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ROUTE LINES AND TRACK GEOMETRIC DESIGN FOR THE RUBBER TIRE AUTOMATED PEOPLE MOVER SYSTEM (APMS) AT SOEKARNO-HATTA INTERNATIONAL AIRPORT, TANGERANG, INDONESIA (STA 03+896 – STA 08+089)

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ABSTRACT

Soekarno – Hatta International Airport (SHIA), as one of the largest airport in Indonesia, consists of three terminal buildings. The long distance between terminals has triggered the airport’s owner to implement a rubber tyred and driverless train equipped with Automated People Mover System called Sky Train. But much to this construction, the area served by Sky train is very limited as only went through within the airport area, between Terminal 1 and Terminal 3. This final project is purposed to develop the route further to make a loop track. Besides, the new route lines also intended to reduce congestion within the airport area by providing an alternative track design with some shelters on the outside of airport area.

The project is done by using the secondary data from various sources and Design Criteria of Rubber Tire APMS, Track Design Handbook for Light Rail Transit (TCRP – RPT 57 & 155) as the basic references and Technical Data of the Rolling Stock as supports to the requirements for the plan of track construction as well as the help from AutoCad 2015, ArcGis 10.3, Google Earth Pro, and Microsoft Office to process the data and depict the results.

The result of this final project concludes that there are two route lines, Centerline 1 and Centerline 2, with the length of route lines are 4,193 meters and 4,179 meters. The route line is constructed with 4.32 meters in width for single track and 8.64 meters in width for double track. Total area that required for the track construction is 36,167 m^2 without passing through the buildings or residential area. Designed as a new alternative option, hopefully this final project result can be used as a recommendation for PT Angkasa Pura II.

Keywords: APMS, Airport, Geometric design, Sky Train

1. INTRODUCTION

Soekarno – Hatta International Airport (SHIA), as one of the largest airport in Indonesia, consists of three terminal buildings: Terminal 1, Terminal 2, and Terminal 3. The long distance between terminals, has trigger the airports owner to build a transit system that efficient enough to be implemented at the airport area. Apparently SHIA provides Free Shuttle Bus to interconnect the terminals. However, this transit buses get intermingled with the other conveyance and often trapped on traffic congestion causing buses left behind schedule. In order to solve this problem, a driverless train called Sky Train is conducted and expected to operate in June, 2017. Sky Train is a rubber tyred and driverless train that equipped with Automated People Mover System (APM

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System) to enable the automatically operation. The usage of Sky Train tend to be compatible for airport area because this conveyance has a flexible capacity, categorized as a massive transportation, user friendly, and convenient enough for a short distance in the range of 300 to 1500 meter.
But much to this construction, the area served by Sky train is very limited as only went through between Terminal 1 and Terminal 3 within the airport area. The route lines are a half-loop design with double tracks as shown in Figure 1.

Figure 1 Current Skytrain Layout
Source: Indonesia SHIA APMS Project, 2017

Therefore, this final project is purposed to develop the route further to make a loop track by determine the optimum Sky Train route lines, design the track geometry, calculate the area that required for the implementation, and propose the suitable structure components of the rubber tire APMS. Besides, the new route lines also intended to reduce congestion within the airport area by providing an alternative track design with some shelters on the outside of airport area as shown in Figure 2. Designed as a new alternative option, hopefully this final project result can be used as a recommendation for the owner of SHIA.

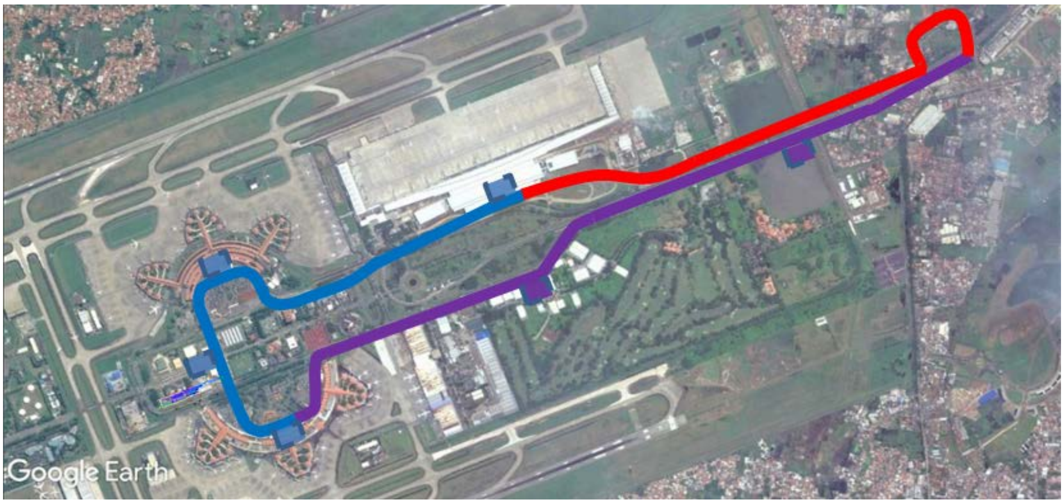


Figure 2 Plan View of Sky Train Layout

2. METHODOLOGY

Methodology is the designing process step that is used for planning, obtaining, and analyzing the data which involved implementation steps from the earliest to the latest step. The first step in this methodology is identifies the problems within the project area. Then, knowing the purpose of the study and deep literature understanding which is used as the guidelines and directives during the calculation, collecting data that is being needed, analyzing the data, and determining design based on the results of data analysis.

