Initial Analysis of the Black Nazarene Procession in Manila City

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Abstract: The Philippines is a highly Christianized country where religious events are often celebrated on a highly massive scale. One of these is the acclaimed Black Nazarene Procession, which is a dynamic religious gathering that attracts a high volume of devotees that generate extreme crowd densities making injuries and fatalities almost inevitable. Despite the rising threat to pedestrian health and safety, limited studies have been conducted to evaluate the pedestrian dynamics with similar nature to the event. Through providing a more systematic evaluation of the pedestrian dynamics in terms of density and speed during the event, the study aims to develop methods and policies which can be used to improve the risk management planning of the Black Nazarene Procession. With the obtained video graphic survey, a static grid analysis was utilized to characterize the actual pedestrian dynamics during the event. It was determined that the density, aggressiveness and group formation of the pedestrians highly influence the dynamics of the procession. In analyzing the density of the pedestrian surrounding the image of the Black Nazarene, the researchers were able to generate an equation that can systematically estimate the total number of participants during the procession. In addition, by evaluating the density behind the image, it was quantified that 68 to 70 pedestrians are needed to push the image to have a smoother traverse procession movement. Furthermore, the duration of the procession on each segment was quantified through time ratios. With the gathered data from varying segments, it was observed that each segment produced varying densities, time ratios and aggressiveness of the pedestrians. Consequently, these data were used to properly allocate human resources of the local government departments during the procession.

Keywords: Mass Gathering, Pedestrian Safety, Pedestrian Flow Model, Dynamic Movement, Macroscopic Analysis, Pedestrian Dynamics, Religious Gathering

1. INTRODUCTION

The increasing rate of urbanization has caused a massive increase in population densities to larger cities that generate large-scale economies. As of 2016, it is estimated that around 54.5% of the world's population have been living on urban settlement (United Nations Department of Economic and Social Affairs, 2016). The continuous attraction of people to big and wealthy cities can be attributed to why these places have increasingly become venues of frequent largescale mass gatherings. Typically, these events include religious processions, festivals, sporting events, concerts, political rallies, and the like (Gayathri, Aparna, & Verna, 2017). Among these gatherings, religious processions are the most prominent and the largest. In 2015, six million people attended the outdoor mass Pope Francis celebrated during his papal visit in the Philippines.

In 2013, the Kumbh Mela Pilgrimage held in the Northern Indian state of Uttar Pradesh have gathered an estimated 30 million pilgrims who together took bathe during the festival. This is considered as both the largest religious gathering of all time and the largest mass gathering in human history ever (Philipson, 2015). McFarlane (2018) reports that religious mass gatherings continuously gains urgent attention due to the rampant increase in mortality and injury cases due to stampedes and other health hazards. During the Ram Janki temple stampede in 2018, 63 people died, while 115 people lost their lives in the Ratangarh temple tragedy in 2013. One of the main causes of the high accident and death rates was evaluated to the poor quality of crowd management.

Figure 1.1. The pilgrims during the Kumbh Mela Festival which happens once in every 12 years (Swarup, 2013)

In the world, Philippines is the third-largest Catholic population, corresponding to 75 million Catholics in the country (Barooah, 2017). In addition, according to Cheney (2005), the Philippines is the only Asian country where 81.03% of the population is Catholic. Filipino Catholics have a unique way of worshipping, where they are known for sincere, enormous and extreme expressions of piety (France-Presse, 2017). Last January 5, 1995, Pope John Paul II's Sunday Mass in the country led to one of the biggest and most memorable religious gathering in history with an estimated four million attendees (Medina & Antonio, 2017).

Figure 1.2. Pope Francis' Papal Visit in the Philippines held in Quirino Grandstand (Bondoc, 2015)

One of the devotional events that Filipinos celebrate yearly is the Peñafrancia festival in Naga city, Bicol. For more than three hundred years, devotees and pilgrims have attended the religious rites of the festival. The Peñafrancia festival links two festivities. The pairing includes the celebration of the Divino Rostro or the Divine Face, usually held in the second week of September and Our Lady of Peñafrancia, celebrated the following weekend in which thousands of Filipino Catholics converge to pay honor to the Bicol's patroness, who is endearingly attributed as "Ina" or Mother by the locals (Fortunado, Fortunado-Sanchez, &

Landy, 2019). The celebration of the Divino Restro is an act to pay homage to the image of Jesus Christ. According to Malabonga (2018), people's devotion may have started in 1882 when a sudden outspread of an epidemic known as cholera in Manila reached Naga city. The locals claimed that the epidemic vanished on the day when the image of Divino Resto was placed at the altar of the town's cathedral. On the other hand, a nine-day prayer or "novena" is dedicated to Our Lady of Peñafrancia. The first day of the novena is committed to traslacion in which a land procession transfers the image to Naga Cathedral. On the ninth day of the novena, the images of Our Lady of Peñafrancia and Divino Rostro are returned to Basilica Minore in a fluvial procession along Naga river where the images are boarded on a boat with Catholic clergies (Malabonga, 2018).

Figure 1.3. Fiesta for Our Lady of Peñafrancia held in Naga city (Falcon, 2014)

Aside from this, every January the feast of the Santo Nino referred as the Holy Child is celebrated in Cebu city wherein devotees from different parts of the country gather (Hermoso & Mosqueda Jr., 2017). It is considered as the most recognizable religious image in our country because it is the oldest one in the archipelago dating back to 1521, when Ferdinand Magellan brought it with him in his monumental journey in Cebu. He offered this image of the Child Jesus, the Santo Nino as baptismal gift to the wife of Cebu's Rajah Humabon, Hara Amihan who was later named Queen Juana (Lizares, 2016). Currently, it is believed to be source of numerous miracles and devotees gather every year to honor the said image. In the recent festival that was held on January 19, 2019, Senior Supt. Royina Garma reported that at least 1.5 million devotees joined the foot procession (Mayol, Talisic, Modragon, & Erram, 2019).

Figure 1.4. Devotees during the 2019 fiesta of Senor (Despojo, 2019)

Out of all the well-known religious gatherings around the world, according to Nivedya (2018), the annual procession of the Black Nazarene ranked top eight. In the recent statistics, 4 million devotees attended the last procession that was held on January 09, 2018 (Ballaran, 2018). However, according to Talabong (2018), over six million devotees attended the last procession. Moreover, based on the assumption of Lagrimas (2018), only 1.4 million devotees attended the procession. Hence, it can be observed that there is a significant difference between the estimated attendees per report. As such, this justifies the need of study in the aforementioned event.

Figure 1.5. The density of the crowd during the 2018 Traslacion (Marquez, 2017)

The procession of the Black Nazarene is a Filipino Catholic tradition that portrays the crucifixion of Jesus Christ with a life-sized statue of suffering Jesus fallen under the weight of the cross (College of the Holy Cross, 2018). For more than 200 years, the church has been celebrating the feast, placing the statue on a gilded carriage every January (Alba, 2009). The Black Nazarene statue is brought out of the church for public adoration, in which it is carried along a 6.5 km route from Rizal (Luneta) Park to the minor basilica of Quiapo as penance and as imitation of Jesus on His way to Golgotha. On New Year’s Day, it is brought out to begin a novena that leads up to the procession on January 9.

