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# Stanchion Re-design for Kuala Lumpur Additional Vehicle (KLAV) 27 Project based on SolidWorks Simulation

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**Abstract**: Kuala Lumpur Additional Vehicle (KLAV) 27 Project is a project of the Alstom-Hartasuma Consortium (AHC) to supply new Light Rail Transit (LRT) for the Kelana Jaya LRT Line. Each KLAV 27 fleet is equipped with stanchions for passengers to grip and prevent their falling during train motion. However, the problem of the existing stanchion arises during the Kelana Jaya LRT Line collision on 24 May 2021. Many passengers are injured after being hit to the interior equipment including stanchion. Therefore, the objective of this research is to identify the design specifications of the existing stanchion and develops a suitable stanchion that complies with passenger capacity and load specification from Original Equipment Manufacturer (OEM) for KLAV 27 Project. This research also analyses the performance of the new stanchion design. The method for data collection is by doing a literature review, reverse engineering on existing stanchion and survey. The SolidWorks software is used for this project for designing, analyzing and simulating the new stanchion design. The result of this research is proposing a new stanchion design by replacing the existing vertical triple stanchion with a triple horizontal stanchion and adding a horizontal stanchion above the door area. From the result, the new stanchion design has adhered to the load specification of the Original Equipment Manufacturer (OEM) for the KLAV 27 Project and improved the percentage of passengers holding the stanchion by 7.14%. This research is necessary for reference for railway industry players for designing a better stanchion design.

**Keywords**: Kuala Lumpur Additional Vehicle (KLAV) 27, Stanchion, Redesign, SolidWorks, Original Equipment Manufacturer (OEM), Kelana Jaya LRT Line

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## 1. Introduction

The Kuala Lumpur Additional Vehicle 27 (KLAV 27) Project is an ongoing project under Alstom-Hartasuma Consortium (AHC) as a main contractor to supply 27 new Light Rapid Transit (LRT) trains set for Kelana Jaya LRT Line [6]. The owner of this project is Prasarana Malaysia Berhad as a public transport company. Each KLAV 27 fleet is equipped with stanchions, handrails and grab handles in compliance with technical specifications to provide physical interfaces for passengers to grip and prevent their falling during train motion. There are vertical triple stanchions located in the middle of the passenger compartment. The problem with these existing stanchions design arise during the Kelana Jaya LRT Line collision on 24 May 2021. Many passengers were injured and serious injuries were caused by being hit by the equipment onboard the train [1].

Prasarana Malaysia Berhad requests AHC to examine the existing stanchion design following that collision by re-design, removing that existing stanchion and installing the new stanchion for the KLAV 27 fleet following the train collision [2]. This research is important to improve on-board safety measures especially the current interior design specifically in the stanchion of all Kelana Jaya LRT Line’s fleet. This study is conducted by solving the problem of the existing stanchion in the KLAV 27 fleet to remove any possible hazard and obstacle inside the Kelana Jaya LRT Line. This study also redesigns a suitable stanchion for the passenger that does not obstruct the passage of passengers inside the Kelana Jaya LRT Line.

The scope of this research is to study the information related to existing stanchion based on Kelana Jaya LRT Line collision case that happen on 24 May 2021. The existing stanchions near the door and around the existing stanchion area onboard the KLAV 27 fleet have been given attention in this research to define the problems. The technical specification from Alstom, which is the Original Equipment Manufacturer (OEM) for the KLAV 27 Project is analysed in terms of passenger capacity and load specification before the redesign process. This research improves the stanchion design by redesigning and proposing the new stanchions design in the research area and simulating the new design of the stanchion by using SolidWorks software to ensure it complies with passenger capacity and load specification from OEM. This research is important to redesign the stanchion design as requested by the Prasarana Malaysia Berhad

