Assessment of the Transferability of Quezon City Flood Evacuation Destination Choice Model to Marikina City, Philippines

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Abstract: One of the evacuation decisions that households resolve during flood disasters is the destination choice. The lack of studies for destination choice modeling can be addressed through the assessment of model transferability. This study evaluated the ability of previously developed Quezon City (QC) flood evacuation destination choice models to predict evacuation travel behavior of households in Marikina City. The QC models developed include household decisions to go to a public shelter, church/seminary, or to the family/relatives' house. Data from households in Marikina City that were affected by the flood event due to the Tropical storm Yagi in 2018 was collected. Results show that the Quezon City public shelter model can predict the decisions of households in Marikina City. However, the church/seminary model showed poor results. Further investigation of transferability of the QC flood destination choice model to a greater population should be done.

Keywords: Transferability, Flood Evacuation, Destination Choice Model

1. INTRODUCTION

Disasters are events where a community experiences loss and exceed its ability to cope using their resources. Natural and anthropogenic disasters are severe environmental disruptions that cause death, destroy infrastructure, damage ecosystems, weaken the economy, and interrupt human activities (Iheukwumere *et al.,* 2020). These natural disasters range from earthquakes, volcanic eruptions, tsunamis, hurricanes, tornadoes, floods, droughts, landslides, or subsidence to asteroid impacts (Tulane University, 2018). Flood events are the most common disasters. In the year 2018, there are 127 cases of floods recorded with 2879 fatalities (Centre for Research on the Epidemiology of Disasters [CRED], 2019). Moreover, 49% of the 396 total natural disasters are flood cases for the year 2019 (CRED, 2020).

Flood-prone areas in Metro Manila are about 31% of its land area. Extreme floods in Metro Manila are due to heavy precipitation, high tide, sea-level rise, excess river runoff, and various anthropogenic factors. For instance, notable typhoons Ondoy (Ketsana) and Pepeng (Parma) placed both the flood-prone areas and non-flood-prone areas of Metro Manila underwater (Regmi, 2017). The extreme rainfall brought by Typhoon Ketsana alone affected 872,097 people in Metro Manila, with 241 fatalities, 394 injuries, 65,521 damaged infrastructures. Infrastructure damages amounted to 570,187,587.00 PHP (Sato and Nakasu, 2011). According to the Marikina City Disaster Risk Reduction Management Office in 2014, almost 90% of Marikina City will be affected by flood when impacted by worst-case scenario flooding. They consider 7 out of 16 barangays in Marikina City to be highly susceptible to flooding. These barangays are Malanday, Industrial Valley Complex, Tañong, Jesus Dela Peña, Sto. Niño, Nangka, and Tumana. In 2018, Marikina City was affected by a flood event caused by a southwest monsoon enhanced tropical storm internationally named Yagi or locally named Karding. According to the National Disaster Risk Reduction Management Council (NDRRMC) in 2018 report, a total of 5,451 households in thirteen barangays of Marikina City were affected by the tropic storm. A total of 4,698 families evacuated from their homes based on the NDRRMC situational reports.

Countermeasures such as evacuation can be done by the government to reduce physical injuries and deaths before a disaster. The National Disaster Risk Reduction Management Framework of the Philippines indicated two types of timing-based evacuation implemented in the Philippines. Preemptive evacuations are done before a disaster hits while forced evacuations are conducted during a disaster. Sequences are used in household evacuation modeling to prevent losses. A widely used sequence is the decision to evacuate, accommodation type, destination choice, departure time, mode choice, and route choice. Decisions can be made simultaneously or sequentially, and household decisions can vary depending on socio-demographic factors and social network characteristics (Abhishek *et al.*, 2019). One of the evacuation decisions that a household should resolve is their destination of choice. Destination choice is the location a household will go to when leaving their home located in high-risk areas. It is a critical step in evacuation planning and emergency management since it is part of the four-step model paradigm in transportation engineering. Despite its importance, there are relatively few studies regarding destination choice modeling (Cheng, *et al.*, 2008).