2.1. Literature Study

The literature study for this final project can be derived by understanding and reviewing some theories from Airport Cooperative Research Program (ACRP, 2010), American Society of Civil Engineers (ASCE, 2008), Handbook of Transportation Engineering (Myer Kurtz, 2011), and Track Design Handbook for Light Rail Transit (TCRP – RPT 57 & 155, 2000). Besides, some final project about conventional railway track design can be taken as references.

2.2. Theoretical Basis

As for the theoretical basis, there are three guide books which is used, Design Criteria of the Rubber Tire APMS (2016), Track Design Handbook of Light Rail Transit (TCRP – RPT 57 & 155, 2012), and A book titled “Jalan Rel” that written by Suryo Hapsoro Tri Utomo in 2009.

2.3. Data Collection

There are some data that must be collected for the calculation specifically existing route line and track design, topography data, station position, construction figure, and train speed design. This data, only secondary data that will be used, can be achieved whether from Technical Data of the Rolling Stock or processed data.

2.4. Data Analysis and Discussion

This is purposed to identify and analysis the data that has been obtained from the previous steps using the theoretical basis and literature reviews. The data is divided into steps as mentioned in the following.

2.4.1. Determine The Route Lines And Track Design

Based on existing route line, technical data of the rolling stock, and topography data.

2.4.2. Calculate the total area that required for the implementation

Can be done by calculated in software applications, such as ArcGis 10.3 and AutoCad 2015, based on topography data, existing route line and track design.

2.4.3. Track Geometric Design

Can be done by comparing theories from Design Criteria of the Rubber Tire APMS and Track Design Handbook of Light Rail Transit (TCRP – RPT 57 & 155). After that, determined the curves by choosing the result that most likely can be applied to the project area due to topographical reason. The last step is to depict the curves, both for horizontal and vertical curves, based on a book titled “Jalan Rel” that written by Utomo, 2009.

2.4.4. Typical Structure

Based on the description of the structures that construct the track without analyzing the reaction forces within the structure itself. The data can be achieved from Indonesia

SHIA APMS Project.

3. RESULTS AND DISCUSSION

3.1. Existing Conditions

3.1.1. Existing Track Design

The existing track design for rubber tired APMS has a length of 3,050 kilometers with 4.32 meters width for single track and 8.64 meters width for double track. There are two route lines that applied throughout the existing design, given name as Centerline 1 and Centerline 2. Centerline 1, located in the inside of half-loop system configuration, contains six horizontal curves while centerline 2 has eight horizontal curves and located on the outer side. This track is designed to transport passengers or airport employees between Terminal 1, Depo maintenance, Integrated Building, Terminal 2 and Terminal 3, in a half-loop system configuration. The type of vehicle that will traverse the system is a rubber-tyred and driverless train equipped, with Automated People Mover System (APMS), operates in 2-car train formation.

