

DETERMINING TRANSIT-ORIENTED DEVELOPMENT
(TOD) TYPOLOGY USING MULTI-CRITERIA
DECISION MAKING (MCDM) IN GEOGRAPHIC
INFORMATION SYSTEM (GIS)

BY

WAN ZAFIRAH BINTI WAN MOHD NAJIB

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International Islamic University of Malaysia

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ABSTRACT

Land use planning and transportation are naturally associated with the creation of towns that are liveable and compact. It is a solution that commonly suggested, which lead to a more sustainable future. Even though the basic philosophy of transit-oriented development (TOD) seem to be same in all context, its specific applications greatly differ in form, function and impacts, calling for context-based TOD typologies that can complement to the existing specification and policy intervention in Malaysia. Furthermore, the TOD typology for the rail stations still not well explored, particularly in the detailed context of land use dimension. Further with the aid of the Geographic Information System (GIS), enables the capability in analysing TOD components by replacing the conventional method of the field survey to update their land use maps and spatial analysis. The objectives for this study are; (1) to identify land-use dimension criteria in order to evaluate TOD potential at the study area, (2) to analyse the potential of rail-based stations for TOD purposes based on five (5) land use dimension analysis, (3) to rank TOD typology of rail-based stations using GIS-MCDM and (4) to recommend the use of geospatial approach as a transportation planning solutions. The area of analysis will be within a 400-meter radius from the stations which comprise of 17 rail-based stations in Shah Alam City Council. The methodology adapted to this study is the GIS-MCDM technique. The analysis of research will concentrate on the land-use evaluation criteria that have been selected, which are coverage area, land availability, gentrification potential, density and diversity. Each of the land-use evaluation criteria will be scored through MCDM technique. Furthermore, the stations will be rank its TOD potential according to the total score. The finding shows that the highest TOD potential station is KTM Shah Alam with a score of 3.700. The least potential station is Subang Jaya Integrated Station with a score of 0.743. Based on the ranking result of the TOD potential analysis, the stations will be specified its typology by referring to PLAN Malaysia. Stations in the Shah Alam City Council area only involved in three TOD typology which is 'second-highest TOD intensity', 'third-highest TOD intensity' and 'specialised TOD'. This study will provide a better understanding of how the land-use dimensions of TOD potential analysis are integrated into GIS application which is significant in many ways. Finally, a few recommendations have been suggested, which included compact development around the stations also will be one of the best ways to improve transit service. Dense and high-density development can help Shah Alam stay relevant in the future. Besides, the implementation of TOD is expected to create a sustainable community of high quality, inclusive, healthy and happy lives.