### 1.1 Kelana Jaya LRT Line Train Collision on 24 May 2021

The collision of two LRT trains on the Kelana Jaya LRT Line involved a 4-car Bombardier ART 200 train, numbered TR40 and a 4-car Bombardier Innovia Metro 300 train which is KLAV 14 model, numbered TR81, which happened between the KLCC LRT station and Kampung Baru LRT station [7]. During the Kelana Jaya LRT Line collision, the total passenger onboard TR81 is 213 passengers to Gombak. The condition of the passenger capacity is under the AW2 or light capacity situation. Therefore, some passenger was seated and standing during the collision. After two LRT trains collided, more than 210 individuals were injured, with 47 of those victims suffering critical injuries [5]. Many people, both seated and standing, were hurt as a result of the incident, including the passenger of TR81 who was ejected and fell to the ground. Some passengers were hurt when the train's glass panels cracked, while others were hurt when it abruptly halted [1]. There were passengers who suffered serious injuries as a result of being thrown into the existing vertical triple stanchion during this collision.

## 2. Materials and Methods

The methodology consists of designing and simulating the new stanchion design by using SolidWorks software. The passenger capacity and load specification are studied and calculated before redesigning the existing stanchion.

## 2.1 Stanchion Design and Specification in KLAV 27 Fleet

The interior of the KLAV 27 fleet shall be equipped with sufficient horizontal and vertical stanchions made from brushed stainless-steel tubing. The function of the stanchions provided onboard the train is to provide a physical interface for passengers to grip and prevent their slips/falls during train motion [4]. The structure of the existing stanchions was studied inside the research area. Figure 1 shows the research area onboard KLAV 27 fleet. Below is the design of the existing stanchion in the KLAV 27 fleet:

i. There shall be three vertical triple stanchions, located along the centerline of each car, one aligned with the center of each door opening. The height of this stanchion is 2100mm. The diameter of the tube is 25.8mm inner diameter and 31.8mm outer diameter [3].
ii. There is a vertical curved stanchion that is incorporated into each windscreen assembly. It is located at the end of the seat assembly. There are four units in the research area. The height and diameter of this stanchion are the same as the vertical triple stanchion [3].
iii. Additional handrails shall be located within the designated wheelchair location, beside doorways and along the equipment [3].
iv. There shall be two horizontal stanchions, secured to the ceiling approximately 450 mm on either side of the train centerline and running for the length of the car interior [3].
v. There are four units of side stanchion in a research area. It is located on both sides of the doorway. The height of this stanchion is 968.2mm and its diameter is the same with vertical stanchion [3].

**Figure 1: The location of the research area**

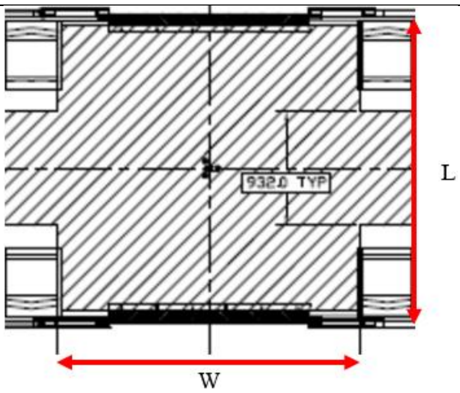
## 2.2 Passenger Capacity

According to the KLAV Interior and Exterior Final Design Review document, when normally loaded to an AW3 capacity, there shall be sufficient handholds for all passengers [3]. Based on Table 1, the passenger capacity in AW3 capacity is 6 $passengers/m^2$. The passenger capacity in the research area is calculated based on AW3 capacity to ensure all the passengers can handhold the new stanchion design. Table 2 shows the sizing and passenger capacity calculation in the research area.Table 1: Passenger capacity onboard KLAV 27 fleet