Filipino Catholics consider the statue to be miraculous, having the understanding that the statue can heal diseases (Nivedya, 2018). Millions of devotees line up at the Quirino Grandstand in Rizal Park for an opportunity to touch and kiss the cross or the foot of the Black Nazarene. The route of the parade is isolated from the surrounding road networks to prepare for the voluminous crowds that are seemingly unmatched by other religious events in the country. The feast attracts extensive crowds to see and touch the statue resulting to a procession that takes 18 to 22 hours, and sometimes even longer (College of the Holy Cross, 2018). In the last 20 years, attendance has grown remarkably, and the route has stretched to satisfy the growing number of attendees. From the data gathered by Supt. Lucile Faycho, of the Manila Police district, the estimates of the attendees increase yearly. Further, according to Orellana (2018), officials of the Quiapo church are expecting a 5% increase in total number of devotees during the 2019 celebration, that will be held from December 31 to January 9. Previous statistics have reported four million devotees attended the last procession that was held on January 9, 2018 (Ballaran, 2018). However, according to Talabong (2018), over six million devotees attended the last procession. Moreover, based on the assumption of Lagrimas (2018), only 1.4 million devotees attended the procession. Additionally, recent numbers for Traslacion 2019 have reported varying number of participants from 1.35 million (Malig, 2019) to a value of four (Cabico, 2019) and five million (Remitio, 2019). Hence, it can be observed that there is a significant difference between the estimated attendees per report. As such, this justifies the need of study in the aforementioned event.

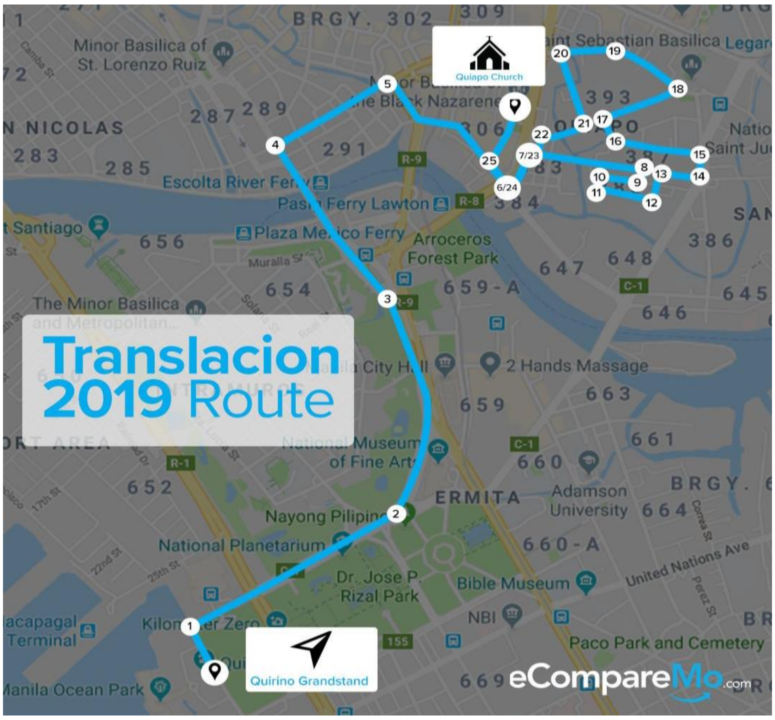


Figure 1.6. The 2019 Traslacion route through which the Black Nazarene image was paraded (Mangali, 2019)

Despite the numerous social, economic, and cultural importance of such events, mass gatherings like that of the Black Nazarene Procession, also come with inevitable negative outcomes. High crowd density also denotes to increase in crime, incidence of injury and illness, and elevated transmission of contagious diseases amongst larger population in a shorter while (Bettencourt, Lobo, Helbing, Kuhnert, & West, 2007). As a matter of fact, during the 2018 procession, the Manila Police have increased the number of policemen to be deployed during the said event from 5,000 the past year, to 6,500 (Remitio, 2018). In 2017, the Philippine Red Cross have reported that at least 1,339 devotees were given medical attention due to sustained injuries, seven of which were considered major injuries (Colcol, 2017).

In line with the growing number of Catholic devotees that yearly attend the procession and the lack of study about their characteristics, the researchers seek to analyze the movement of the devotees. Furthermore, the movement of pedestrians will be analyzed in a macroscale level; thus, information about the devotees' speed, density, and characteristics of movement will be evaluated and recorded as a collective unit. The data that will be gathered in this study will provide significant information that can be utilized for future studies about mass gatherings in the Philippines.

1.1. Significance of the Study

There are studies (Gayathri et al., 2017; Johansson et al., 2012) investigating the crowd dynamics in mass gatherings with respect to crowd safety in other countries. It is common in recent studies that the mass gatherings have a specific location where the crowds gather. However, none have tackled the high pedestrian density situation of the procession of the Black Nazarene where the pedestrians continuously move along a designated route.

This study deals with a high-density crowd moving along a designated route. During the Black Nazarene procession, the crowd densities reach extremes. Consequently, this highly celebrated gathering attracts severe health and safety risks due to abnormal behavior of pedestrians, such as panic stampedes and turbulence, and injuries seems to be a common occurrence (ABS-CBN, 2017). One of the surprising incidents was reported by Hegina and Lozada (2015) where two devotees died during the 2015 procession. In addition, it was also reported in that article that 597 devotees suffered from minor injuries and 21 devotees suffered with major injuries. Moreover, in the recent procession that was held January 09, 2018, it was recorded that one devotee died during the said event while 469 devotees were injured (Peralta-Malonzo, 2018). This has not yet been systematically evaluated; ergo, risk management efforts are constrained due to the lack of information on the pedestrian characteristics in terms of density, speed, and movement during the event.

Hence, the study mainly aims to develop systems and policies which can be used to improve risk management planning of the annual procession through providing a more systematic evaluation of the pedestrian characteristics during the event. This may be in terms of density and speed during the procession.

Further, developed methodologies to describe the pedestrian characteristics may be utilized in analyzing similar mass gatherings in the Philippines, such as the Fluvial Procession of Our Lady of Peñafrancia in Naga City and The Solemn Procession of Señor Santo Niño in Cebu City.

1.2. Objectives

The principal objective of this study is to develop a method which can be utilized to systematically estimate the number of participants and provide policies to improve risk management planning of the Black Nazarene procession. To attain this, the macroscopic dynamics of the procession will be evaluated through the following specific objectives.

1. To determine the macroscopic speed and density of the pedestrian in the Black Nazarene procession at predetermined route segments;
2. To measure and describe pedestrian density in the parade with respect to the distance from the Andas;
3. To quantify the intensity of aggressiveness of the participants through analyzing the people attempting to climb the Andas;
4. To determine the ratio of the stop-time to the total traverse-time of the Black Nazarene procession along the road segments;
5. To determine the average number of pedestrians needed to push the Andas from a stopped position;

2. RELATED LITERATURE

2.1. Past Studies

Around the world, mass gatherings are observed by not just the religious community but also during concerts, sports fests, and cultural events. Each mass gathering around the world exhibits different characteristics in the number of participants, accident and safety ratings, and frequency to name a few.