Also, modeling decisions is important to address the tediousness of data collection. This is in addition to the use of models in forecasting and planning purposes. To evaluate the usefulness of models developed to other contexts, transferability evaluation is conducted. Transferability is the use of results in one study and apply it to another context. It is commonly done due to the logistical, economical, and theoretical benefits (Moon *et al.*, 2017). Past literature shows that models are transferable between cities with similar geographical features, with a decrease in model fit and predictive skill (Zalzal *et al.*, 2019). Also, models for different regions but within the state are more transferable than models from different states (Transportation Research Board, TRB, 2014). Although studies on transferability of models were conducted in studies, these are limited to applications in land use planning, spatio-temporal, and transportation, among others (e.g.Vienneau *et al.*, 2011; Baghestani *et al.*, 2016; Zalzal *et al.*, 2019). Studies in evaluating the transferability of evacuation models are very limited to this date.

This study was conducted to assesses the transferability of the Quezon City evacuation destination models using data from households in Marikina City. The hazard type as a basis for decision-making was the same as the flood. If found that the destination choice model developed for Quezon City is also applicable in Marikina City, the model can be potentially used to predict evacuation behavior in various cities. This information can also be used in developing a flood evacuation plan for Quezon City, Marikina City, and other nearby areas. It combines social sciences and engineering science to help government officials in formulating flood evacuation plans. Results of this study can help in locating the place of evacuation during emergencies and for planning resources needed during future evacuations.

2. LITERATURE REVIEW

Evacuation planning models were developed from the classic four-step transportation planning model (Cheng *et al.,* 2008). This four-step planning model includes demand estimation, trip distribution, mode split, and trip assignment. The importance of forecasting the evacuation travel demand, distribution and assignment of evacuation demand, and mode assignment of evacuees to manage the evacuation demand (Murray-Tuite and Wolshon 2013). The evacuation process is a product of several decisions taken to reach a safe area (Abhishek *et al.,* 2019). These decisions are departure time, evacuation destination, accommodation type, route choice, and others. A widely used sequence in evacuation decisions in increasing modeling frequency is the decision to evacuate, accommodation type, destination choice, departure time, mode choice, and route choice (Ukkusuri *et al.*, 2016). A study by Abhishek *et al.* (2019) concluded that there is no strongly dominant pattern in a household's evacuation decision and the sequence of evacuation decisions varies through a population. However, a system that was developed by Yin *et al.* (2014) says that there are four stages in travel demand modeling. The first stage of the system is the identification of the number of evacuees and the time of departure. The second stage is the evacuation distribution from origin to destination. The third stage of the travel demand modeling is the mode split in which the mode of travel by the evacuees is being identified. The last step is the trip assignment which reports the evacuees' movement to their destination.

2.1 Destination Choice Modeling

Destination choice modeling just like other decisions in evacuation decision modeling considers various factors. Socio-demographic characteristics such as race and income, and risk indicators such as issuance of an order and hurricane category are all associated in evacuation location type modeling (Mesa-Arango *et al.*, 2013). Golshani *et al.* (2018) developed destination choice models for shelter, hotel, home, and family. Households located at high risk of flood, have a professional or graduate degree, have a house type of apartment, and presence of government evacuation order indicates that households are more probable to choose public shelters, however, the high distance of evacuation tour negatively affects the probability of this choice. Meanwhile, households in condominiums and high-risk areas are more probable of choosing hotels, however, high population density negatively affects the probability of this choice. Households with disabled members are likely to stay at home. Households living in apartments positively contribute to staying at home in contrast to households living in townhouses which have a negative effect. Presence of retired members and presence of government evacuation order makes household less probable of staying at home. The presence of retired members positively contributes to choosing family/relatives' house. High population density and high tour evacuation distance also increase the probability of staying at family/relatives' house.