خلاصة البحث

يرتبط تخطيط استخدام الأراضي والنقل بطبيعة الحال بإنشاء مدن صالحة للعيش ومدججة. وهو حل يقترح عادة، مما يؤدي إلى مستقبل أكثر استدامة. وعلى الرغم من أن الفلسفة الأساسية للتنمية الموجهة نحو العبور تبدو واحدة في جميع السياقات، فإن تطبيقاتها المحددة تختلف اختلافاً كبيراً من حيث الشكل والوظيفة والتأثيرات، وتدعو إلى أنماط للتوصيف المستند إلى السياق يمكن أن تكمل المواصفات الحالية والتدخل السياسي في ماليزيا. وعلاوة على ذلك، فإن تصنيف الـ TOD لمحطات السكك الحديدية لم يتم استكشافه بشكل جيد، ولا سيما في السياق التفصيلي للبعد المتعلق باستخدام الأراضي. وعلاوة على ذلك، يمكن بفضل نظام المعلومات الجغرافية من القدرة على تحليل مكونات الـ TOD عن طريق استبدال الطريقة التقليدية للمسح الميداني لتحديث خرائط استخدام الأراضي وتحليلها المكاني. وعلاوة على ذلك، فإن تصنيف الـ TOD لمحطات السكك الحديدية لم يتم استكشافه بشكل جيد، ولا سيما في السياق التفصيلي للبعد المتعلق باستخدام الأراضي. وعلاوة على ذلك، يمكن بفضل نظام المعلومات الجغرافية من القدرة على تحليل مكونات الـ TOD عن طريق استبدال الطريقة التقليدية للمسح الميداني لتحديث خرائط استخدام الأراضي وتحليلها المكاني. والأهداف التي تسعى دراستها هي: (1) تحديد معايير أبعاد استخدام الأراضي من أجل تقييم إمكانات الـ TOD في منطقة الدراسة، (2) وتحليل إمكانات المحطات القائمة على السكك الحديدية لأغراض الـ TOD على أساس تحليل أبعاد استخدام الأراضي الخمسة (5)، (3) وتصنيف الـ TOD في المحطات المعتمدة على السكك الحديدية باستخدام نظام المعلومات الجغرافية MCDM- و (4) التوصية باستخدام النهج الجغرافي المكاني كحل لتخطيط للنقل. وستكون منطقة التحليل ضمن دائرة نصف قطرها 400 متر من المحطات التي تضم 17 محطة تعتمد على السكك الحديدية في إدارة بلدية مدينة شاه علم. وكانت المنهجية المتكيفة مع هذه الدراسة هي تقنية GIS-MCDM وسيتركز تحليل البحوث على معايير تقييم استخدام الأراضي التي تم اختيارها، وهي منطقة التغطية، وتوافر الأراضي، وإمكانية التحسين، والكثافة والتنوع. وسيتم تسجيل كل معيار من معايير تقييم استخدام الأراضي من خلال تقنية MCDM وعلاوة على ذلك، فإن المحطات سوف تكون في المرتبة إمكاناتها TOD وفقاً للدرجة الإجمالية. وتبين النتيجة أن أعلى محطة محتملة للـ TOD هي KTM شاه علم مع درجة 3.700. وتليها المحطة الأقل المحتملة هي محطة سوبانج جايا المتكاملة التي سجلت 0.743. واستناداً إلى نتائج التصنيف في التحليل المحتمل للـ TOD، سيتم تحديد التصنيف الذي تقوم به المحطات عن طريق الرجوع إلى PLAN Malaysia وكانت المحطات في منطقة بلدية مدينة شاه علم تشارك فقط في ثلاثة تصنيفات الـ TOD الذي هو "ثاني أعلى كثافة" الـ TOD، "ثالث أعلى كثافة" الـ TOD و "المتخصصة". وستوفر هذه الدراسة فهماً أفضل لكيفية إدماج أبعاد استخدام الأراضي في التحليل المحتمل للـ TOD في تطبيق نظم المعلومات الجغرافية، وهو أمر هام من نواح كثيرة. وأخيراً، اقترحت بعض التوصيات التي شملت تطويراً متروياً حول المحطات أيضاً ستكون من أفضل الطرق لتحسين خدمة المرور العابر. ويمكن للتنمية الكثيفة والكثافة أن تساعد مدينة شاه علم على البقاء على صلة بالموضوع في المستقبل. إلى جانب ذلك، من المتوقع أن يؤدي تنفيذ نظام الـ TOD إلى خلق مجتمع مستدام يتمتع بحياة عالية الجودة وشاملة وصحية وسعيدة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

.....
Norzailawati binti Mohd Noor
Supervisor

.....
Abdul Azeez Kadar Hamsa
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

.....
Syahriah binti Bachok
Examiner

.....
Muhammad Zaly Shah bin Muhammad Hussein
External Examiner

This thesis was submitted to the Department of Urban and Regional Planning and is accepted as a fulfilment of the requirement for the degree of Master of Science (Built Environment).

.....
Syafiee Shuid
Head, Department of Urban and Regional
Planning

This thesis was submitted to the Kulliyah of Architecture and Environmental Design and is accepted as a fulfilment of the requirement for the degree of Master of Science (Built Environment).