According to the study of Ahmed and Memish (2018), humans have gone to mass gatherings since the 4th century but the formal studies of crowds started only at the middle of the 20th century. One output of those studies was the ranking of the religious and sports related mass-gatherings. In religious mass-gatherings, the Kumbh Mela mass gathering in India holds the world's largest mass gatherings with over 120 million Hindus participating at various locations around the country, while up to 30 million can be observed at a specific location. While the Philippine's Black Nazarene number of participants can amount up to 8 million in a 20 to 24-hour period.

In the past, the procession of the Black Nazarene's crowd flow also exhibits the characteristics for human stampede. According to Ngai, Burkle, Hsu, and Hsu (2009), human stampedes can occur at large crowd gatherings which can result in injuries or even death. In addition, a human stampede can occur when crowds accumulate if a density of 10 people per square meter has been reached and a sudden event forces the crowd to rush into a certain direction. Furthermore, the compression forces present in this situation with just crowds of 6 to 7 people moving in one direction, can amount up to 4500N.

Mass gatherings such as the Procession of the Black Nazarene's exhibits different crowd characteristics to pedestrian traffic characteristics. In the study of Karthika et al. (2018), in mass religious gatherings crowd flows in multiple directions given one destination and does not stop even at large densities. In addition, a plausible cause for crowd density to continue to increase may be attributed to stagnant crowds. In their study, stagnant crowds are those who have reached their intended destination yet remains which cause the people behind them to wait for their turn. This effect causes unnecessary high crowd densities to occur, increasing the chances of a stampede occurring.

Historical observations from India and other countries propose that the stampede in mass gathering, particularly in religious occasions occur frequently; thus, studying crowd behavior scientifically is important. According to Gayathri et al. (2017), understanding the principles and applications of crowd dynamics is significant, especially when dealing with crowd risk analysis and crowd safety. In order to fully understand crowd dynamics, common pedestrian characteristics that affect crowd dynamics were studied such as group formation, self-organization, leader follower effect, queue formation and bottleneck conditions.

Due to the increasing occurrences of stampedes during pedestrian crowding in mass events such as pilgrimages, concerts, and parades, it is timely to study the behavior of pedestrians to develop more refined models. This is in line with the emergence of having more in-depth methods of analyzing pedestrian space-time dynamics to improve necessary disaster risk and management measures during the said events. The study by Lian et al. (2017) represented the movement of pedestrians in two ways. One of which is describing the movement of pedestrians as sequences described in successive spatial lengths between two consecutive points through time. The second method describes the pedestrian movement as a binary point process. Using video camera footages, the movement of pedestrians in a crowd were analyzed. Through the distance-based representation, the Euclidean distance of a pedestrian between two points over a specific length of time was determined to obtain his or her velocity. The point-process-based representation described the movement of a pedestrian as a "go" and the as "stop" when the pedestrian was found to be stationary.

2.2. Crowd Observation Methods

According to Saleh, Suandi, and Ibrahim (2015), crowd observation methods can be classified into two categories: the direct and indirect methods. The direct methods rely mostly on manually detect each person in a crowd by use of key features such as the person's head and/or shoulders. This approach requires less understanding and use of computer software, but it becomes ineffective in very dense crowds. The indirect method requires more procedures but is more effective at very dense crowds. This is done by utilizing more computer software than the direct method, editing video footage to ease the analysis of crowd features. One method used in the indirect method of crowd analysis is using a video filter that shows the edge of an object. This video is then overlaid to a video of the test area when it was empty. Doing so would yield a better video for computer software to analyze.

In mixed traffic flow such as roadways without lanes, or crowd flows a different approach should be considered. According to Nair, Mahmassani, and Miller-Hooks (2011), different sizes of vehicles and/or people tend to create empty spaces, called as "pores", where small vehicles and/or people can squeeze right through. Current traffic models use an ordered flow which may not be appropriate for mixed traffic streams. Mixed traffic flows exhibit a disordered stream where the traffic may flow in one direction but is non-uniform where smaller vehicles and/or people tend to overtake larger ones when flow speed is low while at faster speed larger vehicles and/or people tend to control the flow. This approach utilizes creating a boundary, analyzing empty spaces and movements of both active and passive traffic. This approach may better simulate the flow exhibited by the crowd in the Procession of the Black Nazarene than traditional pedestrian observation methods.

3. METHODOLOGY

3.1. Descriptive Analysis of the Procession

The video cameras used were SJCAM SJ4000 WIFI units. The video quality is Full HD 1080P, generating 1920 by 1080-pixel frames at 30 frames per second. The battery capacity is 900 mAh, allowing a video recording time of 70 minutes. In addition, the cameras are fitted with 32 GB memory cards. The video camera units are also equipped with individual waterproof cases and stands.

It was essential that the video camera locations were identified properly. The road segments qualified for this study were situated along the procession route. An ocular inspection of the procession route was done to identify potential locations where the video cameras can be set up or where CCTV camera footages can be obtained. A vantage point for each road segment was selected based on the following criteria: (a) a facility is available along the road segment where a video camera can be set-up, (b) the facility can provide an elevated view of the road segment, and (c) the facility is accessible to the researchers.

The cameras were set up at four locations, particularly at the National Museum of Anthropology along Padre Burgos Avenue, an arc in Brgy. 383 along Globo de Oro Street, Philippine Seafarers Training Center, Inc. along Arlegui Street, and Brgy. 387 Hall along Arlegui Street. Further, 15 more video footages were obtained from barangay halls as well as from the Metropolitan Manila Development Authority. It was necessary to identify additional locations as the road width of the road section that were being captured were considered. This allowed for the observation and evaluation of the pedestrian dynamics at varying road geometries.