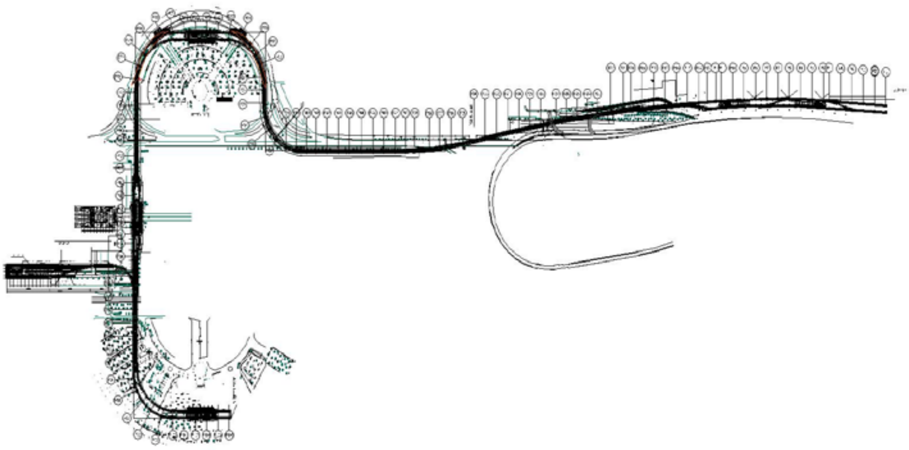


Figure 3 Existing Track Design
Source: Indonesia SHIA APMS Project, 2017

3.1.2. Land Use Condition

The condition of land use within the project area can be interpreted by using visual interpretation and delineating its interpretation by on-screen digitizing of every kind use of land. The digitizing process can be done in ArcGis application software. ArcGis also makes it possible to illustrate a road map in the project area. After that, the output of digitization shall be export to CAD files with the result that the data can be processed in AutoCAD. In addition, the use of Google Earth Pro is required to import the basic map. Has finished the process, the use of land in the project area differs between buildings owned by the airports owner, hotel, residential area, forest or plantation, lake, and highway.

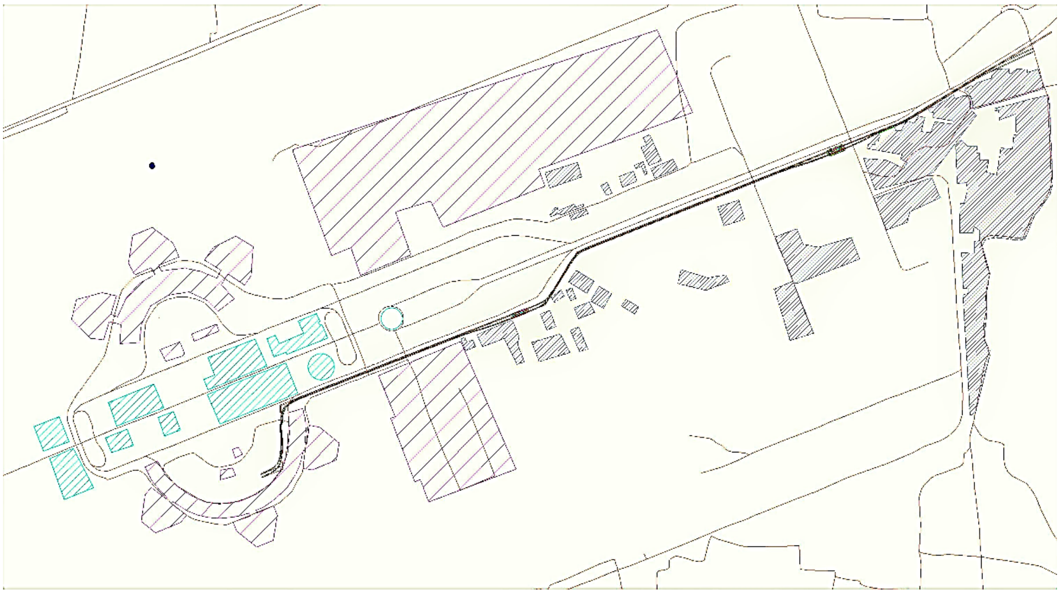


Figure 4 Land Use Map

3.1.3. Topographic Condition

Topographic conditions are used to determine the elevation plan of track design and represent contour lines which illustrated the steepness or gentleness of slopes. A contour map can be downloaded from USGS National Geologic Map Database followed with contour map overlay in AutoCad. The result in Figure 5 shows the difference of elevation around the design area that ranging from 15 meters to 3 meters.

The elevation of the contour line based on its color:

15 meters	7 meters
13 meters	5 meters
11 meters	3 meters

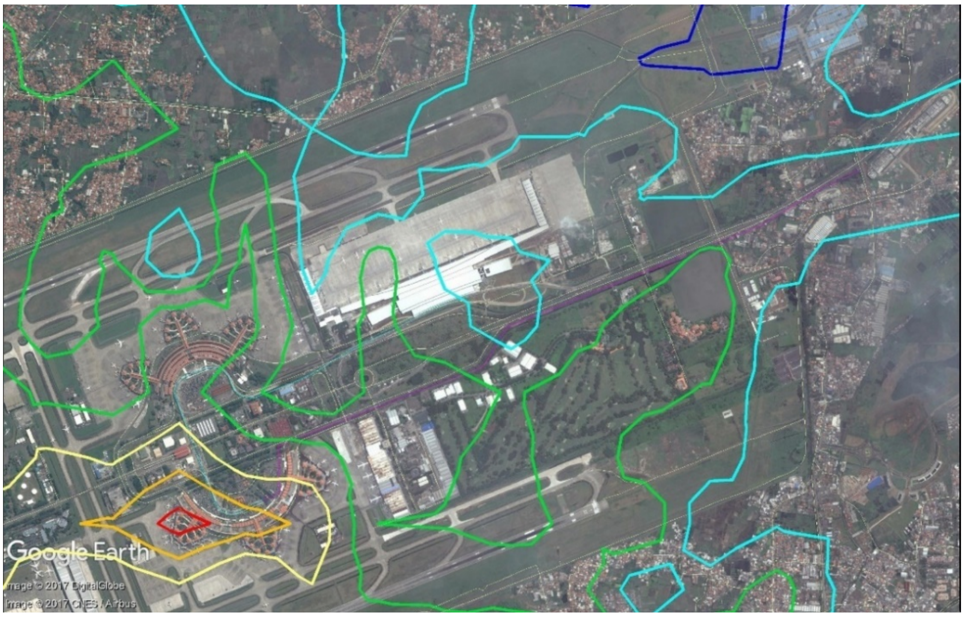


Figure 5 A Contour Map

3.2. Calculated the Area for the Implementation

Calculated the area for the implementation can be obtained by analyzing the data from the result of land use mapping along with a contour map in an attempt to prevent land use conflicts. In this final project, the use of AutoCad software is choosen to measure the area by using “hatch” command to specify the area needed for implementation. Total area to be counted is limited to the width of track aside from considering the clearance area. Finally, the area needed for track construction is 36.167 m^2 without passing through the buildings or residential area.

3.3. Geometric Design of Sky Train

3.3.1. Route Line Design Overview

The drawing of route line design is depicted by using AutoCad along with a basic map from Google Earth Pro and land use map from ArcGis. The line is designed with a length of 3.4 km and will travels through two shelters along its route, specifically a shelter in the cargo area and another one that located within hospitality area. Shelter in the cargo area is intended to accommodate the cargo employees so that they can easily transported within the airport area as well as outside the airport. Meanwhile, the other shelter which located in the hospitality area is expected to facilitate more passenger. In addition, these Shelters also close enough to the main street from the outside of airport area so that the passengers do not have to enter within the airport area. The design of route line will apply two route lines throughout the new design, given name as Centerline 1 and Centerline 2. Centerline 1, located in the inside of half-loop system configuration. Figure 6 illustrates the new route lines in purple line along with the existing design in blue.

Figure 6 Route Line Design Overview

3.3.2. Determination of Track Width

As stated in Technical Data of the Rolling Stock, the track consists of running road, guide wheels, vehicle clearance and emergency walk way. Two types of track are applied in this design, single track and double track, depending on the structure and geometric design. Based on the existing design, total track width for a single track is 4.32 meter and 8.64 meter for a double track. The ultimate reason for determination of the new track width, as it has the same size to the previous design, because the same vehicle is used so it has the same track gauge as well. Furthermore, the same size also facilitates the operating system and fixed facilities that house or physically supports the operating system equipment.

3.3.3. Alignment Stationing

Stations are reference points that are placed along the horizontal measurement of a route centerline. This stations is purposed to make it easier to determine the length of the route line and mark the important points on curves. In this design, there are two route lines that will be stationed, defined as Centerline 1 and Centerline 2. The distance between two adjoining stations along a route is 25 meter.

Table 1 Centerline 1 stations

No	Stationing								Length (m)	Description
	Start Point				End Point					
1	STA	3	+	896	STA	4	+	036	140	Straight Line
2	STA	4	+	036	STA	4	+	146	110	Curve 1
3	STA	4	+	146	STA	4	+	519	373	Straight Line
4	STA	4	+	519	STA	4	+	639	120	Curve 2
5	STA	4	+	639	STA	4	+	882	243	Straight Line
6	STA	4	+	882	STA	4	+	952	70	Shelter 1
7	STA	4	+	952	STA	6	+	138	1186	Straight Line
8	STA	6	+	138	STA	6	+	249	111	Curve 3
9	STA	6	+	249	STA	6	+	399	150	Straight Line
10	STA	6	+	399	STA	6	+	510	111	Curve 4
11	STA	6	+	510	STA	6	+	554	44	Straight Line
12	STA	6	+	554	STA	6	+	624	70	Shelter 2
13	STA	6	+	624	STA	7	+	665	1041	Straight Line
14	STA	7	+	665	STA	7	+	834	169	Curve 5
15	STA	7	+	834	STA	7	+	914	80	Straight Line
16	STA	7	+	914	STA	7	+	083	169	Curve 6
17	STA	8	+	083	STA	8	+	089	6	Straight Line

Table 2 Centerline 2 stations

No	Stationing								Length (m)	Description
	Start Point				End Point					
1	STA	3	+	896	STA	4	+	131	235	Straight Line
2	STA	4	+	131	STA	4	+	241	110	Curve 1
3	STA	4	+	241	STA	4	+	520	279	Straight Line
4	STA	4	+	520	STA	4	+	640	120	Curve 2
5	STA	4	+	640	STA	4	+	675	35	Straight Line
6	STA	4	+	675	STA	4	+	743	68	Curve 3
7	STA	4	+	743	STA	4	+	785	42	Straight Line
8	STA	4	+	785	STA	4	+	853	68	Curve 4

