SIMULATION AND EVALUATION OF AUTONOMOUS RAIL
RAPID TRANSIT (ART) IN KUCHING AND KOTA
SAMARAHAN BASED ON THE MULTI-AGENT APPROACH

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Bachelor of Computer Science with Honours
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ABSTRACT

Public transport infrastructure is one of the crucial factors that affect a country’s growth progress. By having an excellent public transport system, it forms an essential lifeline and maintains the flow of the country’s economy, especially in the urban areas. Kuching is the heartland of Sarawak and one of the most visited cities in Sarawak, and Kota Samarahan becoming popular due to numerous educational institutions, including local and overseas. Due to the growths of the population, congestion often occurs between these two main cities. Introducing advanced public transport can tackle the problem. Railway transportation played a vital role for residents in terms of mobility and convenience. On the other hand, urban rail transit is a diverse and dynamic system. Traffic is often inconsistent and contradictory. The spatial-temporal characteristics of an individual were complicated to calculate by the mathematical model due to scale and complex. A multi-agent system approach is introduced in this project, to solve the spatial-temporal of passenger flow and evaluate the effectiveness of transportation. Moreover, we will create a simulation model in AnyLogic Software and includes a multi-agent-based approach to specific characteristics of passenger travel behaviors and the interactions between travelers and trains. Therefore, the studies aim at using simulation and multi-agent system approach to solve and evaluate urban rail transit.
ABSTRAK

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Kuching, the state capital of Sarawak, is possibly one of the most beautiful cities in South East Asia. There are approximately 700,000 citizens lives in Kuching. Besides, Kota Samarahan is also known as “Town of Knowledge” due to many institutes that included local and overseas, such as Universiti Malaysia Sarawak (UNIMAS) and Universiti Teknologi Mara (UiTM). Both places are considered as the two major cities in Sarawak with tremendous opportunities for work, land properties, institutes, organizations, shopping malls, and investors. Therefore, many residents are travel between these two places for jobs and studies. Besides, tourists from West Malaysia or foreign country also likes to visit here. Due to the high amount of population between these two places, heavy traffic often occurred.

Recently, the Sarawak State Government has received many reports from drivers that the traffic is horrible during the off-hour and peak hours. Drivers are stuck in the traffic and can only wait for traffic police to outwait the traffic jam. (Samuel & Rintos, 2019). At first, the State Government proposed that install LRT will be solved the problem, but the project was cut off due to budget constraints, and they are focused on rural area water and electric supplies. After a few discussions by the state government, they come out with a suggestion which is planning to implement Autonomous Rail Rapid Transit (ART) in Sarawak to reduce car usage and solve the problem.

ART is an urban transport system that has been neither a train nor bus, but they do have rubber wheels and run on specify lane, which painted with double-dashed white lines, rather than traditional railway tracks. Besides, ART is an autonomous driving system, which means it can function without a driver. It is also an eco-friendly transport system which is it produces fewer noises, and fewer emissions compare to other petrol vehicles. ART using electric traction
from a battery that can be recharged at the stations in about 30 seconds for the next run, or it can recharge in 10 minutes at the end of the line. The ART comes with a maximum speed of 70 km/h, and the capacity is approximately 300 – 500 people followed by 3 to 5 carriage.

"The autonomous features mean it is programmed, optically guided with GPS and LIDAR technologies, into moving very precisely along an invisible track." (Newman, 2018). Besides, Newman (2018) found out that "It can slide into the station with millimeter accuracy and enable smooth disability access. It passed the ride quality test when I saw kids running up and down while it was going at 70kph – you never see this on a bus due to the sway." (Newman, 2018).

In this study, the ART system will be designed using AnyLogic Software Simulation Tools to develop a virtual network and using multi-agent approach to evaluate the effectiveness of the ART system.
1.2 Project description

This project is to develop an ART network using AnyLogic software. AnyLogic software is a simulation tool that can simulate a 2D or 3D graphical image, and it also provides some features such as an agent-based approach. Besides, the primary purpose of using this software is to analyze and simulate possible ART networks and evaluate the operational effectiveness and sustainability of ART networks based on multi-agent approach between Kuching and Kota Samarahan.