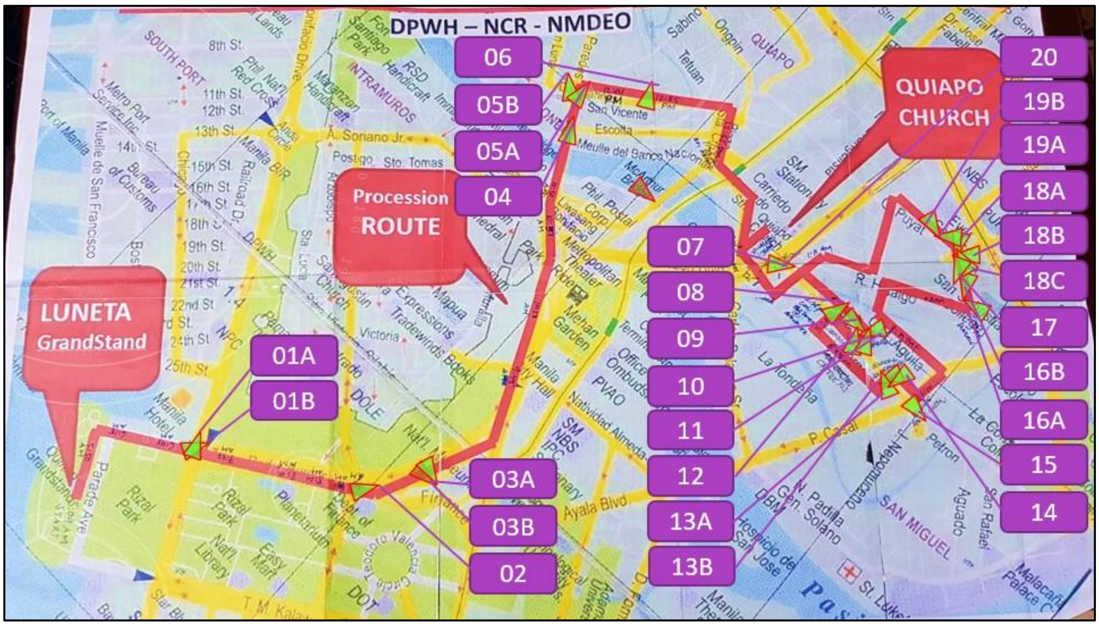


Figure 3.1. Procession route with camera locations

Furthermore, road sections along the procession route were characterized by obtaining their road geometries. Tape measures were used to measure distances between notable points in the field of view of the cameras, such as fixed objects and the actual road widths. Moreover, these geometric road measurements were used to further calibrate the video footages from the videographic survey.

3.2. Pedestrian Macroscopic Speed and Density

The pedestrian movement that was necessary to observe was the collective movement of the crowd as a unit as they traversed along the procession route. The duration of the procession was observed with the use of video cameras. Each camera was assigned to its respective location, capturing a particular road segment along the procession route.

3.3. Density-Distance Map

Figure 3.2. Grid analysis setup with row labels for Fraternal St.

Pedestrians may be set on performing different activities or have varying intentions during the Black Nazarene procession. The density-distance analysis aims to quantify and describe the pedestrian density at different distances ahead and behind the Andas.

Multiple square grids with a length two meters per side were set along the road segments as seen in the video footages. Two columns of grids were established parallel the road direction. Furthermore, several grids were set perpendicular the road direction to an extent where the total width of the grids was less than or equal to the road width of the segment. Snapshots of the video footages were taken for every four-meter distance the Black Nazarene procession moves forward. Six snapshots ahead and six snapshots behind the Andas were taken. At each snapshot, the number of pedestrian heads within each grid were counted. The density of the pedestrians was calculated by dividing the number of counted pedestrians by the area of the grids. The speed of the parade would be used to analyze the pedestrian macroscopically. A density map, shown in Figure 3.3, that would graphically describe the varying densities at different locations with respect to the Andas.

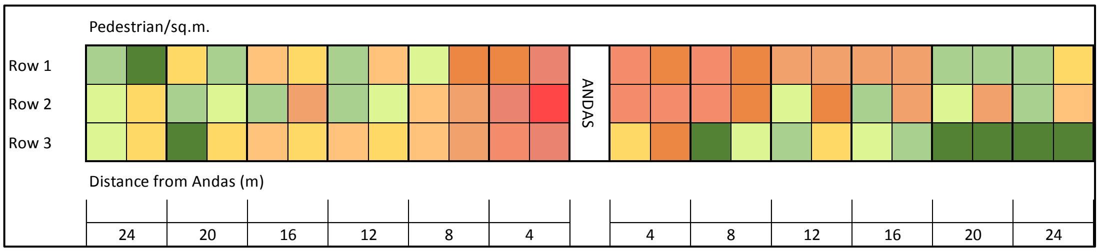


Figure 3.3. Sample of density-distance map

3.4. Pedestrian Estimation

In order to systematically obtain an estimated number of participants during the procession, the length of the parade was first established. The length of the parade is the observable extent of participants within which the pedestrians are actively participating in the procession. It was identified that the length of the parade has two main sections: area behind the Andas and area ahead of the Andas. By using the multiple grid analysis in Chapter 3.3 on five different locations, formulas were developed where the density of the pedestrians behind and ahead of the Andas are functions of the distance from the Andas. With the parade length being constant, the only varying parameter needed to obtain the number of participants in a given segment is the road width with respect to the distance from the Andas. With the varying densities at each meter behind and ahead of the Andas, multiplying them with the corresponding road width provides an estimate number for the pedestrian count. By using the trapezoidal method, the cumulative number of pedestrians that took part in the procession was obtained.

3.5. Hustle Rate

Some factors that affect the Black Nazarene procession movement may be induced by the behavior of the participants. The hustle rate aims to quantify the aggressiveness of the pedestrians surrounding the Andas.

Due to the visual limitations caused by the angle of the camera footages, the sides of the Andas were divided into four parts. Each face of the Andas walls represents a certain percentage of the whole Andas perimeter. The longer edges represent 30%, while the shorter sides represent 20% of the Andas perimeter. It is assumed that the behavior of the pedestrians who attempt to climb the Andas is the same at all sides. With this, only the visible percentage of the Andas will be accounted for.

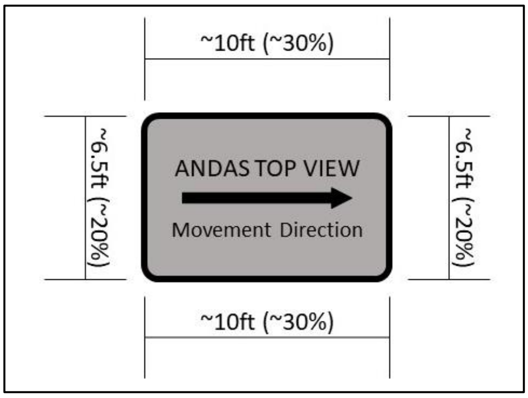


Figure 3.1 Assumed percentage of total pedestrians attempting to climb the Andas per side

A predetermined time period was allotted to observe and count the pedestrians who attempted to climb the Andas. With the obtained video footages, the number of pedestrians that attempted to climb the Andas were counted with respect to the set time. The total number of pedestrians that attempted to climb the Andas was obtained by dividing the number attempted climbs by the percentage of the visible Andas perimeter. Subsequently, the hustle rate for a road section was generated through dividing the total number of pedestrians that attempted to climb the Andas by the set time the Andas traversed through the segment.

The hustle rate may indicate the aggressiveness of the pedestrians participating in the Black Nazarene procession. The causality between the hustle rate and the effective road width will be investigated through the regression analysis.

3.6. Time Ratios

The movement of the Black Nazarene procession may be described by the duration of its movement and stagnancy along a road segment. The time ratio analysis characterizes the movement of the Black Nazarene procession in terms of the stop-time, go-time, and traverse-time.

A predetermined time of observation was established for each road segment. This is referred to as the traverse-time. The duration within the traverse-time at which the Andas was stagnant is determined as the stop-time. Such data was recorded using a stopwatch. The difference between the traverse-time and stop-time is the go-time.

The ratios of stop-time to traverse-time, or stop-traverse ratio, and stop-time to go-time, or stop-go ratio, were obtained. In evaluating the magnitude of the stop-traverse and stop-go ratios, the movement or immobility of the Black Nazarene procession along a particular road segment can be described. The causality between the stop-traverse ratio and effective road width of the road segment was further assessed.