Table 2 Centerline 2 stations (Extention)

No	Stationing								Length (m)	Description
	Start Point				End Point					
9	STA	4	+	853	STA	4	+	879	26	Straight Line
10	STA	4	+	879	STA	4	+	949	70	Shelter 1
11	STA	4	+	949	STA	4	+	989	40	Straight Line
12	STA	4	+	989	STA	5	+	057	68	Curve 5
13	STA	5	+	057	STA	5	+	128	71	Straight Line
14	STA	5	+	128	STA	5	+	196	68	Curve 6
15	STA	5	+	196	STA	6	+	122	926	Straight Line
16	STA	6	+	122	STA	6	+	233	111	Curve 7
17	STA	6	+	233	STA	6	+	401	168	Straight Line
18	STA	6	+	401	STA	6	+	512	111	Curve 8
19	STA	6	+	512	STA	6	+	542	30	Straight Line
20	STA	6	+	542	STA	6	+	612	70	Shelter 2
21	STA	6	+	612	STA	6	+	680	68	Straight Line
22	STA	6	+	680	STA	6	+	748	68	Curve 9
23	STA	6	+	748	STA	6	+	817	69	Straight Line
24	STA	6	+	817	STA	6	+	885	68	Curve 10
25	STA	6	+	885	STA	7	+	641	756	Straight Line
26	STA	7	+	641	STA	7	+	810	169	Curve 11
27	STA	7	+	810	STA	7	+	901	91	Straight Line
28	STA	7	+	901	STA	7	+	070	169	Curve 12
29	STA	8	+	070	STA	8	+	075	5	Straight Line

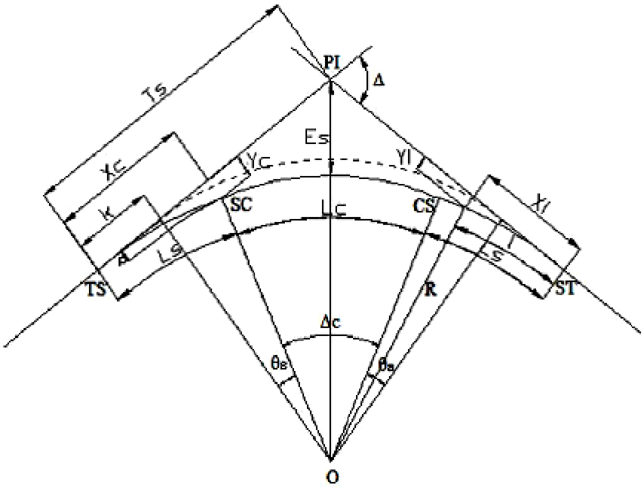
3.3.4. Horizontal Curve

According to the route lines design, Centerline 1 includes 6 horizontal curves while Centerline 2 includes 12 horizontal curves. The double amount of horizontal curves on Centerline 2 caused by the location of shelter and land use condition. Calculation on horizontal curves can be done by using some formulas that derived from Design Criteria of the Rubber Tire APMS (that currently used by Indonesia SHIA APMS project) and TCRP (as geometric design guidebook for Light Rail Transit).

Table 3 Horizontal Curve Calculation

No	Components of Horizontal Curve	APMS	TCRP
1	Speed in Design (Vr)	35 – 50 kph	65 – 90 kph
2	Curve Radius (R)	R ≥ 50 m	R ≥ 150 m
3	Superelevation (e)		$e = \frac{B\,V^2}{g\,R}$
4	Circular Curve Length (Lc)	Lc > 0,28 V Lc > vehicle length	Lc ≥ 0,57 V
5	Transition Curve Length (Ls)	$Ls \geq \frac{V^3}{14R}$	Ls = 0,38 Ea Ls = 0,008 Ea V
6	Straight Line between Curves (L_T)	L_T > 0,28 V L_T > vehicle length	L_T ≥ 0,57 V L_T ≥ vehicle length
7	Widening at Curve (W)	$W = \frac{10000}{R}$	

After that, depicted the curves by following the formulas from a book titled “Jalan Rel” that written by Utomo, 2009.



Curve and spiral formulas :

$$\theta s = \frac{Ls}{2 \times R}$$

$$\Delta c = \Delta - 2\,(\theta s)$$

$$Xc = Ls - \frac{Ls \times \theta s^2}{10}$$

$$Ys = \frac{Ls \times \theta s}{3}$$

$$k = Xc - R \sin \theta s$$

$$p = Ys - R\,(1 - \cos \theta s)$$

$$Es = (R + p) \sec \frac{\Delta}{2} - R$$

$$Ts = (R + p) \tan \frac{\Delta}{2} + k$$

$$Lc = \frac{\Delta c}{360^\circ} \times (2\,\pi\,R)$$

$$L_{total} = Lc + 2\,Ls$$

Figure 7 Horizontal Curve Depiction (Utomo, 2009)