In the model developed by Mesa-Arango *et al.* (2013), destination choices are public shelter and churches, family-and-relatives, hotels, and others. Location risk due to hurricanes, distance from the origin to destination, natural geographic feature, metropolitan area, and existing regions were also used in their study in building a decision choice model. Using nested logit modeling, it was found that variables affecting destination choice include hurricane position, household geographic location, race, household income, preparation time, changes in evacuation plans, past experiences with major hurricanes, household members working during the evacuation, and evacuation warning. Cheng *et al.* (2008) developed a friend/relative model and a hotel/motel model considering factors such as trip distance, travel costs, destination population, number of hotels/motels at the destination, risk indicators, ethnicity, metropolitan area indicator, and interstate highway proximity indicator. Parameter estimates for family/relatives' model show that destination population, metropolitan area, and white percentage are proportional to destination attraction or utility. Risk indicator and origin to destination distance indicates evacuees consider increased in negative utility. Interstate proximity was found to be insignificant in building the friend/relative model. The hotel/motel model shows that the number of hotels, interstate proximity, and white percentage positively contribute toward the attraction of the destination. Origin to destination distance and risk indicator still shows negative utility. The variable, metropolitan area was eliminated because it was found insignificant for the hotel/motel model.

Using a spatially correlated logit model and multinomial logit models, Parady and Hato (2016) considered socio-demographic characteristics (gender, age, the number of children, and the number of elderlies in the household) and tsunami evacuation characteristics (origin-destination distance, distance to sea at origin, destination distance to sea, altitude at origin, and altitude of destination). Variables considered for the utility function are origin-destination network distance, origin-destination difference in average zone altitude, number of landlines, and number of shelters. A multinomial model and two spatially correlated logit models were developed in the study. In the three models, origin-destination distance showed negative parameter estimate values while the other variables are positive. The negative values of the origin-destination distance negatively increase the utility. The positive values of other parameters indicate that the evacuees are more likely to choose the officially designated shelters due to these variables.

2.2 Existing Destination Choice Models

Wilmot *et al.* (2006), using a gravity model found the need for calibration of every accommodation type independently. However, the study ignores the process of how households choose between destinations. Additionally, the multinomial logit models developed by Cheng *et al.* (2008) using Hurricane Floyd in 1999 were only developed for people evacuating to family/relatives or hotels/motels. Both models were tested and claims that there are no significant differences. This study requires strong aggregation assumptions and does not account for the type of destination.

The logistics regression models developed for Florida (Smith and McCarty, 2009) considered family/relatives' homes, hotels/motels, and public shelter as the destination choice. These models were developed separately for each accommodation. Some variables such as race, age, and education were not considered as significant variables, unlike previous studies. New significant variables found by Smith and McCarty are previous experience with floods and the number of years living in their homes. Additionally, Mesa-Arango *et al.* (2013) created a household-level model for hurricane evacuation destination type choice using data during the flood event in 2004 by Hurricane Ivan. A gap that can be highlighted in this study is the consideration of several endogenous variables. Additional socioeconomic information is also needed in the study. Also, Parady and Hato (2016) built three destination choice models for tsunami evacuation using a spatially correlated logit with the adjacency-based allocation parameter, and a spatially correlated logit with the distance-altitude allocation parameter. There are two major gaps in the research that are worth highlighting. The first is that households were not considered in the study. Socio-demographic factors were not found to be statistically significant. The second limitation is that the destination choice models were independently developed from other phases of evacuation.

2.3 Quezon City Household Destination Choice Model

Lim (2016) developed an evacuation destination choice model using data collected in QC

Philippines in 2013. From data collected, the study shows that 48.6% of households in Quezon City, Philippines chose public shelters as their destination of choice while 23.0% and 28.4% went to churches/seminaries and family/relatives' homes respectively. It is also indicated that most of the households stayed at their destination within 1-2 days. Factors identified as important to the choice of destination include socio-demographic characteristics of the household, household capacity-related information, hazard-related information, and destination-specific information. The QC models indicate that evacuees prefer closer secure destinations. Comparing the likelihood of choosing between public shelters or homes of family and relatives, evacuees that were warned by the authorities and with low monthly income have a higher likelihood of evacuating to public shelters. Households that have the equipment, are farther from the source of hazard, and received warning from the authorities have a higher probability of choosing public shelters. Additionally, farther evacuation distances and longer duration of stay at the destination show that households are likely to go to public evacuation centers. Also, households that stay longer in the destination are more probable to spend more, therefore, when households spend money on necessities, the less likely they will stay in that destination in the future. Evacuees that travel less than 200 meters will likely choose family/relatives' house. Further, the model estimation for church/seminaries indicates that presence of flood equipment, traveled more than 200 meters when evacuating, stayed more than two days are indicators that households will likely choose churches/seminaries compared to family/relatives' house. When households must spend money on their stay in the destination, the less likely they will choose it again in the future. Household monthly income, the distance of the house from the hazard, and source of warning were also found significant in destination choice.