3.7. Push Formation

Throughout the procession, the Andas was observed to stop moving multiple times. With each stop, it was noticeable that pedestrians behind the Andas cleared the area and used it to rush towards it. This analysis aims to quantify push formations.

The video footage of the procession was used to observe the instances the Andas stopped along the route. An event was qualified to be recorded as a data point once the pedestrians behind the Andas cleared the area. A push was classified into two categories using a dummy variable, M, where M=1 when the push caused the Andas to move, while M=0 when the Andas was not displaced along the push direction. The length of pushing pedestrians parallel to the pushing direction was measured. A length that corresponds to M=1 was measured as the distance from the Andas to the last person to join the pushing group right before the instant the Andas started moving along the push direction. A length that corresponds to M=0 was measured as the distance from the Andas to the last person to join the group when the Andas did not displace, or from the Andas to the person who deflects opposite the direction of the push right after joining the group.

The data points in the two categories (M=1 and M=0) were subjected to the Analysis of Variance Test to determine the significance between the differences in the mean lengths of the two groups. Using the mean pedestrian density within two meters behind the Andas as found in Chapter 3.3 and the pushing area (determined using the mean length of pushing pedestrians and the Andas width), the average number of people needed to push the Andas to cause it to move was obtained.

4. RESULTS

4.1. General Results and Observations

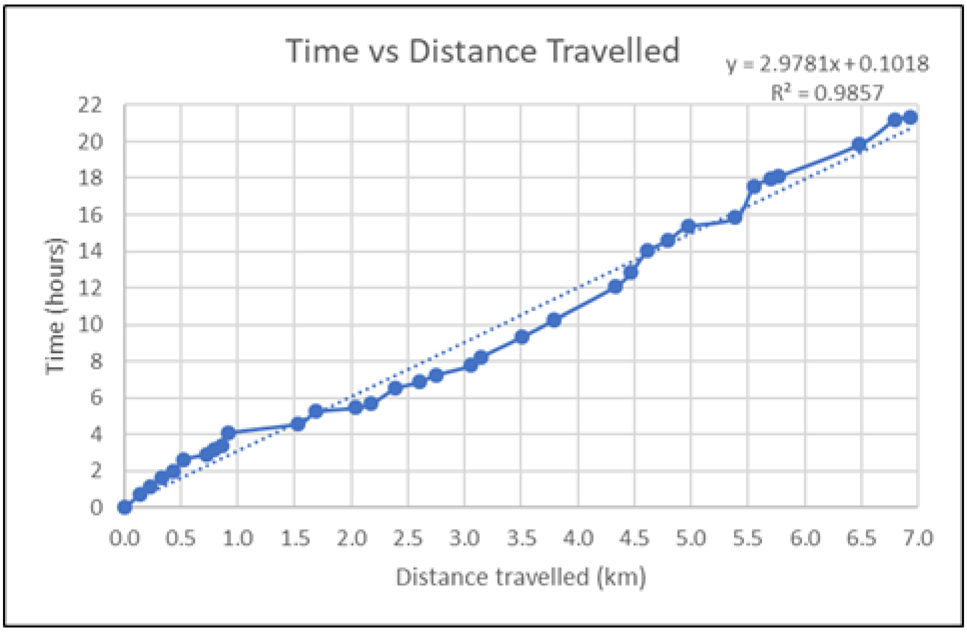
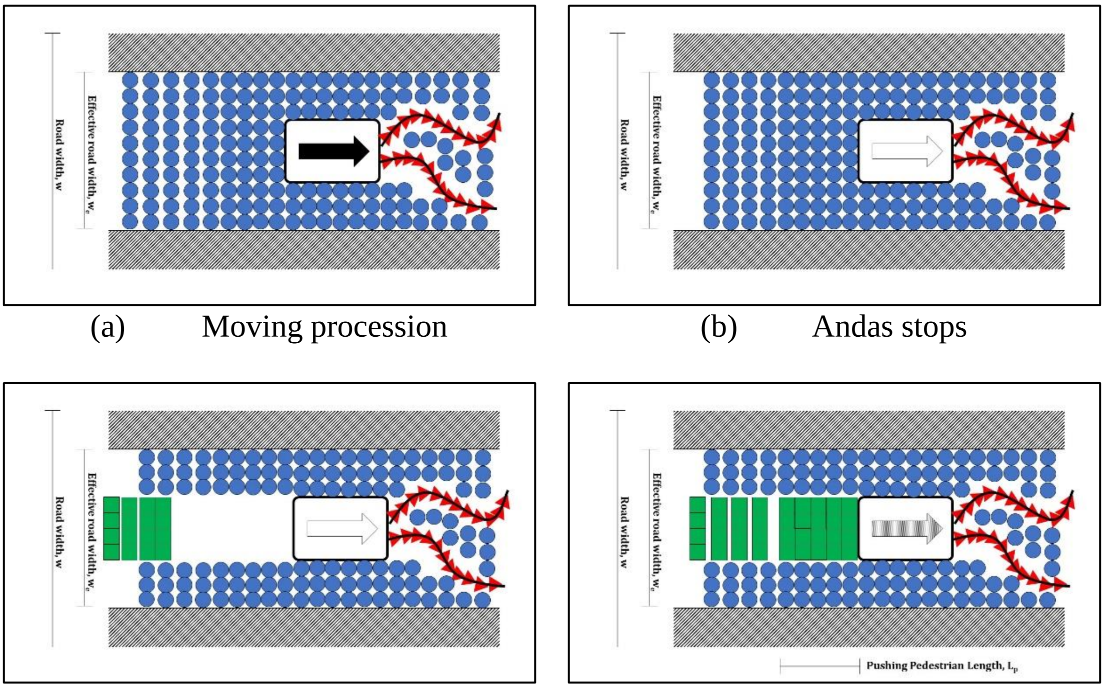


Figure 4.1. Time-Distance diagram of the procession during the 2019 Traslacion

The procession held on January 9, 2019 left its traditional starting point at the Quirino Grandstand at approximately 5:09:00 AM. It went on and reached its final destination at Plaza Miranda at approximately 2:30:00 AM the next day. Noted however is the slight deviation to the traditional route experienced towards the end part of the procession. The total route length was calculated at 6.938 kilometers, traversed for a total time of 21 hours and 21 minutes. By far, this has been one of the longest processions of the image; closely at par to 2012's 22-hour long parade. On a procession route map, the location of the Andas at specific times was documented by the Department of Public Works and Highways through marking the exact position of the Andas with timestamps throughout the route. The timestamps were plotted against the corresponding distance the procession travelled, presented in Figure 4.1 The trend line generated appeared linear with $R^2 = 0.9857$; implying a strong linear relationship between time and distance. The reciprocal of the slope of the curve represents the overall speed of the entire procession in which a value of 0.33 kph was obtained.

Furthermore, the general crowd behavior observed in the procession was evaluated. The levels of heterogeneity amongst the participants are presented in Figure 4.2: (1) the pushers represented by the green squares, (2) rope holders represented by the red triangles, and (3) the ordinary devotees which are represented by the blue circles.