The last step, determined the curves by choosing the result that most likely can be applied to the project area due to topographical reason. Results from Design Criteria of the Rubber Tire APMS and TCRP are presented in Table 4**.**

Table 4 Comparison of Design Criteria of the Rubber Tire APMS and TCRP based on Total Central Angle of Curve (Δ)

No	Components of Horizontal Curve	Symbol	Unit	Total Central Angle of Curve (Δ)									
				4°		7°		10°		37°		70°	
				APMS	TCRP	APMS	TCRP	APMS	TCRP	APMS	TCRP	APMS	TCRP
1	Speed in Design	Vr	km/h	40	40	40	40	40	40	40	40	40	40
2	Curve Radius	R	m	800	800	800	800	600	600	100	150	100	150
3	Cant	i	%	0,57	–	0,57	–	1,10	–	4,60	–	4,60	–
4	Superelevation	e	m	–	0,03	–	0,03	–	0,04	–	0,16	–	0,16
6	Transition Curve Length	Ls	m	6	12	6	12	8	15	46	60	46	60
7	Straight Line between Curves	L_T	m	23,8	23,8	23,8	23,8	23,8	23,8	23,8	23,8	23,8	23,8
8	Widening at Curve	W	mm	12,5	–	12,5	–	16,7	–	100,0	–	100,0	–
9	Central Angle of Spiral	θs	deg	0,21	0,43	0,21	0,43	0,38	0,72	13,18	11,46	13,18	11,46
10	Central Angle of Circular	Δc	deg	3,57	3,14	6,57	6,14	9,24	8,57	10,64	14,08	43,64	47,08
11	Tangent Distances from TS to PC	k	m	3,00	6,00	3,00	6,00	4,00	7,50	22,96	29,96	22,96	29,96
12	Offset from the Main Tangent to PC	p	m	0,00	0,01	0,00	0,01	0,00	0,02	0,89	1,01	0,89	1,01
13	Total External Distance of Spiralized Curve	Es	m	0,49	0,50	1,50	1,50	2,30	2,31	6,39	9,24	23,17	34,35
14	Total tangent distance from TS to PI	Ts	m	30,94	33,94	51,93	54,93	56,49	59,99	56,72	80,49	93,61	135,70
15	Circular Curve Length	Lc	m	49,83	43,83	91,69	85,69	96,67	89,67	18,57	36,85	76,13	123,20
17	Tangent Distance from TS to SC	Xc	m	6,00	12,00	6,00	12,00	8,00	15,00	45,20	59,21	45,20	59,21
18	Tangent Offset at SC	Ys	m	0,01	0,03	0,01	0,03	0,02	0,06	3,53	4,00	3,53	4,00
19	Total Curve Length	L_{TOTAL}	m	61,83	67,83	103,69	109,69	112,67	119,67	110,57	156,85	168,13	243,20

Based on the above table, the length of transition curve from TCRP design has a value two times greater than the length from APMS design, it means that total length of curve from TCRP also longer than the length from APMS design and passing the curve become more comfortable. Although more comfortable, a horizontal curve that produced by TCRP design can not be applied to restricted area due to its great amount of length curve.

3.3.5. Vertical Curve

Vertical curve is designed based on a topographic map that shows the elevation of the land using contour line. So, the first step to do is interpolate every 100 m on its route line as shown in the table below.

Table 5 Elevation Stations on the Existing Land

No	Station Point	Elevation (m)
1	STA 3 + 896	5.2
2	STA 3 + 996	5.3
3	STA 4 + 96	5.4
4	STA 4 + 196	5.5
5	STA 4 + 296	5.6
6	STA 4 + 396	5.7
7	STA 4 + 496	5.8
8	STA 4 + 596	6
9	STA 4 + 696	6.4
10	STA 4 + 796	6.7
11	STA 4 + 896	7

No	Station Point	Elevation (m)
12	STA 4 + 996	6.8
13	STA 5 + 96	6.6
14	STA 5 + 196	6.4
15	STA 5 + 296	6.2
16	STA 5 + 396	6
17	STA 5 + 496	5.8
18	STA 5 + 596	5.6
19	STA 5 + 696	5.4
20	STA 5 + 796	5.2
21	STA 5 + 896	5
22	STA 5 + 996	5

Table 5 Elevation Stations on the Existing Land (Extended)

No	Station Point	Elevation (m)
23	STA 6 + 96	5
24	STA 6 + 196	5
25	STA 6 + 296	5
26	STA 6 + 396	5.8
27	STA 6 + 496	6.4
28	STA 6 + 596	7
29	STA 6 + 696	7
30	STA 6 + 796	7
31	STA 6 + 896	7
32	STA 6 + 996	7
33	STA 7 + 96	7