.....
Abdul Razak Sopian
Dean, Kulliyah of Architecture and
Environmental Design

DECLARATION

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*This thesis is dedicated to my beloved parents and families for laying the foundation
of what I turned out to be in life.*

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
BRT	Bus Rapid Transit
CPTED	Crime Prevention Through Environmental Design
CTMSDF	Cape Town Municipal Spatial Development Framework
DPN	Dasar Perbandaraan Negara
GIS	Geographic information systems
HSR	High-Speed Rail
IDP	Integrated Development Planning, Africa
ITDP	Institute for Transportation and Development Policy, China
KTM	Keretapi Tanah Melayu
LRT	Light Rapid Transit
LTA	Land Transport Authority, Singapore
MCDM	Multi-Criteria Decision Making
MRT	Mass Rapid Transit
MSE	Metro South East, Cape Town
MTR	Mass Transit Railway, Hong Kong
NDRC	National Development and Reform Commission, China
NPP	National Physical Plan
NUP	National Urban Policy
PDCU	Projects Development and Coordination Unit (PDCU), Ministry of Infrastructure, Transport and Communications, Malta
RFN	Rancangan Fizikal Negara
RMK-10	Rancangan Malaysia Ke-10
RMK-11	Rancangan Malaysia Ke-10
RTS	Rapid Transit System, Singapore
TCT	Transport for Cape Town
TOD	Transit-Oriented Development

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

This research will focus on the land use analysis in transit-oriented development (TOD) concept. The land use dimension identified will be analysed using geospatial technologies of Geographic Information System (GIS), by using Multi-Criteria Decision Making (MCDM) technique. An evaluation will be carried out to analyse and rank all 17 rail stations in Shah Alam City Council area as potential TOD. The first chapter of the research will concentrate on the preliminary part of the study. It includes the formulation of the goal and objectives of the study. The structure of the study also will be discussed to give a better understanding of the research.

1.1 BACKGROUND OF THE STUDY

Cities face with several environmental issues in an increasingly industrialised world, including urban development, inadequate resource utilisation, and land redistribution, traffic congestion and atmospheric emissions. Land-use and transport planning are inevitably linked to the development of working, energy-efficient and people-oriented urban areas (Kodukula, 2018). It is a solution that commonly suggested and can lead to more sustainable development in the future. In the meantime, the idea of accessibility as an interface between transport and land use interactions is one of the first techniques to create a useful structure for the integration of transport and land use planning (Fard, 2013). The idea of transit-oriented development (TOD) is another systematic approach adopted by such implementation. It is an attempt to monitor land use and progress in

the transportation network. A generally accepted definition is a complex form of high population size, mixed and dispersed urban land use in an accessible area around a transit stop (Calthorpe, 1993).

TOD is currently being glorified and have been practised in developed and developing countries. The concept of TOD has become popular in the United States, the world's most car-dependent country since the 1990s (Cervero, 2013). Malaysia was also no exception to seize the opportunity to introduce TOD, which was proven successful in other countries. TOD is often seen as a remedy to the car-dependent community. It is because, by attracting a mixture of dwellings, commerce, works, and public activities within walking distance from the rail station, this approach can attract society to use transit and consequently can reduce road congestion, enhance air quality and contributing to climate stability. The TOD also means integration of land use and transportation, which can stimulate trend in developing communities that are vibrant, liveable and sustainable. It stressed on the creation of compact, walkable, pedestrian-oriented, mixed-use communities centred on high-quality train systems (Transit Oriented Development Institute, 2018). To facilitate transit use and improve transit systems, TOD focuses mainly on stations linking current and expected developmental concentrations. TOD also increases flexibility as it generates alternatives to land use in the automotive sector.

Meanwhile, TOD has also become the dominant land-use planning model. It is one of the key aspects of accessibility assessment and the key to urban environmental design. Land use planning for stations should be coordinated as early as possible, according to Cervero (2006). In such a rational manner, transport and land use are connected (Waddell, 2011). One aspect will influence the other. Land use also affects travel behaviours (Sarkar and Mallikarjuna, 2013) meanwhile, Ratner and Goetz (2013)

claim that TOD also affects land use and urban structure. Therefore, cities are reliant on proactive land-use planning for their efficient implementation (Dutta, 2012). In order to create value, improvements in existing land use are needed to achieve desired outcomes (Salat and Ollivier, 2017). It is possible to reconfigure land-use through effective land-use planning. Analysis of land-use features plays a vital role in the development of a successful area TOD. In terms of land-use changes, it is about increasing densities and mixing functions. Whereas, in terms of improvements in transport, it is a case of increasing the competitiveness of automobile alternatives by improving their mobility and making door-to-door speed efficient.