**Table 1: Passenger capacity onboard KLAV 27 fleet**

| Symbol | Passenger per car | | | | Passenger per train |
|---|---|---|---|---|---|
| | H/K car | | J1/J2 car | | |
| | Seated | Standing | Seated | Standing | |
| AW1 (seated) | 31 | - | 29 | - | 120 |
| AW2 (light) | 31 | 107 ($4p/m^2$) | 29 | 114 ($4p/m^2$) | 562 |
| AW3 (service) | 31 | 161 ($6p/m^2$) | 29 | 171 ($6p/m^2$) | 784 |
| AW4 (crush load) | 31 | 214 ($8p/m^2$) | 29 | 228 ($8p/m^2$) | 1004 |

**Table 2: The sizing and passenger capacity calculation in the research area**

| Size of the research area | Passenger capacity calculation |
|---|---|
| <br>Area of the research area, $A$:<br>$A = L \times W$<br>$= 2.445m \times 2.2998m$<br>$= 5.623m^2$ | The passenger capacity per meter square under AW3 is 6 $passengers/m^2$.<br>The total passenger capacity, $PC$:<br>$PC = AW3 \times A$<br>$= 6\ passengers/m^2 \times 5.623m^2$<br>$= 33.738\ passengers$<br>$\approx \mathbf{33\ to\ 34\ passengers}$ |



2.3 Load Specification

According to the KLAV Stanchion Load Qualification Test Procedure document, the objective of the load test is to demonstrate that the performance criteria of the stanchion will be present on the Kuala Lumpur Additional Vehicle (KLAV) fleet can meet the requirements of the system specification. Each stanchion should be withstanding a horizontal load of 1400N in any direction [4].2.4 Passenger Capacity Survey for Kelana Jaya LRT Line

The data on the passenger capacity is obtained by doing the passenger capacity survey to determine the passenger capacity in the research area during peak hours onboard Kelana Jaya LRT Line. The method of carrying out this survey is by counting the number of standing passengers and the number of standing passengers who use the stanchion in the research area. The result of the passenger capacity survey is the maximum capacity of the passengers in the research area is 33 passengers. It is proved that the theoretical passenger capacity calculated in Table 2 is the same as the passenger capacity in the real situation. The passengers that use the stanchion during train motion is 26 passengers. From this survey, there are 7 passengers not using the stanchions. One of the factors that the passenger not using the stanchions because the KLAV fleet did not provide horizontal stanchions above the door area. The maximum passenger capacity that uses vertical triple stanchion is 7 passengers. Table 3 shows the maximum capacity of passenger for each category.

**Table 3: Maximum capacity of passengers for each category**

| No. | Category | Number of passengers |
|---|---|---|
| 1 | Passengers in study area | 33 |
| 2 | Passengers that use the stanchion | 26 |
| 3 | Passengers that use vertical triple stanchion | 7 |
| 4 | Passengers do not use stanchion | 7 |

2.5 Proposal of the New Stanchion Design

Based on the result of the passenger capacity survey as shown in Table 3, the new stanchion design should handhold at least 30 passengers. The finding from the passenger capacity survey, there are patterns in the position of the standing passengers inside the research area. Figure 2 show the position pattern of the standing passenger inside the research area. Based on Figure 2, a yellow box represents a standing passenger inside the research area.

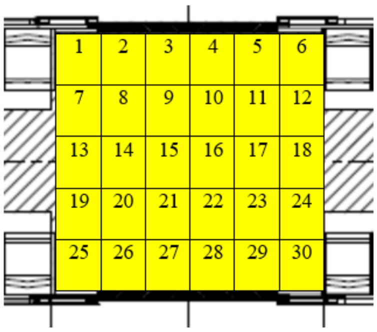



**Figure 2: The position of the standing passenger pattern inside research area**

The new stanchion design should not have the existing vertical triple stanchion in the middle of the research area. The vertical triple stanchion is replaced with the horizontal stanchion. Based on the position of the standing passenger's pattern as shown in Figure 2, the new stanchion design should have 5 lines of horizontal stanchions with 6 handgrips each line that can handhold 30 standing passengers inside the research area. Figure 3 show the sketch of the new stanchion design from the plan view.