No	Station Point	Elevation (m)
34	STA 7 + 196	7
35	STA 7 + 296	7
36	STA 7 + 396	7
37	STA 7 + 496	7
38	STA 7 + 596	7
39	STA 7 + 696	8
40	STA 7 + 796	9
41	STA 7 + 896	11
42	STA 7 + 996	11.8
43	STA 8 + 89	12.6

Table 5 shows that the elevation, from STA 3+896 to STA 7+596, is practically on flat ground with a height difference of 2 meters so the applied of vertical curve is not necessary. It takes only two vertical curves to overcome the height difference on STA 7+596 to 8+089. Moreover, elevated construction also contributes in determining the amount of vertical curve because when the gap between adjacent longitudinal slopes is small, then the pier height will be adjusted. In addition, the position of vertical curve shall not be applied within horizontal curve area. Calculation on vertical curves also can be done APMS (that currently used by Indonesia SHIA APMS project) and TCRP (as geometric design guidebook for Light Rail Transit). After that, depicted the curves by following the formulas from a book titled "Jalan Rel" that written by Utomo, 2009.

Table 6 Vertical Curve Calculation

No	Components of Vertical Curve	APMS	TCRP
1	Longitudinal Slope (g)	$g \leq 6\%$	$g \leq 6\%$
2	Curve Radius (R)	R ≥ 1000 m	
3	Length of Vertical Curve (l)	$l = R\left(\frac{g1}{1000} \pm \frac{g2}{1000}\right)$	$l = 0{,}01 \mid g1 - g2 \mid R$

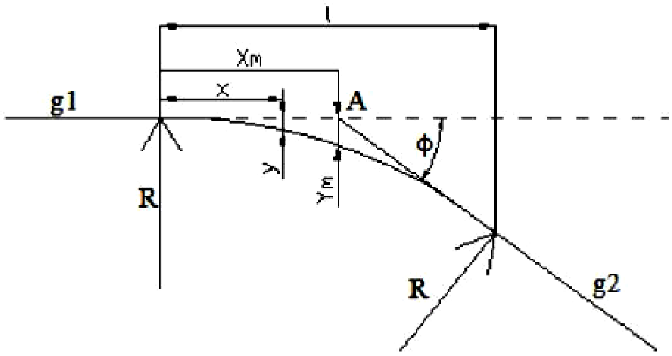


Figure 8 Vertical Curve Depiction
Source: Utomo, 2009

The calculation result of vertical curve is explained in the description below.

Table 7 Elevation Stations on the important points of Vertical Curves

No	Point	Station Point				Length (m)	Elevation (m)	
							Existing Road	Finishing Road
1	BVC	STA	7	+	307	10	7	15,54
2	PVI	STA	7	+	317	10	7	15,54
3	EVC	STA	7	+	327	253	7	15,72
4	BVC	STA	7	+	580	10	7	20,8
5	PVI	STA	7	+	590	10	7	21
6	EVC	STA	7	+	600		7	21

Vertical Curve from STA 7+307 to STA 7+327
Stationing BVC1=7+307 Elevation= 15,54 m
Stationing PVI1 = 7+317 Elevation = 15,54 m
Stationing EVC1= 7+327 Elevation = 15,74 m
Based on APMS,
R = 1000 m
φ = 2%
l = 20 m
y = 0,05 m
Based on TCRP,
l = 20 m

3.4. Typical Structure

The suitable structures of Sky Train track can be chosen by comparing the advantages and disadvantages of each type of structure component. The components of Sky Train structure are indicated below.

3.4.1. Pile Foundation

Basically, pile foundation is a long cylinder of a strong material such as concrete that is pushed into the ground to act as a steady support for structures built on top. This pile is generally designed to resist bending moment and axial tensile stress from the soil. The amount of pile foundation is determined by considering the soil types as well as its properties.

3.4.2. Pile Cap

Pile cap, also forms part of the foundation, is a very thick cap of concrete that extends over a small group of piles and serves as a base on which pier can be constructed. This thick concrete mat is then designed as a place for steel reinforcements that connect spun pile with pier. Afterward, the load of the pier is distributed to all the piles in the group. In conclusion, concrete pile cap is used for this construction.

3.4.3. Pier

Also known as beam or column, as Sub Structure which is driven into the ground to serve as the leg or support the upper structure and transfer the loads from superstructure to foundation below it.

3.4.4. Pier Head

Pier head or pier cap refers to the cap that sits on top of piers, providing additional support and dispersing the load to the piles below. This concrete pier head includes as Sub Structure.

3.4.5. Girder

The components that connects all the pier head. As a part of Superstructure, the term "girder" is typically used to support for the deck slab and responsible for transferring the load down to the foundation.