Apart from the advantages mentioned, TOD typology is also one of the essential elements in planning TOD. The TOD typology was established to distinguish the features of the different TOD network (Huang et al., 2018). Based on the typology established, the effects of complementarity between TOD stations were studied to recognise how their results relate to the TOD network on a large scale (Huang et al., 2018). There is growing interest in developing a TOD typology, considered as a mechanism for advising political vision and evaluation (Higgins & Kanaroglou, 2016). The benefit of establishing the TOD typology as efficient for town planning processes and operations since a similar range of approaches can be integrated within the same TOD typology nodes and also the recognition of general development potential (Kamruzzaman et al., 2014).

On the other hand, multi-criteria analysis is widely used because of the practicality with which non-marketable effects and qualitative parameters are assessed for these purposes (Delle and Filippi, 2011). Multi-Criteria Decision Making (MCDM) techniques are commonly used in transportation planning to provide their inputs to various evaluation criteria in a relative valuation of alternative developments (Figuera

et al., 2005). As an evaluation technique for transportation plans, MCDM has gained prominence, and the use of these techniques rises by the day in the assessment of transport projects, including freight transportation, infrastructure allocation, location decisions, and so on (Pérez et al. 2015, Macharis, & Bernardini, 2015). Singh et al. (2014) conducted the first TOD planning study. They established a spatial TOD index for evaluating TOD ranks in the whole study area. MCDM is a standard method for solving problems that required several uncertainties and was used to address the TOD challenge.

Besides, this research aims to highlight a straightforward method which rail-based stations in Shah Alam City Council can employ to implement the TOD concept. Through GIS analysis, it can be evaluated the land use dimension around rail-based TOD nodes. This study will focus on the application of GIS techniques, specifically on spatial analysis and MCDM techniques. The land-use dimensions that will be considered in this study are coverage area, land availability, gentrification potential, density and diversity. The selected land-use dimensions will become the evaluation criteria in the analysis stage to rank the potential TOD concept in Shah Alam City Council.

1.2 PROBLEM STATEMENT

Geographic information systems (GIS) are extensively applied in many sectors such as environment, vegetation, hydrology and urban planning. After more than two decades of being introduced into the planning industries, GIS has become one of the essential components for planners. The use of GIS application amongst planners has been prominent since the 1990s. In the context of their work, planners decided to embrace this ‘modern’ approach, particularly in terms of mapping and land data storing

(Abdullah et al., 2010). GIS was introduced in Malaysia in the early 1980s. In 1981, the Malaysian Department of Agriculture first used GIS (Idrus & Harman Shah, 2006). GIS was officially used in planning in Malaysia only over a decade later.

The Town and Country Planning Act, 1976 (Act 172) (amended in 2001) requires the preparation of plans at different spatial and administrative levels to ensure efficient and effective planning. In the restructuring of the development planning system, the amended Act plays a significant role in requiring that the GIS be incorporated into the preparation of development plan procedure at all planning hierarchies, whether at the local or regional level. GIS application has long been used in planning activities, including the formulation of plans and development control (Johar et al., 2003).

Early implementation of GIS, has been viewed as a map drawing tool and has therefore been used as one. Maps have been drawn using GIS software without the attributes of data. Given the availability of GIS technology and digital maps, spatial analyses were still performed manually. However, the findings of these analyses were drawn onto the maps using GIS (Abdullah et al., 2010). Today, GIS is a piece of common knowledge among planners in Malaysia. Formal GIS training is now offering to all planning graduates at all planning schools in the country. Even though these technologies have been used widely in urban planning, but the exposure and utilisation of GIS applications in Malaysia are not at its best, especially in TOD planning.

Yaakup et al. (2006) revealed that the problems of urban planning are challenging to plan and develop at the state level in their study. Blueprint is the previous process used in town planning, which is plotted using manual drawings. The other issues that the paper highlights are no monitoring system planning and no development for the urban planning database. Geospatial data storage accessible and consistent format has

been introduced for the solution. It is possible to share geospatial information with other departments and to analyse and display the data easily.