1.3 Problem statement

Kuching is the capital and most populous state of Sarawak and Kota Samarahan is also known as “Town of Knowledge” because of many institutes that included local and oversea. Because of this reason, many drivers are travelling these two places every day and suffer heavy traffic during working hours and off-hours. Furthermore, drivers need to drive up to approximately 30 KM of the distance between Kota Samarahan and Kuching, and this will need some time to reach.

Traffic and transportation often show a complex and contradictory behavioral problem. To solve this problem, a multi-agent approach is implemented in this project to tackle spatial and temporal passenger flow and assess the transportation performance. Multi-agent system is an approach based on the idea that a network consists of decentralized individual 'agents' and that according to regional information, that agent communicates with other agents.
1.4 **Objective:**

1. To develop ART network - Samarahan Line 1 which is from Kuching to Kota Samarahan.
2. To simulate possible networks and terminals before going to the construction phase.
3. To evaluate the effectiveness and sustainability of the ART.

1.5 **Brief Methodology**

In the beginning, we will collect data and do requirement analysis. Statistic Traffic data is collected from Ministry of Transport Sarawak and from other online sources. Second, we will need ART Network Diagram in order to simulate virtual network based on the proposed network. Furthermore, to simulate virtual network, we will be using AnyLogic Software Simulation Tool assist us to create meaningful diagram. This is because, AnyLogic provide huge rail library, template and documentation to guide us. After that, AnyLogic also provide multi-agent-based approach to evaluate the effectiveness of the ART virtual diagram.

1.6 **Scope**

Using AnyLogic to design a virtual terminal for ART and evaluate the effectiveness.

1.7 **Significance of Project**

The findings of this study will redound to the benefit of society, considering that the ART will be the first transit system install in Sarawak. Using AnyLogic software simulation tools, we can model a virtual network map and then use a multi-agent approach to test the efficacy of ART. From the study, we can foresee that the ART would able to solve the current problems and the sustainability of the ART system.
1.8 Project Schedule

![Gantt Chart of Project Schedule]

*Figure 1.1 Gantt Chart of Project Schedule*
1.9 Expected outcome

Using the software to simulate ART network and show the effectiveness and sustainability of the ART virtual network between Kuching and Kota Samarahan.

1.10 Project Outline

The project outline for this project will include five chapters to design a virtual network for ART and evaluate the effectiveness and sustainability of the virtual network based on multi-agent approach.

1. Chapter 1: Introduction

This chapter explains the description of the project in detail and includes the introduction of the overall project, problem statement, project aims, scope, objectives. Methodology, the significance of the project, project schedule, and expected outcome.

2. Chapter 2: Background & Literature Review

This chapter describes the ART and literature review for this project. Similar articles and current systems will be selected for the literature review of the reviewed system. Depending on the features and functionality, the systems evaluated will be discussed. Besides, this chapter also clarifies the methods, and software tools that are used to develop the proposed requirement.
3. Chapter 3: Methodology

In this chapter, the requirement analysis and design will be included in the development of the proposed system. The requirement for the client and the system functional and non-functional requirements, as well as the requirements for hardware and software, will be addressed in the review section. Besides, in the design part, the design of the overall project will be drawn up in the chapter. The design will display a simple virtual network map that builds based on Light Railway Transit (LRT) draft network proposed by the state government.

4. Chapter 4: Implementation

The implementation of the proposed system will be specified in this chapter. The design of interfaces and the production of the system will be presented in a technical form. Screenshots of the results and functions of the proposed system will be attached and explained in this chapter.

5. Chapter 5: Experimental Analyses and Evaluation

Functional and non-functional testing will be performed in this chapter. System testing will be included in this chapter.
CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A literature review is an essential part of the exploration of a project. It is “a critical, analytical summary, and synthesis of the current knowledge of a topic.” (Harvey, 2010). The proposed project is using simulation software tools, which is known as AnyLogic Software, and this software also provide multi agent-based approach to develop this system. It is designed to meet the project objectives set out in Chapter 1. In this chapter, we will examine the existing or similar system based on this proposed system in terms of functions and features, a comparison will be made between revised systems and the proposed system. At the end of this chapter, the existing system will be evaluated and addressed to use a suitable solution to incorporate the proposed method. This chapter will also discuss the tools and technology that will be used for the system.