The pushers are the group of people intended to initiate movement on the Andas. On the event wherein the Andas is on a full stop, there are times wherein this group blends easily with the ordinary crowd. To serve their purpose however, a path is cleared for them to run over as a group and initiate movement to the parade by applying forward thrust to the main body of the Andas. This is often done intermittently until the initiation of movement becomes successful; which is highly related to the density and number of people pushing. Upon movement, the pushers continue to push until the Andas goes to its next stop.



(a) Moving procession (b) Andas stops

(c) Cleared pathway for pushers (d) Push formation behind Andas

Figure 4.2. Graphical representations of the kinds of participants during the procession based on their intentions

The rope holders are the group of people intended in holding the two ropes attached to the front of the Andas. Aside from assisting in the movement, another major purpose of this group is to lead the Andas's direction. They are needed to pull the Andas towards the designated route given that people always attempt to sway away from it so that the image can pass by their areas. Unlike the pushers however, the movement of the pedestrians holding the rope were very much noticeable due to their very unpredictable movement leading to intense swaying motions. Rope holders also have three maneuvers that corresponds to the proper way of handling the rope. The first one is the *"Balikat"* or the placing of the ropes over their shoulders. This maneuver is done when the holders decide to rest their arms. The second one is the *"Bewang"*. This is the most important maneuver since it is associated with movement. During *Bewang*, the rope holders can exert maximum force for movement. Lastly is the *"Otso"*. This is performed when the rope becomes entangled and needed to be straightened. They perform this by putting the rope over their heads and attempt to untangle the rope from there.

The last group of people which makes up most of the procession are the ordinary devotees. These are the participants who are neither the pushers nor the rope holders. Their only intention is the main goal which is to get in touch with the image carried by the Andas. Unlike both pushers and rope holders whose direction is always forward, the direction of this group's movement is always heading towards the Andas. Devotees can often get aggressive in attempting to do their intention. A significant number of them get ahead by jumping out and stepping on people's shoulders and heads. Pulling each other out to get ahead is also a normal occurrence during the procession. The aggressive nature of the devotees is what often lands them to huge risks and hazards.

4.2. Stop-time Analysis

Moreover, the Stop time of the Andas along the identified road sections were recorded. Stop-time to Go-time and Stop-time to Traverse-time ratios were obtained to describe the movement of the procession with respect to the duration at which the Andas was stationary or at rest along the road segments of varying characteristics.

Table 4.1. Ratios between Stop time, Go time, and Traverse time per identified road segment

Segment	Camera	Stop Time (sec)	Go Time (sec)	Stop/Go	Stop/Traverse	Stop/Traverse
1	01A	1889	663	2.849	0.740	0.692
	01B	308	171	1.801	0.643	
2	2	2547	1528	1.667	0.625	0.625
3	03A	177	160	1.106	0.525	0.494
	03B	225	262	0.859	0.462	
4	4	270	91	2.967	0.748	0.748
5	05A	150	72	2.083	0.676	0.661
	05B	193	106	1.821	0.645	
6	6	11	83	0.133	0.117	0.117
7	7	823	296	2.780	0.735	0.735
8	8	1085	58	18.707	0.949	0.949
9	9	286	24	11.917	0.923	0.923
10	10	1141	45	25.356	0.962	0.962
11	11	177	75	2.360	0.702	0.702
12	12	378	20	18.900	0.950	0.950
13	13A	392	26	15.077	0.938	0.925
	13B	412	40	10.300	0.912	
14	14	1521	48	31.688	0.969	0.969
15	15	2161	891	2.425	0.708	0.708
16	16A	557	225	2.476	0.712	0.475
	16B	14	45	0.311	0.237	
17	17	455	59	7.712	0.885	0.885
18	18A	317	8	39.625	0.975	0.793
	18B	56	33	1.697	0.629	
	18C	307	89	3.449	0.775	
19	19A	115	59	1.949	0.661	0.599
	19B	73	63	1.159	0.537	
7	20	21	51	0.412	0.292	0.292

As shown in Table 4.1, the maximum Stop time to Traverse time was recorded to be 0.969, indicating that 96.9% of the time the Andas was not moving along segment 14. Various factors could have caused these stagnations. The increasing time the procession spends stagnant along a particular location along the route may increase the risk of injuries due to the lengthened exposure to various hazards. Pedestrians may be exposed to chaotic behavior and extreme densities for extended periods of time. The Stop- ime to Traverse time ratios were correlated with the effective road widths along the route. This generated an inverse relationship with the R^2 value of 0.0349, indicating a weak relationship between the two variables. This suggests that varying the road widths along which the procession traverses through does not significantly and correspondingly affect the duration the procession becomes stagnant, and in turn the trop-traverse ratio.

4.3. Density-Distance Analysis

Figure 4.3. Density-distance maps illustrating the varying densities behind and ahead the Andas at increasing distances

Based on the data from the videographic survey, presented in Figure 4.3 is the density of the pedestrians with respect to their distance from the Andas. It can be observed from the figure that the maximum densities of people are located closest to the Andas; and as distance from the Andas goes farther, density begins to decrease. The high pedestrian densities on close proximities behind the Andas is the manifestation of the main intention of the participants defined earlier. The will to touch the image alongside the designated pushing behavior to move forward promotes huge attraction towards the Andas. Based solely on the data gathered, the observed maximum and minimum densities were approximately 11.8 people per square meters and 0.75 people per square meter respectively. The maximum density observed was significantly higher compared to what was established by Dr. Oberhagemann (2012) in his research regarding crowd densities at major public events. According to him, a density of five p/m^2 is maximum for the space between people to allow for comfortable movement. Beyond this, at approximately six to eight p/m^2, movement is still possible, but the maneuver would require the individual to exert significant amount of force to counter the accumulated push force generated by the other individuals who also try to move. However, it should be noted that the study cited took into consideration the dimensions of a typical German man; which are typically larger built compared to their Asians due to their Caucasian descent. Furthermore, similar study conducted in 2009 implied that the behavior of Asians towards crowd and movement is very different than others. Upon comparing the walking speeds between Asians and Europeans, it was found that even though both descents walk very similar speeds at low densities, Asians have a tendency to walk faster when density increases. Furthermore, the study suggest that Asians are not bothered so much about bumping into others (Chattaraj, Seyfried, & Chakraborthy, 2009). This behavior was easily observed during the Traslacion. People are not only seen forcefully pushing around others, others even resort to climbing past others and stepping into each other's heads and shoulders just to get in touch with the image. Therefore, the density was always the highest surrounding the Andas due to the aggressive maneuver of some participants that includes putting themselves literally on top of others.

Furthermore, it can be observed that the density of the pedestrians located farther than nine meters behind the Andas was observed to be generally lower than the average density along the section. It was noted that the pedestrians at this distance were passive followers who did not actively participate in causing the forward movement of the Andas through pushing. The low densities allowed some pedestrians to carry various articles, such as flags and replicas of the Black Nazarene. Further, the pedestrian densities in front of the Andas is notably erratic; patches of low-density areas are easily observed. This may be due to the competitive behavior of the pedestrians to hold the rope. The voids become evident as people stand clear from between the ropes to avoid being caught in between.