Furthermore, Kassim et al. (2011) found out that no planning mechanism enables oversight of the administration of the planning process. Therefore, GIS application was used to standardise the format for the town planning department. The outcome attained in the town planning development is more precise using this technology. Simultaneously, it can cut the budget and time consumption in the flow process that does not have repetition data.

The usage of web-based GIS is considered the best way to resolve the confusion, inconsistency and contradictions tangled in the planning procedure. In particular, in terms of transparency and accessibility, it provides significant potential for enhancing the planning system and thus leads to better governance (Yaakup, 2006). Problems in accessing related information are generally correlated with the common problems of major cities, creating the progression of development control more difficult (Selamat et al., 2012). Thus, providing an efficient development and decision-making process is incredibly essential. This can be accomplished by the readiness of reliable, high-quality data and the use of relevant, efficient and effective methods. Apparently, latest and accurate data is required at all planning and monitoring levels, from the national level until to local authorities, to assist policy planning organisational processes and to plan implementation.

This well-integrated and complete system is part of the core fundamentals that will decide the eventual success of the implementation of GIS in the creating of plans. The integration shows that the GIS features can be improved by applying to the existing system and analytical resources, and by using the GIS software tool to the total benefit. It will also be used to support decision - making, considering existing planning

situations, physical constraints and future impacts. The implementation of GIS has managed to bring the difficulties of planning for land use towards a more systematic and insightful framework.

Besides, GIS and MCDM have been widely used in the last two decades to address site selection problems. Once GIS was combined with MCDM techniques, it offers a useful tool for choosing the ideal location for urban transport development. Based on these situations, the MCDM techniques offer various skills and procedures for formulating the benefits, drawbacks and possibilities related with the issue of decision making, assessing the alternatives in particular requirements (Malczewski, 1999). The GIS system is used to perform the spatial analysis required during the site screening phase, while the MCDM technique is used for the assessments.

For TOD planning in Malaysia, the use of GIS in TOD analysis was not comprehensively explored until now. Planners still choose to apply the conventional method of the field survey to update their land use maps and also for spatial analysis. This technique brings up several problems such as time-consuming, laborious and expensive. The reason for a practitioner would instead use a manual site inventory method compared to geospatial technology although this technology has more advantages because of the lack of utilisation of GIS in analysing TOD components especially in Malaysia (Fard, 2013).

Furthermore, the simplicity with which GIS can operate geographical information has also created a significant challenge as operators who are inexperienced with GIS systems, or the nature of geographical information can simply confuse invalid inquiry with valid ones (Yaakup et al., 2005). Hence, practitioners more are willing to use a comfortable method for them in analysing the data. On the other hand, GIS has proved to be an important technique for assessing possible solutions to urban planning

issues. Database planning can be interrogated extensively to generate several alternative solutions to problems with urban planning (Yaakup et al., 2005). GIS is also considered a powerful tool for urban facility monitoring. GIS is used for spatial data integration, interpretation, and display. Transport professionals thought GIS to be a dominant instrument for designing and assessing transport systems, performing transport facilities impact assessments and integrating transport and land use planning (Olba, 2006). Next, GIS enable planners to use geospatial features such as map overlay, connectivity measurement and buffering to accomplish spatial analysis (Yeh, 1999). The abilities of GIS seem that can take advantage to be applied in this study.

The planning strategy for potential urban growth in most developing countries, such as Malaysia, is not always taken comprehensively, resulting in a significant dependency on private cars, which is further congested. Malaysia in early urban planning tends to apply single land-use zoning in land development which is only focused on particular land use not comprehensive for all entire areas of growth and surrounding. Practices that emphasise single-zoning land development and land-use segregation have long been believed to encourage widespread use of private vehicles (Berry, 2001). As a result, most cities suffer from traffic congestion, and life becomes unsustainable (Shubho, 2014).

In Malaysia, the promotion of TOD as a foundation of land use planning has been around since 2010 through the National Physical Plan and the 10th Malaysia Plan (RMK-10). Now, the government through the concepts of the 11th Malaysia Plan (RMK-11), the National Physical Plan 3 (RFN 3) and the National Urban Policy (DPN 2) have also encouraged this concept to be adopted mostly in the existing cities areas (infill) or new area (greenfield) and even transit stations. This approach aims to provide