2.4 Model Transferability

According to the Transportation Research Board (2014), individual coefficients are not significantly when models are estimated using data from different regions. First, TRB (2014) found that variables characteristics that apply to population segments are more transferable compared to individual factors. Second, smaller group variables are more transferable than the alternative-specific constants. Third, models that deal with activity generation and scheduling are more transferable than models that deal with mode choice and location choice. And fourth, models for areas within the same states are more transferable than those that are from different states. Moreover, Patton *et al.* (2015), by applying four different neighborhood-specific models to each other, tested the transferability of land-use regression models. Root-mean-square error (RMSE) and the coefficient of determination (R^2) were used to assess the model compared to the neighborhood-specific models. Transferred models with explanatory variables from the original neighborhood and recalibrated coefficients performed as well as original models.

Further, city-specific land-use regression models were generated by Zalzal *et al.* (2019) for ultra-fine particles using data collected from Montreal and Toronto, Canada. City-specific models were created in each city before transferring to the other city with and without recalibration. The calibrated model showed a decrease in performance with the coefficient of determination for both Toronto and Montreal. Additionally, Baghestani *et al.* (2016) used transferability test statistics (TTS), transfer index (TI), and ρ^2 c-trans in transferring study mode choice model for work trips in Iran. A model developed for Qazvin, Iran was transferred to Shiraz, Iran at a parameter level and a structural level. The transferability test statistic tests the equality of parameters in estimation and application context with an acceptable range of less than the critical χ^2. The transfer index, the ratio of the estimated model to the application context model, was acceptable. The ρ^2 c-trans or the goodness of fit of the estimated model for the application context also has an acceptable range of zero to one. Models are proven to be transferable using the TI and ρ^2 c-trans, unlike the TTS which rejected the null hypothesis. Baghestani *et al.* suggest that models be calibrated for other cities and models be extended to compare with probit and logit or nested logit models.

Moreover, Moon *et al.* (2017) proposed a method of describing an application niche of a model during the model selection process. Model users acquire information from previous studies and/or previous model transfers to create a model performance curve and heat map. The method was demonstrated by using a model created to predict the ecological condition of plant communities in riverine wetlands of the Appalachian Highland physiographic region in the USA. Transferability was assessed across a riverine wetland in the contiguous United States, wetland types in the Appalachian highland physiographic region, and wetland types in the contiguous United States. Moreover, Vienneau *et al.* (2010) compared land-use regression models for NO_2 and PM_{10} from Great Britain to the Netherlands using R^2 regression analysis but resulted in poor performance. The performance of transferred models is substantially worse compared to country-specific models due to huge differences of variables between the countries. The conclusion of Vienneau *et al.* is that care is needed in transferring models across different study areas, and in creating large inter-regional models. Further, Allen *et al.* (2011) also assessed the transferability of land-use regression models between cities and pollutants through R^2 regression analysis. Models transferred between cities did not perform as well as locally calibrated models.

3. METHODOLOGY

In this section, details presented include that of the study area, evaluation of QC evacuation destination choice model, processes of data collection, and assessment of the transferability of the QC model to Marikina City.

3.1 Study Area Context

The geography and composition of Marikina City can be seen in Figure 1 which also displays the flood hazard map following the rainfall return rate in the city. The red marks indicate that flood hazards are at least 1.5 meters high. The orange marks indicate that flood hazards are from 0.5 meters to 1.5 meters. Lastly, the yellow marks indicate that flood hazards are at most 0.5 meters.

Based on the 2015 census of the population by the Philippine Statistics Authority (PSA) (2015), Marikina has a total of 450,741 individuals. According to Marikina City Disaster Risk Reduction and Management Office (MDRRMO) in 2014, Marikina is one of the largest cities in Metro Manila in terms of land area which is approximately 21.5 square km or 2,150 hectares composed of 16 barangays. It is about 3.42% of Metro Manila's land area. Marikina comprises 39.7% residential, 19.2% commercial and industrial, 17.4% for roads, 8.3% for priority development, 7.2% mixed-used zones, 6.3% for parks, institutional and cultural heritage, and 1.8% for cemeteries. Marikina lies on a location called the Marikina Valley nestled amid mountain ranges and rolling hills. The north of Marikina occupies most of the south bank of the Nangka river. The east of Marikina is bordered by the Sierra Madre Mountains of Antipolo. The southeast slices by Sapang Baho River which occupies the northwest bank. Marikina city is sliced by the Marikina River. The topography is characterized as flat terrain, with a mildly sloping portion visible in the eastern part of the city.

