m . c_m \qquad [3]$$

where

$^{t}S_{i,j}$ = suitability index for cell i,j at time t
$^{t}x_{i,j}$ = score of criterion m at cell i,j at time t
w_m = weight for criterion m
c_m = Boolean value for constraint

$$^{t+1}u_{i,j} = f\,((^{t}u_{i,j}).(^{t}S_{i,j}).(^{t}P_{a,b,i,j}).(^{t}N_{i,j})) \qquad [4]$$

where

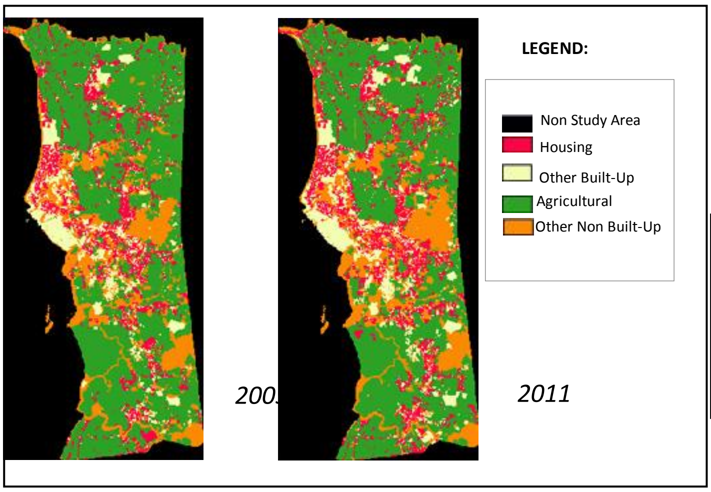
$^{t+1}u_{i,j}$ = the potential of cell i,j to change at time $t+1$
$^{t}u_{i,j}$ = cell state at time t
$^{t}S_{i,j}$ = suitability index for cell i,j at time t
$^{t}P_{a,b,i,j}$ = probability of cell i,j to change from state a to b at time t
$^{t}N_{i,j}$ = neighbourhood index of cell i,j

[4] Average plot size for various types of landed properties priced RM150,000 and below in all three different districts sold under private housing projects within the first half of 2012-2014 (Valuation and Property Services Department 2012, 2013 and 2014).

RESULTS AND DISCUSSIONS

Land use activities in 2005 and 2011 are shown in Figure 3a below. Housing includes both housing schemes and village dwellings. Other built-up covers commercial, services, transportation, utilities and industrial areas. Agriculture represents crop cultivation and farming of livestock and aquaculture. Other non built-up contains environmentally sensitive areas and vacant land.

The observed and predicted probabilities of changes in land use activity are shown in Figure 3b. The accuracy of land use transition evaluated using Kappa Index of Agreement (KIA) is at 83.75 per cent, reflecting approximately 84 per cent of the classified sites are of the same activity between the two years, and therefore reducing the probability of random classification (Malczewski, 1999).




```
Given :    Probability of changing to :

           Cl. 1  Cl. 2  Cl. 3  Cl. 4

Class 1  : 0.6960 0.0993 0.1140 0.0907
Class 2  : 0.1270 0.6840 0.0553 0.1337
Class 3  : 0.1050 0.0505 0.7152 0.1293
Class 4  : 0.1271 0.1042 0.1452 0.6235
```

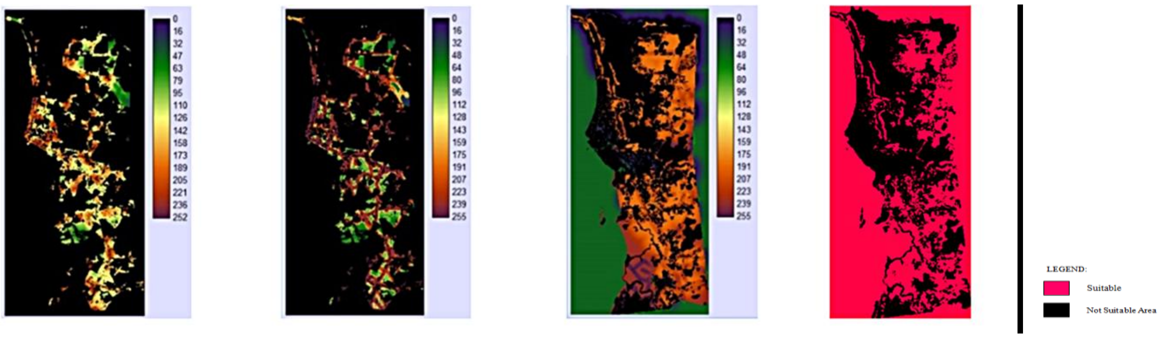
Figure 3: Land Use Patterns for 2005 and 2011 (left) and Land Use Activities Transition Matrix (right)

Development criteria and their respective weightings for Housing, Other Built-Up and Agriculture derived using AHP technique are shown in the following Table 1. Suitability map for all land uses are shown in the following Figure 5 based on AHP weightings (a = Housing, b = Other Built-Up and c = Agriculture) and Boolean Logic (d = Other Non Built-Up).