2.2 Review on the current and existing systems (ART and LRT)

Autonomous Rail Rapid Transit (ART), also known as Trackless Tram due to its patterns of movement, ART can operate without rail on the road while the LRT using steel wheels and run on the specific track. The ART uses rubber wheels that drive on the road surface, which prevents the significant part of civil works related to rail infrastructure for being needed. Besides, the ART incorporates a range of autonomous vehicle guidance technologies along its corridor to adopt "virtual rails". The primary elements of the guidance system are imaging detection for optical guidance, satellite navigation, radar point scanning, and inertia management. Furthermore, compared to traditional LRT systems, the big difference in implementing ART is that ART prevents digging and interference with buried infrastructure such as water supply, power cables, telephone lines, stormwater systems, or wastewater systems, which will add significantly to the cost when disrupted. On the other hand, the cost of
ART can be considerably lower than the light rail. Newman et al. (2019) studies, it stated the following:

In a report commissioned by the City of Parramatta in Sydney, Bodhi Alliance, and EDAB Consulting estimated that a Trackless Tram option would have capital costs three times less than a light rail option. The most significant uncertainty in these figures is around construction costs in the road and tracks, as well as the needs of particular design requirements around stations.

Besides, building a light rail line on top of this critical infrastructure is highly undesirable, as reaching them may involve digging up the line at enormous cost. Generally, these services are relocated when a light rail line is built, increasing the capital cost of the line being installed. Such expenditure was found in the recent studies in Penang LRT, which the researchers are estimating construction costs for Penang’s LRT is RM 220 million per kilometre, while ART construction costs at RM 16.9 million to RM 22.5 million per kilometre for each set of three carriages plus a station. Also, ART can be easily maintained, including new routes introduced or routes modified compare with LRT, which need to undergo heavy infrastructure construction and a long time to implement new routes or maintenance. (Lim & Ahmad, 2019). As shown in Table 2.1, the ART specification was summarized.

In conclusion, with all the credit towards ART, ART will likely replace LRT and Bus Rapid Transit (BRT) systems. This is because ART has the ability to imitate all of these systems best qualities while utilizing High-Speed Rail technology. Furthermore, the significant decrease in price makes ART extremely attractive for local government. It is also filling the niche that currently occupied by LRT and BRT. ART system is likely to reduce the high amount of car usage in Kuching and Kota Samarahan while offering greater accessibility.
Table 2.1. Vehicle specifications for 3-module ART

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>31.6m</td>
</tr>
<tr>
<td>Width</td>
<td>2.65m</td>
</tr>
<tr>
<td>Weight (loaded)</td>
<td>51 tonnes (average 9 tonnes per axle)</td>
</tr>
<tr>
<td>Capacity</td>
<td>250 – 300 people</td>
</tr>
<tr>
<td>Max speed</td>
<td>70km/h or 50 mph</td>
</tr>
<tr>
<td>Gradient / slopped</td>
<td>13% or 13°</td>
</tr>
<tr>
<td>Turning Radius</td>
<td>15m</td>
</tr>
<tr>
<td>Design Life</td>
<td>30 years</td>
</tr>
</tbody>
</table>

Note. Adapted from https://www.crrcgc.cc/en/g7389/s13996/t286142.aspx. Copyright (2018) CRRC All Rights Reserved
2.3 **Comparison of the ART, BRT, and LRT**

Table 2.2 shows the comparison of characteristics of corridor based urban rapid transit systems.

In the table, we can see that Table 2 compare three urban transit system based on six criteria. Newman et al. (2019) conducted that table as following:

Table may rate some characteristics higher or lower however it is the conclusion of the authors after extensive investigations, analysed and set out above, that the Trackless Tram System is the preferable option over the BRT or LRT in the corridor connection niche of transport as well as the city-shaping niche of urban planning.

Table 2.2. Indicative comparison of characteristics of corridor based urban rapid transit systems. With the scale (√ = above average, √√ = Good in overall, × = inefficient)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Bus Rapid Transit (BRT)</th>
<th>Light Rail Transit (LRT)</th>
<th>Trackless Tram System (TTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed and Capacity</td>
<td>√</td>
<td>√</td>
<td>√√</td>
</tr>
<tr>
<td>Ride Quality</td>
<td>×</td>
<td>√</td>
<td>√√</td>
</tr>
<tr>
<td>Land Development Potential</td>
<td>×</td>
<td>√</td>
<td>√√</td>
</tr>
<tr>
<td>Cost</td>
<td>√</td>
<td>×</td>
<td>√</td>
</tr>
<tr>
<td>Disruption during the construction period</td>
<td>√</td>
<td>×</td>
<td>√√</td>
</tr>
<tr>
<td>Implementation Time</td>
<td>√</td>
<td>×</td>
<td>√</td>
</tr>
<tr>
<td>Overall</td>
<td>√</td>
<td>√</td>
<td>√√</td>
</tr>
</tbody>
</table>