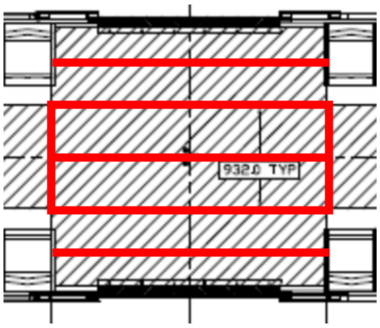



**Figure 3: The proposal of the new stanchion design from the plan view**

2.2 Method of Design and Simulation of New Stanchion Design

For this project, the SolidWorks software is used for designing the new design of stanchion. The process begins with sketching the concept design of each part on paper to facilitate the design process. This concept design is then transferred to a 2D Solid Works environment for proper dimension and scale. This 2D design is then converted to a 3D part in a 3D environment for real-world visualization. Each part is designed separately for a product with multiple parts and then assembled in SolidWorks assembly. Figure 4 shows the flowchart of the design process stage. In this project, there are two type of stanchion was created, which is triple horizontal stanchion and horizontal stanchion above door area.

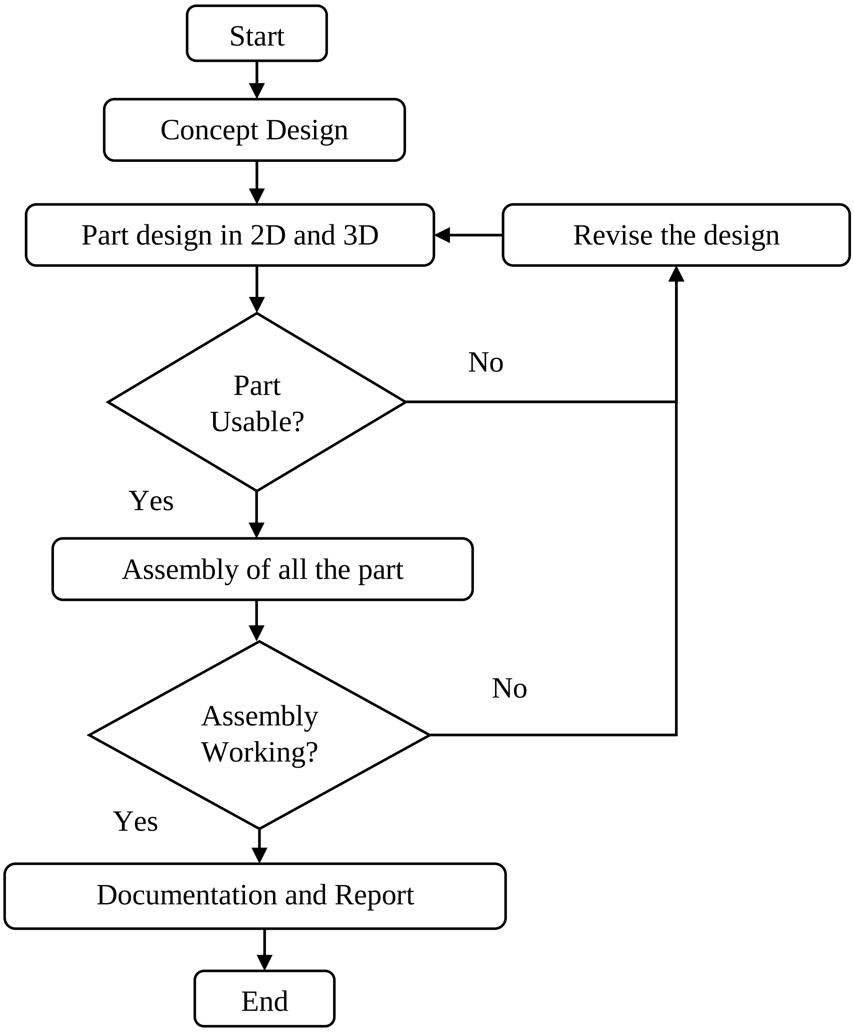



**Figure 4: Flowchart of design stage**

This software can also simulate the product as a structural analysis tool by using FEA and predicting a product's real-world physical behavior by virtually testing CAD models. The force is applied to the new stanchions to test whether the component follows the specification. There are several types of reaction force that can be applied to the product which are resultant force, torque, bending force, pressure, centrifugal force and bearing load. The result of this simulation can be stress, factor of safety (FoS) and displacement of the reaction force on the new stanchions. For this research, the triple horizontal stanchion and horizontal stanchion above the door area were simulated and the simulation was based on the static test.

## 3. Results and Discussion

The result of the new stanchion design will be discussed in this chapter in terms of the passenger capacity and load specification. The design of the existing stanchion and the new design will be compared to analyse the passenger capacity. This chapter also shows the simulation result of the new stanchion design to prove that this stanchion is follow the load specification from OEM for the KLAV 27 Project.

### 3.1 New Stanchion Design

There are some improvements in designing the new stanchions by replacing the vertical triple stanchion with a triple horizontal stanchion and adding a horizontal stanchion above the door area.