Through evaluating the pedestrian densities at varying distances, formulas were developed where the density of pedestrians is evaluated as a function of the distance from the Andas behind

$$d_{behind_i} = -1.394\, ln(\ell_i) + 9.38\ [R^2 = 0.9237] \qquad (Eq. 1)$$

and ahead.

$$d_{ahead_i} = 7.9392 e^{-0.014\ell_i}\ [R^2 = 0.6462] \qquad (Eq. 2)$$

In Equations 1 and 2, d_i, measured in pedestrians per square meter, is the density of the pedestrians at distance ℓ_i, measured in meters, behind or ahead the Andas. After obtaining the density at a certain distance, it is multiplied by the road width, R_{wi}, measured in meters, to obtain the number of pedestrians per meter length. Taking the summation of the number of pedestrians from distance ℓ=1 m to the total length of the parade behind or ahead the Andas measured in meters, L, the total number of pedestrians behind and ahead the Andas can be obtained as shown in Equations 3 and 4, respectively.

$$Ped_{behind_k} = \sum_{i=1}^{L_{behind}} \left[\left(d_{behind_i}\right)\left(R_{w_{ki}}\right)(1m)\right] \qquad (Eq. 3)$$

$$Ped_{ahead_k} = \sum_{i=1}^{L_{ahead}} \left[\left(d_{ahead_i}\right)\left(R_{w_{ki}}\right)(1m)\right] \qquad (Eq. 4)$$

The total number of pedestrians in the parade at an instant can thus be calculated using Equation 5.

$$Ped_{total_k} = Ped_{behind_k} + Ped_{ahead_k} \quad (Eq. 5)$$

In developing the system that can generate a total estimate of the participants in the procession, the following assumptions were taken into consideration:

1. The ropes attached in front of the Andas are straightened at the instant of estimating the number of pedestrians ahead of the Andas. Thus, the length of the parade ahead of the Andas is the length of the ropes, which is 50 meters.
2. A new set of participants are estimated at each instant.
3. The length of the procession is constant along the route.

Estimating the total number of pedestrians that participated during the procession can be obtained by evaluating a definite integral.

$$area = \int_a^b f(x)dx \quad (Eq. 6)$$

where *b* is the number of times the participants in the crowd assumes a new set of pedestrians at every instant and *f(x)* is the total number of pedestrians as a function *b*. As for this study, the value for *b* is in accordance with the second assumption. This means that *b* is the number of instances that can be estimated along the whole route.

The number of pedestrians participating in the procession was approximated further using the trapezoidal rule.

$$area = \int_a^b f(x)dx \approx \sum_{k=1}^{N} \frac{f(x_{k-1}) + f(x_k)}{2} \Delta x_k$$

$$= \frac{\Delta x}{2}\left(f(x_0) + 2f(x_1) + 2f(x_2) + \cdots + 2f(x_{N-1}) + f(x_N)\right)$$

$$area = \frac{\Delta x}{2}\left(f(x_0) + 2\sum_{k=1}^{N-1} f(x_k) + f(x_N)\right) \quad (Eq. 7)$$

$where$

$$N = \frac{total\ route\ length}{interval\ between\ new\ sets\ of\ participants};$$

$$\Delta x_k = \Delta x = \frac{b-a}{N}$$

It must be noted that the length of the parade behind the Andas was found to be approximately 80 meters, while the extent of the parade ahead the Andas was estimated at 50 meters according to the first assumption. Thus, L_{behind}=80 meters and L_{ahead}=50 meters. Further, as b=6,

Through Eq. 7, an estimated number of 454,306 total number of participants throughout the procession was obtained. This number was determined to be somehow precise in comparison to the estimate reported by reliable news channels of around 390,000 devotees along the procession (Malig, 2019). Peak number of people during the procession was observed at the starting point, which was at the Quirino Gandstand where a mass; attended by more than half a million people, was held prior to the procession. Furthermore, the change in number on the latter part of the procession corresponded to the variation of road widths along the route.

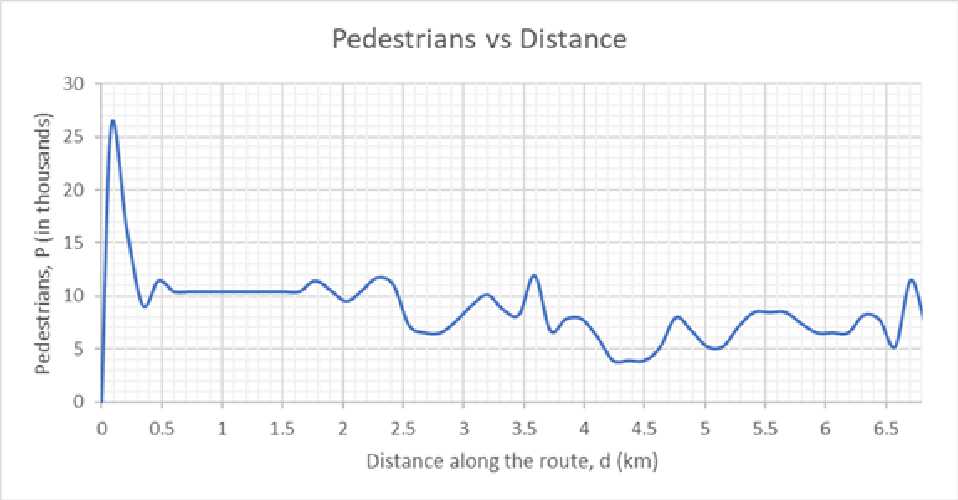


Figure 4.4. Number of pedestrians varying as the distance travelled by the procession progressed along the route

4.4. Hustle Rate

One of the goals of the pedestrians participating in the procession was to reach or touch the image of the Black Nazarene mounted on the Andas. This required pedestrians to jump over the crowd to reach the Andas. These actions were also observed when pedestrians left the Andas or the area near the Andas. Such actions are considered aggressive as they produce riotous acts and disruptive behavior. It is significant to note that the aggressive behavior may cause serious injuries to the participating pedestrians due to the nature of the behavior. The acts include pedestrians stepping on the shoulders and heads of other participants to quickly move towards and away from the Andas. Increased Hustle Rate entail high levels of safety risk to both the aggressive pedestrian and the affected participants

Segment	Person/Min
1	32.40
2	30.80
3	39.00
4	29.60
5	68.31
6	43.83
7	55.60
8	50.60
9	28.80
10	48.00
11	38.86
12	54.52
13	47.02
14	48.45
15	35.80
16	34.40
17	40.32
18	68.57
19	65.00
20	28.00

Figure 4.5. Hustle rates along the observed road segments

To quantify the level of aggressiveness of the pedestrians along road segments, the attempts to reach and move away from the Andas per unit time was tabulated. The percentage of the Andas perimeter that was observed was also noted. This yielded the ratios which denote the number of pedestrians attempting to reach or move away from the Andas per minute. The highest Hustle Rate recorded was observed to be 68.57 aggressive pedestrians per minute at segment 18, while the lowest hustle rate was 28 aggressive pedestrians per minute at segment 20. Furthermore, it was presumed that the effective road width of the section has a significant relationship with the level of aggressiveness of the pedestrians. However, determining the R^2 value between hustle rate and effective road width yielded a very weak correlation; thus, implying that altering the initial route with varying road widths will not have any significant change in the level of pedestrian aggressiveness.