2.4 Review on the software tools

In this proposed project, a simulation software tool was introduced known as AnyLogic Simulation Software tools. AnyLogic is a modeling tool developed by The AnyLogic Company (former XJ Technologies). It consists of a multimethod simulation approached, such as agent-based, discrete events, and system dynamics simulations. AnyLogic is also a cross-platform simulation tool to operate on Windows, macOS, and Linux. AnyLogic is commonly used to simulate a variety of situations and places, for instance, healthcare centre, markets, and competition, business process, social, ecosystem dynamics, road traffic, aerospace, etc.

One of the powerful features is AnyLogic Libraries, which provide various types of template. One of the libraries that will be used in this project is known as The Rail Library. It supports the modelling, simulation, and visualizing operations of a rail yard in any situation. Besides, it is possible to integrate rail yard models with discrete event or agent-based models related to loading and unloading, resource allocation, maintenance, business processes, and other transportation activities.

Also, AnyLogic support GIS integration which allows user to map data in models and to create geospatial routes for agents automatically. The main tile map features in AnyLogic include, users can access all stored data along with online maps such as towns, regions, road networks, buildings, universities, bus stops, etc. Besides, agents can be placed in desired points on the map and moving around on the existing roads and routes. Last but not least, AnyLogic also provides a cloud platform to allow the user to store the data to the AnyLogic Cloud. It enables users to store, access, run, and share online simulation models, as well as analyze the results of experiments.
2.5 Review of the multi agent-based approach

A multi-agent system (MAS) is a powerful method for research and is suitable for large-scale and complex problems. (Abourraja et al., 2017). MAS is a distributed and robust system consisting of one or more sub-systems, also called organizations, in each of which several agents communicate, negotiate, and collaborate to achieve specific goals. Agents are computer systems that are able to act in an environment via certain behaviors and to adapt their internal states to the changes that take place. (Wooldridge, 2009). Agents can be independent and even benefit from their experiences and make decisions to solve a problem effectively.

The development of a multi-agent framework for the management of a complex and dynamic system is often a problematic and repetitive activity, requiring a modeling approach to simplify the design process.

2.6 Review of the multi agent system - Swarm Intelligent (SI)

Swarm Intelligence (SI) is part of the multi-agent system. We will briefly describe and apply in this project. SI was inspired by the concept of social insects such as bees, wasp, ants, and termites. Each of the colonies of social insects is very flexible and can adapt well to the changing environment. When there is a shortage situation, the 'higher specialization' workers will be taking on the duties of the 'lower specialization'. This versatility makes it possible for the colony to be resilient and sustain its life despite major disturbances. Besides, the behavioral of individual insects in a colony social insect is documented. Examples, bee dancing during food procuring, secretion pheromone of the ants, and performance of certain actions signalling to the other insects continue the same activities. “These communication systems between individual insects contribute to the formation of the ‘collective intelligence’ of social insect colonies. Recently, the term ‘swarm intelligence’, denoting this ‘collective intelligence’, has come into use.” (Teodorovic', 2003). Overall, SI is a concept rather than a
technology. It is a bottom-up approach to controlling and optimizing distributed systems. SI using robust, decentralized, and self-organized techniques.

2.7 Summary

ART is a new type of transit system created by High-Speed Rail hybrid technologies applied to buses. Besides, ART is a new type of transit infrastructure, providing innovative and transformative opportunities for cities needing public access and electrical connections to enable urban regeneration. ART offers economic opportunities to make use of new land development potential. With the coming of the Autonomous Technological era, ART presents a new and unique transit option that can not only incorporate state-of-the-art technology but deliver enormous economic, social, and environmental benefits to expanding cities all over the world.

In conclusion, ART is likely to replace LRT in cities and provide far more opportunities for creating the much-awaited transformation to more urban regeneration and less reliance on the car as well as its associated multiple economic, social, and environmental benefits.