#### 3.1.1 Triple Horizontal Stanchion

Figure 5 shows the design of the triple horizontal stanchions that replace the vertical triple stanchions in the KLAV 27 fleet. Each horizontal stanchion in this new design will provide 6 handgrips that can handhold 6 standing passengers per horizontal stanchion. In total, this new design is capable of handhold 18 passengers. The existing vertical triple stanchion is removed from the new design due to the safety of the standing passenger onboard the train. During the Kelana Jaya LRT Line collision case on 24 May 2021, the vertical triple stanchions is one of the stanchions that the standing passengers fall on it during the collision. To eliminate this risk, the existing vertical triple stanchion is removed from the new stanchion design and replaced with the triple horizontal stanchion. Based on the new stanchion design in Table 4, there are no vertical stanchions in the middle of the research area. The risk of the passenger hitting on the stanchion in the middle of the standing area can be avoided.

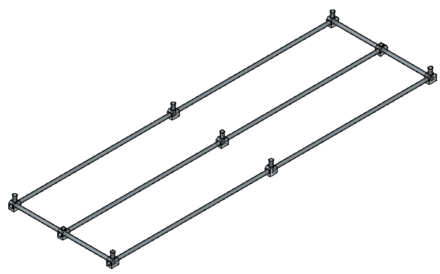


**Figure 5: The Triple Horizontal Stanchion design**

#### 3.2.2 Horizontal Stanchion above the Door Area

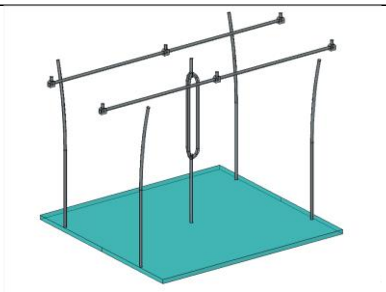
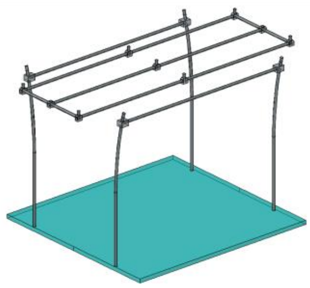
Figure 6 shows the new horizontal stanchion located above the door area. This is the additional stanchion component in the KLAV fleet to improve the safety of the standing passengers, especially at the door area. The horizontal stanchion in this new design will provide 6 handgrips that can handhold 6 standing passengers. This new stanchion will be placed above both door areas. In total, this stanchion can handhold 12 passengers. The finding from passenger capacity survey found that there were some passengers who did not hold any existing stanchion during peak hours, especially at the door area. This gives the risk of falling to the standing passengers because they have the highest degree of freedom when train movement and braking. To solve this problem, the new stanchion design will provide a horizontal stanchion above the door area so that the standing passengers near the door area can handhold that stanchion.