4.5. Push Formation

Pedestrians play an important role in the procession especially in every instance that the Andas stops. It was observed that the pedestrians at the back of the Andas highly influence the forward movement of the Andas. Noticeably, a formation of pedestrians intended to push the Andas was needed to cause the Andas to move. This formation of pedestrians varies in lengths. Looking into it, the researchers discovered that a mean length of 2.8 meters of pedestrians (M=0 with n=59 observed pushes) was not able to cause a forward movement to the Andas. In contrary, an average length of 3.5 meters of pedestrians (M=1 with n=37 observed pushed) caused the Andas to move. With the use of ANOVA, the results between the two means generated a p-value of $4.6\text{x}10^{-7}$, which suggest a significant difference between the means. This supports the claim that an increased length of pedestrians pushing behind the Andas will cause it to move than a short length of pedestrians.

Two parameters were essential to obtain the average number of pedestrians needed to push the Andas from a stopped position and cause it to move: the pushing area and the mean pedestrian density within two meters behind the Andas. Using the obtained pedestrian length of 3.5 meters behind the Andas and the Andas width of 2 meters, the pushing area was found to be 7 sq.m. In addition, Figure 4.3 illustrates that the mean pedestrian density within two meters behind the Andas is 9.7 pedestrians per sq.m. This value is used due to the observed nature of the pushing pedestrians. As pedestrians push the Andas, the whole group of pushing pedestrians display maximum density uniformly. Multiplying these two variables yields an average of 68 Andas pushers. Therefore, it was found that there should be at least 68 pedestrians uniformly pushing the Andas to cause movement to it from a stopped position.

4.6. Risk Management and Policy Development

Through the Time Ration Analysis, it was determined that various road segments had different stop-traverse ratios. Increased stop-traverse ratios may result in a higher exposure of the pedestrians to health and inkury risks. One possible policy that would be able to decrease the multiple stops of the Andas during the procession would be to have a designated Push Formation Volunteers (PFV) that would push the Andas if it was stopped or stuck for a long duration of time. As mentioned, it would require at least 68 volunteers compacted in an area of 7 sq.m. to move the Andas. Therefore, a policy that would involve 68 to 70 volunteers situated at different locations along the route would ensure a smoother transition of the Andas movement.

After quantifying the risky behavior of pedestrians and their aggressiveness through hustle rate, it was observed that the hustle rate varies in different segments, indicating that there is a need of more safety personnel in the areas with the higher hustle rate. Different segments resulted to different hustle rates; thus, the segments with the higher values must be addressed with higher number of government units, policemen, and medical units. Proper allocation of human resources to these areas would mean a faster and more sufficient aid to the needs of the pedestrians.

Lastly, it was observed that different agencies produce significantly different estimations of participants in the procession. With this, the researchers generated a risk management tool that would provide a systematic method of estimating the number of participants for given road segments. Furthermore, this would allow government units to better allocate resources such as police and medical units to more dense road segments.

5. CONCLUSION

Different pedestrian characteristics were observed and analyzed in order to describe systematically the dynamics of the procession. It was identified that the road segments along the route of the procession have varying road widths; from a minimum width of 6 meters to a maximum width of 40 meters. It was observed at different segments that the dynamics of the procession greatly vary. Through a static grid analysis, it was discovered that three main factors highly affect the dynamics of the procession: density, group formation and the aggressiveness of the pedestrians.

In order to characterize the dynamics of the procession, the macroscopic speed and density of the procession were gathered. With the given data from the Department of Public Works and Highways, the researchers were able to plot a graphical representation of the whole duration of the procession. This presented the time and the corresponding distance on which the Andas moved. The results produced a strong relationship between time and the corresponding distance of the Andas. With this, it was discovered that the average speed of the procession was 0.33 kilometers per hour; finishing a 6.938-kilometer route in 21 hours and 21 minutes. In addition, it was observed that the identified road segments produced varying densities. The results implied that on the front position of the Andas, densities generated an erratic behavior. Evidently through visual observation presented, the behavior of people in front of the Andas was very unpredictable due to the presence of the rope attached to the Andas which caused random movements. On the other hand, the densities behind the Andas were identified to have a more consistent result. It can be observed that as the distance of the pedestrians from behind the Andas increases, the density decreases. Furthermore, the maximum density recorded was 11.8 ped/m^2 situated right behind the Andas.

With the observed high pedestrian densities behind the Andas, it was discovered that the densities behind greatly influence the forward movement of the Andas. This was manifested by the pushing behavior of the pedestrians to cause the Andas to move forward. With this, the result was then further analyzed. It was then discovered that 68 to 70 pedestrian volunteers are needed to move the Andas forward. With this finding, it is important to implement a policy regarding the number of volunteers at the back of the Andas to ensure smoother traverse of the procession.

In addition, results also presented that the densities in front and at the back of the Andas can be used to represent an active length of pedestrian parade. With the use of this active length and the densities obtained, the researchers were able to produce a method on how to systematically estimate the total number of pedestrians. An equation based on these findings was generated and utilized by the researchers. It was discovered that in the previous event, 454,306 actively participated in the procession. Furthermore, the method provided by the researchers will be able aid the lack of methods in estimating the number of participants in the said event.

Lastly, it was also observed that the aggressiveness of the pedestrians and the duration of the stoppage of the Andas greatly affect the risk and safety issues of the pedestrians. With this, the researchers were able to quantify these factors through hustle rate and stop-time ratios. The results presented that hustle rate varied in different segments. The highest Hustle Rate recorded was observed to be 68.57 aggressive pedestrians per minute at segment 18, while the lowest hustle rate was 28 aggressive pedestrians per minute at segment 20. On the other hand, it was also noticeable that the Stop-Time ratio have varied throughout the route and it was manifested along segment 14 that the maximum ratio obtained was 0.969, indicating that the Andas was at still 96.9% of the time on that segment, while the least ratio was reported at 11.7 % on segment 6. With these observations, these factors were examined and discovered to have no correlation to their corresponding road width. However, the results obtained were utilized in order to locate the segments at which higher risk and safety issues may generate. Different segments resulted to different hustle rates and stop-time ratios; thus, implicating that the segments with the higher values must be addressed with a higher number of government units, policemen, and medical units. With the data gathered, a policy regarding proper allocation of human resources to these areas would mean a faster and more sufficient aid to the needs of the pedestrians.

Given that this is an annual event that is not likely to discontinue any time soon, with its scale increasing every year, analyzing and understanding all the factors that correspond to its dynamics, the researchers were able to generate a method of estimating the number of active participants in the procession. In addition, possible policies were also identified at which the government agencies may apply to aid the needs of the pedestrians.

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