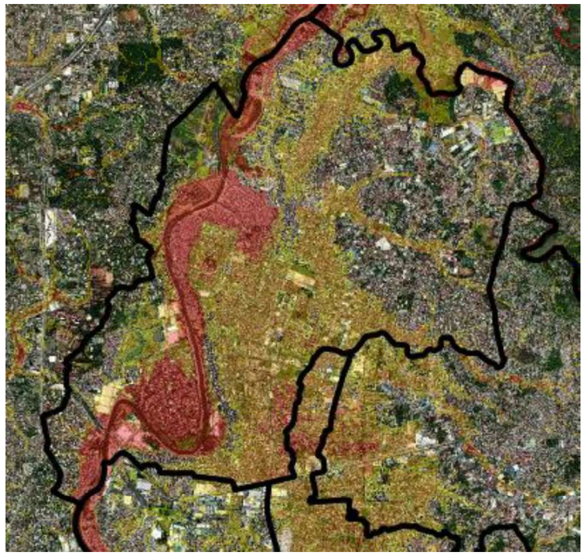

Figure 1. Marikina City 5-year flood hazard map.
Source: Nationwide Operational Assessment of Hazards (2020)

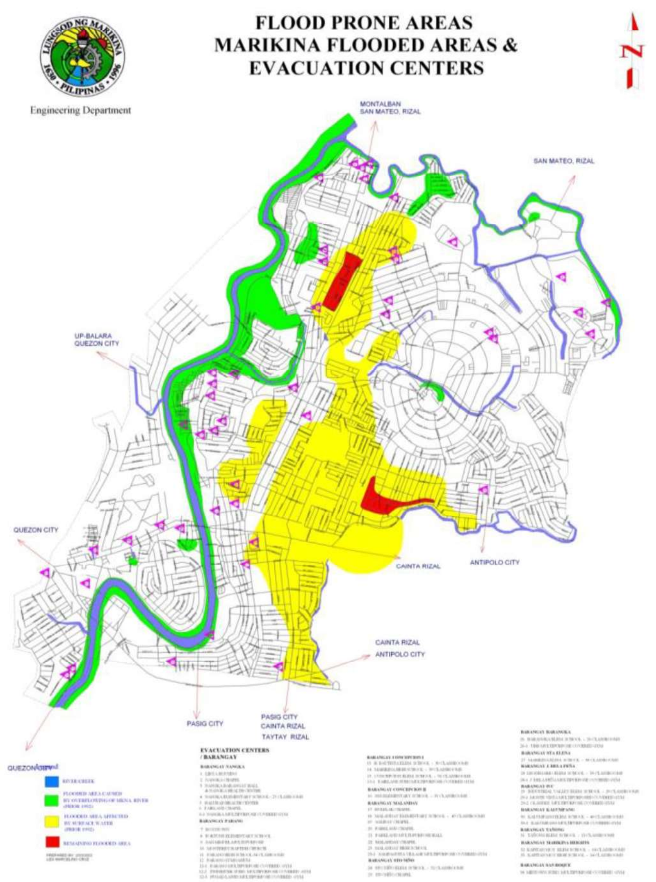

Figure 2. Flood-prone areas and evacuation centers in Marikina City.
Source: Marikina City Disaster Risk Reduction Management Office (2014)

Figure 2 shows flood-prone areas and evacuation centers in Marikina City. Barangay Nangka has Libya Housing, Nangka Chapel, Nangka Barangay Hall and Health Center, Nangka Elementary School, Balubad Health Center, Fairlane Chapel, and Nangka Multi-purpose Gym as evacuation centers. Meanwhile, Barangay Malanday has Bulelak Chapel, Malanday Elementary School, Aglipay Chapel, Parkland Chapel, Parkland Multi-purpose hall, Malanday Chapel, Malanday High School, and Sampaguita Village Multi-purpose Covered Gym. Also, Barangay Santo Niño has Santo Niño Elementary School and Santo Niño Chapel. Lastly, Barangay Tumana has Concepcion Integrated School and another Santo Niño Chapel.