Table 1: Development Factors and Weightings per land use category

Factor	**Housing**	**Other Built-Up**	**Agricultural**
Proximity to CBD/Workplace	0.2293	0.2337	
Proximity to public health facilities	0.1589		
Proximity to school	0.1129		
Proximity to flood-prone areas	0.2038	0.0718	0.1884
Proximity to road network	0.0674	0.5785	0.0810
Proximity to sensitive areas	0.0375		
Proximity to other facilities	0.1216		
Proximity to existing housing	0.0685	0.1161	
Soil Classification			0.7306
Consistency Ratio	*0.08*	*0.09*	*0.06*

From these four outputs (see Figure 4), prediction for land use pattern in the year 2017 is simulated (see Figure 5.a), and specifically housing land distribution is shown in Figure 5.b. KIA is at 88.92 per cent.



(a) (b) (c) (d)

Figure 4: MCE-based Suitability Maps

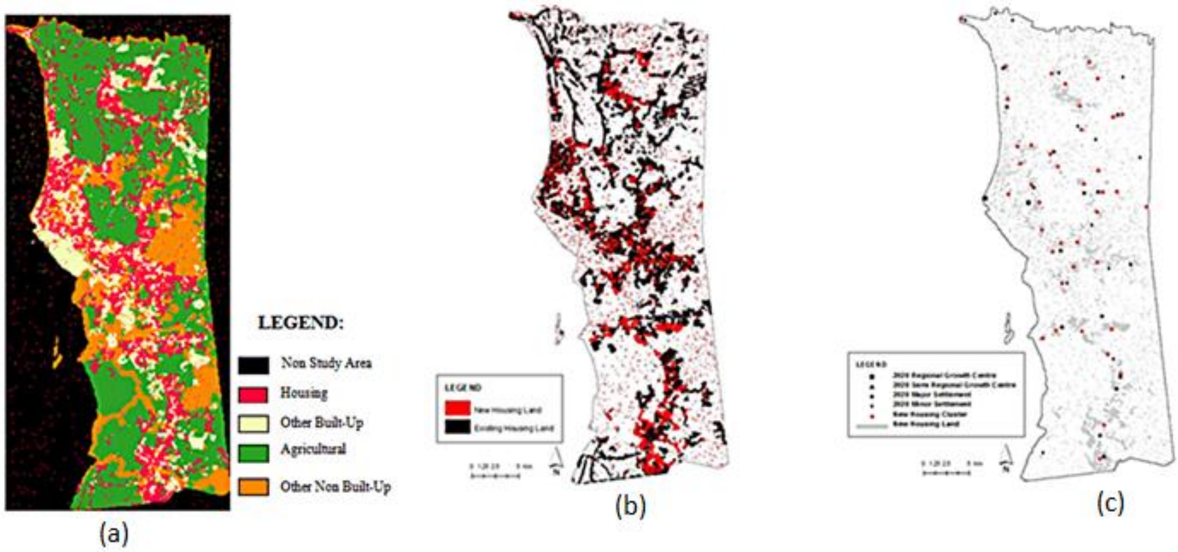


Figure 5: (a) Prediction of land use pattern 2017, (b) prediction of housing land pattern, and (c) prediction of new housing clusters 2017.

Housing land clusters (see Figure 5.c) are found to be located within close proximity to the predicted growth centres and settlements identified by PDTCP (2007), and in line with the compact city growth concept (Federal Department of Town and Country Planning, 2006) to maximise the usage of existing urban space and control the land encroachment at peri-urban areas. As PDTCP (2007) stipulated that commuting time between the dwelling unit and workplace within a major conurbation is within 45 minutes, and Seberang Perai is located within George Town Conurbation, it is assumed that any dwelling location in the region is suitable for current or potential Seberang Perai residents who are working in Penang Island. Also, fragments of new housing land are likely to be of new village dwellings as the lands are formerly agricultural plots.

CONCLUSION

Simulation of future housing land pattern using CA Markov Model can assist housing decision makers and developers to identify more suitable housing sites that are able to cater for evolving needs of various levels of household incomes. As Penang State is striving to become a developed state, the expected higher income can be translated into higher demand for affordable housing. This study has demonstrated the capability of CA Markov model to predict housing land pattern that takes into account preferences of house buyers, and sustainable land usage and management practices by the developers and decision makers. While this neighbourhood effects-based prediction is unable to anticipate new leapfrog-form development, an alternative sprawl pattern influenced by land value, this alternative tool for housing site selection can still assist various initiatives to provide affordable and liveable housing for middle income-earners. Availability of more affordable housing options in

Seberang Perai will provide a win-win situation for Penang State by boosting socio-economic development in Seberang Perai and at the same time liberates Penang Island from various problems associated with very high population density.

Acknowledgement

Authors would like to thank the Ministry of Higher Education (MoHE) for funding this research under Fundamental Research Grant Scheme (203/PHUMANITI/6711472), Northern Zone Project Office of Department of Town and Country Planning, Penang State Department of Town and Country Planning and all in-depth interview sessions and questionnaire respondents.

REFERENCES

Anderson, L. T. (1987). Seven methods for calculating land capability/suitability. *Planning Advisory Service (PAS) Report No. 402*. Chicago: American Planning Association.