**Figure 6: Horizontal Stanchion above the door**

3.4 The Different between Existing and New Stanchion Design

Based on Table 4, the number of passengers in the research area remains because the size of the research area remains the same, which is 33 passengers in the AW3 passenger capacity. The existing stanchion is capable of handhold 26 passengers. That means 7 passengers not using the stanchion inside the research area. The new stanchion design is capable of handhold 30 passengers after totaling the passenger capacity of the triple horizontal stanchion and horizontal stanchion above the door area. In comparison with the number of passengers using the existing stanchion, there is an improvement of 7.14% in passenger capacity using the new stanchion design. The 7 passengers that used the existing vertical triple stanchion as shown in Table 3 can use the horizontal triple stanchion in the new stanchion design.

**Table 4: The difference between the existing and new designs of stanchions**

| Item | Existing Stanchions | New Stanchions |
|---|---|---|
| Stanchion design |  |  |
| Number of passengers in the research area | 33 | 33 |
| Number of passengers using the stanchion | 26 | 30 |

3.5 Simulation Result of the New Stanchion Design

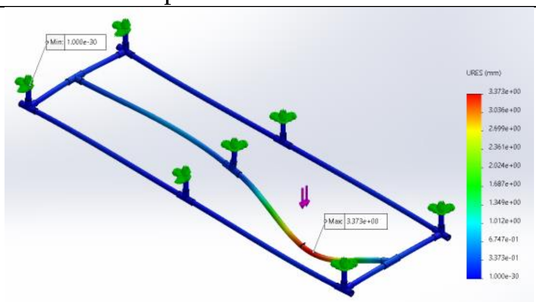
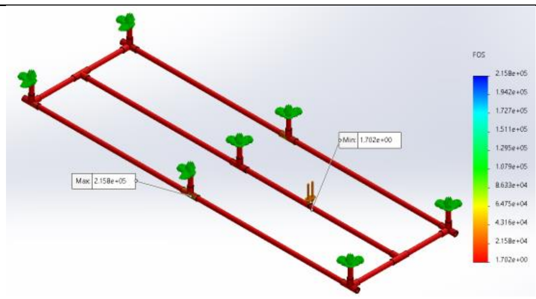
The purpose to simulate this new design of the stanchion is to ensure the new design of the stanchion follows the technical specification from Alstom, which is the Original Equipment Manufacturer (OEM) for the KLAV 27 Project. According to the KLAV Vehicle Interior and Exterior Final Design Review document, the stanchion needs to withstand 1400N [3]. For this project, the new design of the stanchion is simulated to ensure that the stanchion can withstand 1400N of force. There are two categories of the simulation result for this project which are displacement and Factor of Safety (FoS).

The purpose is to analyse the displacement to determine the deflection of the new stanchion when the force is applied to it. The FoS is the parameter to determine the safety and reliability of the structure that represents the structure's strength to the expected maximum applied load. If the value of the FoS is below 1, it means that the whole structure is not stable and dangerous. The higher FoS value indicates a higher level of safety that has a significant safety margin beyond the expected loads. For this project, if the value of FoS is above 1 it means that the new design of the stanchion is capable to withstand 1400N of force and the new design of the stanchion is follow the technical specification by the OEM, Alstom.

3.5.1 Triple Horizontal Stanchion

Based on Table 5, the maximum deflection is 3.373mm which occurs at the applied force area and the minimum FoS value is 1.702. The deflection while force is applied on the stanchion is acceptable and the minimum value of FoS is above 1. The conclusion of the triple horizontal stanchion analysis is this new design of stanchion is capable to withstand 1400N of force and follow the technical specification by the OEM, which is Alstom.