3.2 Quezon City Flood Evacuation Destination Choice Model

The QC flood destination choice model developed by Lim (2016) for public shelters is shown in Table 1 and for church/seminaries in Table 2. The transferability of these was assessed using data from Marikina. The destination choice of homes of family/relatives was the basis of estimation for the two models.

Table 1. Quezon city parameter estimates of the model households for public shelters

Variable	**β**	**S.E.**	**OR**	**T-Stat**	**P-Value**	**95% Confidence Interval**	
						Lower	**Upper**
Constant	-0.695	0.319		-2.18	0.029	-1.319	-0.07
capacity-related characteristics							
Indicator variable for INCOME (1 for income >PHP 5,000.00, 0 o.w.)	-0.491	0.172	-0.388	-2.859	0.004	-0.828	-0.154
Indicator variable for EQUIP (1 for those who have equipment for flood, 0 o.w.)	0.358	0.422	1.43	0.847	0.397	-0.47	1.186
Indicator variable for DIST (1 for >20 m house location from source of flood, 0 o.w.)	0.222	0.101	1.248	2.2	0.028	0.024	0.42
Indicator variable for SWARN (1 if authorities are source of evacuation advice, 0 o.w.)	0.604	0.243	1.829	2.484	0.013	0.127	1.08
evacuation destination-specific characteristics							
Indicator variable for DCOST (1 if households paid some costs for instance food while staying at destination, 0 o.w.	-0.002	0.001	-0.002	-2.778	0.005	-0.003	0
Indicator variable for EDIST (1 for travel distance to destination >200 m, 0 o.w.)	0.798	0.142	2.22	5.6	0	0.518	1.077
Indicator variable for DUR (1 if households stayed more than 2 days at destination, 0 o.w.)	0.835	0.311	3.306	2.689	0.007	0.227	1.444

Source: Lim et al. (2016)

For public shelters, the model states that the household income with a coefficient (β= -0.491) means that households with income greater than PHP 5,000.00 have a lower likelihood of choosing public shelters compared to family/relatives' house when everything else remains constant. The coefficient for the presence of equipment against flood (β=0.358), shows that households that have equipment against flood are more likely to select public shelters. The coefficient of distance from the source of hazard (β=0.222), indicates that households farther from the source of the flood have a higher probability of going to public shelters compared to family/relatives' house. The source of evacuation warning is also significant in choosing the destination choice. The result (β=0.604) shows that when the warning received came from the authorities, households are likely to go choose public shelters. The coefficient of cost of stay at destination (β=-0.002), means that when households must pay for their needs, the less likely they will choose it again. The coefficient of the distance traveled (β=0.798), shows that those who traveled more than 200 meters when evacuating are more likely to go to public shelters while households who traveled less than 200 meters have a higher probability of choosing the homes of family/relatives. The last significant variable, duration of stay (β=0.835), means that households that stayed more than two days have a greater probability of choosing public shelters than family/relatives' house.

Table 2. Quezon city parameter estimates of the model households for church/seminaries.

Variable	β	S.E.	T-Stat	P-Value	OR	95% Confidence Interval	
						Lower	Upper
Constant	-0.704	0.369	-1.905	0.057		-1.428	0.02
capacity-related characteristics							
Indicator variable for INCOME (1 for income >PHP 5,000, 0 o.w.)	-0.301	0.199	-1.511	0.131	-0.26	-0.692	0.089
Indicator variable for EQUIP (1 for those who have equipment for flood, 0 o.w.)	1.218	0.426	2.856	0.004	3.379	0.382	2.053
hazard-related characteristics							
Indicator variable for DIST (1 for >20 m house location from source of flood, 0 o.w.)	-0.031	0.124	-0.245	0.806	-0.03	-0.274	0.213
Indicator variable for SWARN (1 if authorities are source of evacuation advice, 0 o.w.)	-0.544	0.282	-1.926	0.054	-0.419	-1.097	0.01
evacuation destination-specific characteristics							
Indicator variable for DCOST (1 if households paid some costs for instance food/water while staying at destination, 0 o.w.)	-0.003	0.001	-2.497	0.013	-0.003	-0.005	0.001
Indicator variable for EDIST (1 for travel distance to destination >200 m, 0 o.w.)	0.761	0.172	4.436	0	2.141	0.425	1.097
Indicator variabe for DUR (1 if households stayed more than 2 days at destination, 0 o.w.)	0.352	0.389	0.904	0.366	1.422	-0.411	1.114