Al-Shalabi, M. A., Mansor, S., Ahmed, N. & Shiriff, R. (2006). GIS based Multicriteria Approaches to Housing Site Suitability Assessment. *Shaping the Change: XXIII FIG Congress, October 8-13, 2006*. Munich, Germany.

Banai-Kashani, R. (1989). A New Method for Site Suitability Analysis: The Analytic Hierarchy Process. *Environmental Management, 13(6),* 685-693. New York: Springer-Verlag.

Batty, M. (1997). Cellular automata and urban form: a primer. *Journal of the American Planning Association, 63(2)*. pp 266-274.

Department of Agriculture (n.d.). *Peninsular Malaysia Penang State Hydrological Soil Group Map* (at 1:75,000).

Department of Statistics, Malaysia. (2011). Population Distribution and Basic Demographic Characteristics 2010. Retrieved from http://www.statistics.gov.my/portal/download_Population/files/census2010/Taburan_Penduduk_dan_Ciri-ciri_Asas_Demografi.pdf

Department of Statistics (2015). *Household Income and Basic Amenities Survey 2014*. Department of Statistics, Malaysia.

Department of Survey and Mapping, Malaysia (1987). *Topographic Map*. Kuala Lumpur: Department of Survey and Mapping.

Department of Survey and Mapping, Malaysia (2005). Maklumat Keluasan dan Perimeter Negeri-Negeri, Daerah-Daerah dan Pulau-Pulau di Malaysia. Kuala Lumpur: Department of Survey and Mapping.

der Merwe, J.H. (1997). GIS-aided land evaluation and decision-making for regulating urban expansion. A South African case study. GeoJournal, 43. pp. 135–151. The Netherlands: Kluwer Academic Publishers.

Eastman, J.R. (2003). *IDRISI Kilimanjaro: Guide to GIS and Image Processing, Manual Version 14.00*. Worcester, USA: Clark Labs, Clark University.

Federal Department of Town and Country Planning of Peninsular Malaysia (FDTCP), (2006). *National Urbanisation Policy*. Kuala Lumpur: FDTCP.

Federal Department of Town and Country Planning (FDTCP). (2009). Hill and Highland Planning Guidelines. Ministry of Housing and Local Government, Malaysia.

Federal Department of Town and Country Planning (FDTCP). (2011a). *Housing Planning Guidelines, Second Draft (17/6/2011)*. Ministry of Housing and Local Government, Malaysia.

Federal Department of Town and Country Planning (FDTCP). (2011b). *Planning Guidelines for Environmentally Sensitive Areas, Draft*. Ministry of Housing and Local Government, Malaysia.

Grinstead, C.M. & Snell, J.L. (1997). *Introduction to Probability*. American Mathematical Society.

Khazanah Research Institute (2015). *Making Housing Affordable*. Kuala Lumpur: Khazanah Research Institute. License: Creative Commons Attribution CC BY 3.0.

MacDonald, S. (2011). Drivers of house price inflation in Penang, Malaysia: Planning a more sustainable future. *Penang Institute Research Paper*. Retrieved from http://penanginstitute.org/v3/files/research_papers/Drivers_of_house_price_inflation.pdf

Malczewski, J. (1999). *GIS and Multicriteria Decision Analysis*. Canada: John Wiley & Sons.

Penang State Department of Town and Country Planning (PDTCP). (2007). *Penang State Structure Plan 2020*. Government Gazette 51, 13(1) Penang: PDTCP.

Quah, J.H. (2010, September). Priced off Penang: Who can afford an island home? *Penang Economic Monthly*.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*. New York: McGraw-Hill.

Samat, N., Hasni, R. & Elhadary, Y.A.E (2011). Modelling Land Use Changes at the Peri-Urban Areas Using Geographic Information Systems and Cellular Automata Model. *Journal of Sustainable Development, 4(6),* 72-84. doi: dx.doi.org/10.5539/jsd.v4n6p72

Smit, B. Ludlow, L. Johnston, T. and Flaherty, M.S. (1987). Identifying important agricultural lands: A critique. Canadian Geographer 31(4): 356-365

Suffolk Coastal District Council (2015). *Using the GIS to view the 2014 strategic housing land availability assessment*. Retrieved from http://www.suffolkcoastal.gov.uk/yourdistrict/planning/devcontrol/gis/shlaaguide/

Valuation and Property Services Department (2012). *Property Market Report, First Half 2012*. Ministry of Finance Malaysia

Valuation and Property Services Department (2013). *Property Market Report, First Half 2013*. Ministry of Finance Malaysia

Valuation and Property Services Department (2014). *Property Market Report, First Half 2014*. Ministry of Finance Malaysia

Wang, X., Yu, Sheng & Huang, G.H. (2004). Land allocation based on integrated GIS-optimization modeling at a watershed level. *Landscape and Urban Planning, 66(2),* 61–74.

Interview

J. Panil, personal interview, October 9, 2014

H. Saad, personal interview, October 10, 2014

N. Ideris, personal interview, October 10, 2014

N. Mohd Basar, personal interview, October 10, 2014