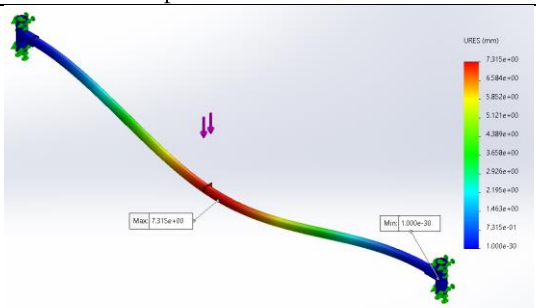
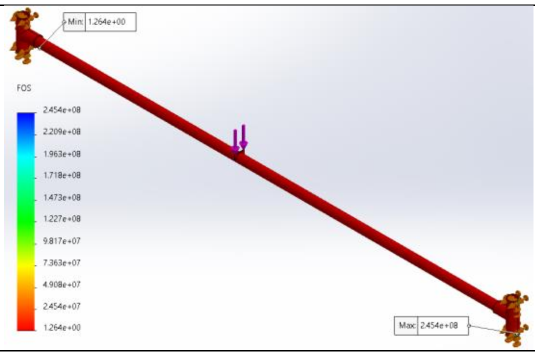
**Table 5: Simulation result for triple horizontal stanchion**

| Displacement simulation | Fos Simulation |
|---|---|
|  |  |
| 3.373mm | 1.702 |
| Acceptable | Passing |

3.5.1 Horizontal Stanchion above Door Area

Based on Table 6, the maximum deflection is 7.315mm which occurs at the applied force area and the minimum FoS value is 1.264. The deflection while force is applied on the stanchion is acceptable and the minimum value of FoS is above 1. The conclusion of the triple horizontal stanchion analysis is this new design of stanchion is capable to withstand 1400N of force and follow the technical specification by the OEM, which is Alstom.

**Table 6: Simulation result for triple horizontal stanchion**

| Displacement simulation | Fos Simulation |
|---|---|
|  |  |
| 7.315mm | 1.264 |
| Acceptable | Passing |

## 4. Conclusion

The first objective was to identify the design specification of the existing stanchion. From this objective, the existing stanchion located near the door area was analysed in terms of design structure, passenger capacity and load specification before the redesign process. There are four types of existing stanchions in the research area which are vertical curved stanchions, vertical triple stanchions, side stanchions and horizontal stanchions. The passenger capacity in the research area is 33 passengers and the passenger using the existing stanchion is 26 passengers under AW3 capacity. The stanchion should be withstanding a load of 1400N from any direction. The finding from this study also found that the existing vertical triple stanchion located in the middle of the standing passenger area has a risk to the passenger, especially during the LRT Kelana Jaya collision case that happened on 24 May 2021.

The second objective was to develop a new design of stanchions that complies with passenger capacity and load specification by redesigning the existing stanchions. This project was developing the stanchion design by redesigning the existing stanchions in the research area using SolidWorks as a design and simulation software. The new stanchion design follows the technical specification from Alstom, which is the Original Equipment Manufacturer (OEM) for KLAV 27 Project. There are two changes in the new stanchion design, which are triple horizontal stanchion and horizontal stanchion above the door area. The existing vertical triple stanchion was replaced by the triple horizontal stanchion to eliminate the risk to passengers and a horizontal stanchion above the door area is added to ensure all the passengers in the research area can handhold the stanchion.

The final objective was to analyse the new stanchion design performance that enables obtaining the design specification. Based on the finding in Chapter 3, the triple horizontal stanchion and horizontal stanchion above the door can handhold 18 passengers and 12 passengers respectively. Therefore in total, the new stanchion design can handhold 30 passengers. The percentage of passengers using the stanchion has increased to 7.14% and the new stanchion design can handhold more passengers than the existing stanchion design. Based on simulation data in Chapter 3, the new stanchion design follows the load specification from OEM because its capable to withstand the load of 1400N as mentioned in the KLAV Vehicle Interior and Exterior Final Design Review document.

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