Source: Lim et al. (2016)

For church/seminaries, the coefficient of the presence of equipment against flood

(β=1.218) means that households that are prepared for flood have a higher probability of choosing church/seminaries. The coefficient of the cost of staying at the destination (β=-0.003), indicates that when households spend at the destination for their basic needs, the less likely that they will choose that destination in the future. The distance traveled when evacuating, with coefficient β=0.761, means that households who traveled more than 200 meters when going to destination are likely to choose church/seminaries compared to homes of family/family. The variable, duration of stay with coefficient β=0.352, indicates that households that stayed more than two days at the destination have a higher probability of going to church/seminaries than choosing homes of family/relatives. The coefficient of household income (β=0.301) indicates that households with incomes higher than PHP 5,000 have a lower likelihood of choosing church/seminaries compared to homes of family/relatives. The coefficient of the distance of their house from the source of the flood (β=-0.031) and coefficient of the source of evacuation warning (β=-0.544) are also significant in choosing flood evacuation destination due to evidence in the literature.

3.3 Design of Questionnaire

The design of the questionnaire was based on the questionnaire used by Lim (2016). The questionnaire was divided into three sections. The first section contained socio-economic and household characteristics. The second section included the evacuation experience during their evacuation in 2018. Section three contained comments and suggestions for future evacuations. Questions were designed to collect the necessary data of socio-demographic characteristics of the household and capacity (age, gender, marital status, educational status, presence of senior citizens, presence of small children), household capacity-related information (household monthly income, house ownership, house floor levels, type of house material), risk-related factors (the distance of residence from the source of hazard, presence of flood equipment/materials, source of evacuation warning), and destination-specific characteristics (distance traveled to the destination, cost of stay at the destination, duration of stay at the destination). The questionnaire developed in English was translated into Filipino.

3.4 Data Collection and Preparation

The Marikina City government (MCG) recommended a list of high flood risk areas in Marikina City. The number of evacuees from Marikina in the 2018 flood disasters due to tropical storm Yagi was also obtained from MCG. The flood risk areas considered in the study were identified through Marikina City Disaster Risk Reduction Management Office (MDRRMO) Contingency Plan in 2014. The MDRRMO identified seven highly susceptible barangays in the city. The four barangays that have the biggest population, the largest land area and history of evacuation due to the flood disaster in 2018 were selected. These barangays are Malanday, Nangka, Tumana, and Santo Niño. The street map of the four high-risk barangays is shown in Figure 3. According to the 2015 census of the Philippine Statistics Authority, Malanday, Nangka, Tumana, and Santo Niño have 12,250, 9,609, 9,816, and 7,143, households, respectively. These four barangays also have the largest land area among the seven barangays identified as highly susceptible to flood. According to the MDRRMO (2014), Malanday has 87.37 hectares, Nangka has 145.55 hectares, Tumana has 181.97 hectares, and Santo Niño has 145.55 hectares.

Face-to-face interviews were conducted through coordination with the sub-district's local officials between September 2020 and October 2020. The variables used as shown in Table 3 were collected through the survey. From the four barangays, the pooled population of data for high-risk areas in Marikina City is 38,818 households. To obtain a 90% confidence level with a 5% margin of error, at least 269 household respondents were needed. 480 household survey questionnaires were distributed. The data was summarized and cross-checked for validity based on the questions needed. Responses with missing and invalid information were discarded and were removed from the analysis. The data was summarized and coded according to the requirement of the statistical tool in transferring the model of the previous study in Quezon City to the present study area, Marikina City as shown in Table 3. A total of 362 observations was used for data analysis.