Actually, there are a lot of girder types that can be used for construction. In this section, there are four types of girder that will be explained down below based on its shape: Box Girder, T Beam, I Beam, and U Beam. The suitable types of girder that used in this design is Precast U Girder because this shape has two webs which makes it stronger than T or I Beam that only has one web. T or I Beam also easily lead to occurrence of buckling with vertical force in center. For box girder, the weight is high and most costly than the other types of girder that can be not economical**.**

3.4.6. Slab

A concrete slab includes as Superstructure which connects main track decking with the both sides of the girder. Horizontal slabs of steel reinforced concrete are used to construct driving road.

3.4.7. Parapet

Parapet is a barrier at the edge of deck slab as guard rails and to prevent the spread of fires. This parapet classified as "plain parapet" which is simply a basic, flat wall extension.

3.4.8. Driving Road

Defined as a running surface that physically guides APM vehicles to travel exclusively on it

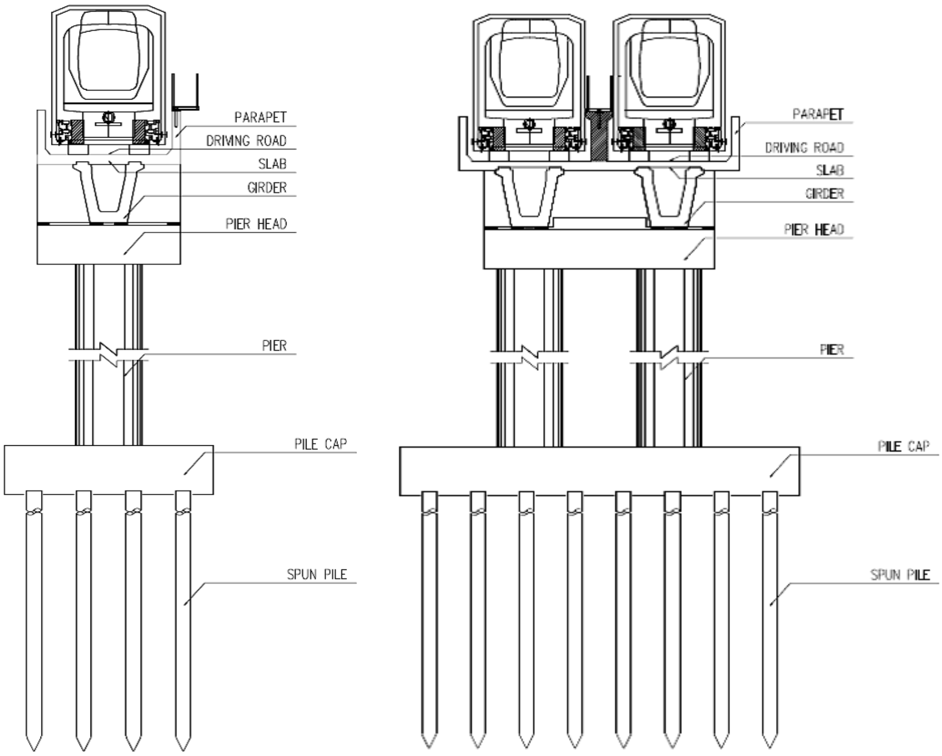


Figure 9. Typical Structure of Single and Double Track

4. CONCLUSION

Based on the results of this final project, it can be concluded that:

a) The optimum Sky Train route line can be determined based on two maps that can be achieved from the existing condition, a land use map to determine the route line design and a contour map to specify the vertical curve design. A new route lines is designed with a length of 3.4 km and will travels through two shelters along its route, specifically a shelter in the cargo area to accommodate the cargo employees and another one that located within hospitality area to facilitate more passenger. In addition, these Shelters also close enough to the main street so that the passengers do not have to enter the airport area with the result that the congestion within the airport area will be reduced.

b) Total area for the implementation can be obtained by analyzing a land use map along with a contour map, then use “hatch” command to specify the area. Total area to be counted is limited to the width of track aside from considering the clearance area. Finally, the area needed for track construction is 36,167 m^2 without passing through the buildings or residential area.

c) Based on the existing design, total track width for a single track is 4.32 meter and 8.64 meter for a double track. The reason for determination of the new track width, as it has the same size to the previous design, because the same vehicle is used so it has the same track gauge as well.

d) According to the route lines design, Centerline 1 which located in the inside of half-loop system configuration includes 6 horizontal curves while Centerline 2 includes 12 horizontal curves and located on the outer side. The double amount of horizontal curves on Centerline 2 caused by the location of shelter and land use condition.

e) According to the elevation stations on the existing land, from STA 3+896 to STA 7+596, is practically on flat ground with a height difference of 2 meters so the applied of vertical curve is not necessary. It takes only two vertical curves to overcome the height difference on STA 7+596 to 8+089.
f) The suitable structure components of the rubber tire APMS are spun pile, concrete pile cap, solid pier, concrete pier head, U girder, flat slab, parapet, and driving road.

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