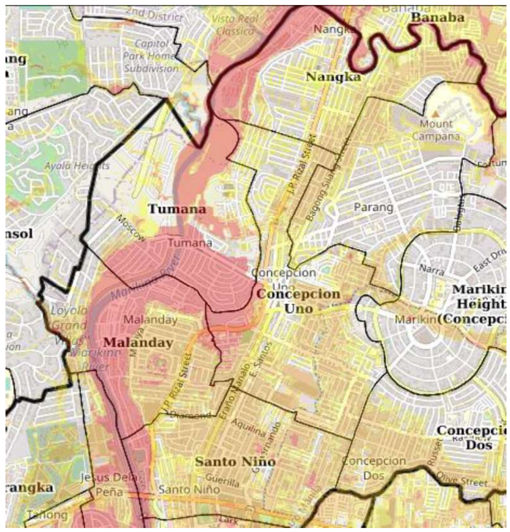

Figure 3. Street Map of Malanday, Nangka, Santo Niño and Tumana, Marikina City.
Source: Nationwide Operational Assessment of Hazards, 2020

Table 3. Variables in household data set and coding used.

Variable	Code	Description
Destination Choice (DDEC)	1	Public Shelter
	2	Church/Seminary
	3	Family/relatives' House
Capacity Related Characteristics		
Monthly income of the household (in Philippine peso, PHP) (INCOME)	1	1,000-5,000
	2	5,001-10,000
	3	>10,000
Presence of prepared equipment/materials for flood (EQUIP)	1	Otherwise
	2	With Equipment
Hazard Related Characteristics		
Distance from the Source of Hazard (DIST)	1	0-10m
	2	11-20m
	3	21-30m
	4	>30m
Source of Evacuation Warning (SWARN)	1	Friends/relatives/television/radio
	2	Sub-district/village official
Destination Specific Characteristics		
Cost for food and water while staying at the destination (DCOST)	1	No cost incurred
	2	Cos ranged from PHP 100-2,000
Distance Travelled to Destination (EDIST)	1	10-200 meters

Variable	Code	Description
	2	200-400 meters
	3	>400 meters
Duration of Stay at the Destination (DUR)	1	1-2 Days
	2	3-4 Days
	3	>4 Days

Source: Lim et al. (2016)

3.5 Model Transferability Assessment

The utility function for flood evacuation destination type choice is shown in Equations 1, 2, and 3 where $U_{ph,}$, U_{ch} and U_{fh}, are the utility functions for destination type choice, of public shelters, *p*, church/seminaries, *c,* and family/families' homes, *f*, respectively. U_{ch} is equal to 0 since it was used as the basis for model estimation. ε the error terms corresponding to the model parameters shown in Tables 1 and 2. While the probability of choosing an evacuation destination type of a household, h, $P_{ph,}$, P_{ch} and P_{fh}, for public shelters, *p*, church/seminaries, *c,* and family/families' homes, *f,* are shown in Equation 4, 5, 6, respectively. Using the QC coefficient values as presented in Tables 1 and 2, the data from Marikina was used as independent variable inputs. Utilities for each destination type choice were determined using equations 1, 2, and 3. Then, the probability of a category being chosen was according to actual decisions from the Marikina data were calculated using equations 4,5, and 6. After these, the predicted probability is assessed and compared to the actual decision of households in Marikina. The values of the computed predicted probability greater than 0.5 govern whether a household, h, chooses among the destination choices.

$$U_{ph} = -0.695 - 0.491\,INCOME + 0.358\,EQUIP + 0.222\,DIST + 0.604\,SWARN - 0.002\,DCOST + 0.798\,EDIST + 0.835\,DUR + \varepsilon_{ph} \tag{1}$$

$$U_{ch} = -0.704 - 0.301\,INCOME + 1.218\,EQUIP - 0.031\,DIST - 0.544\,SWARN - 0.003\,DCOST + 0.761\,EDIST + 0.352\,DUR + \varepsilon_{ch} \tag{2}$$

$$U_{fh} = 0 - 0.704 \tag{3}$$

$$P_{ph} = \frac{e^{U_{ph}}}{e^{U_{ph}+U_{ch}+U_{fh}}} \tag{4}$$

$$P_{ch} = \frac{e^{U_{ch}}}{e^{U_{ph}+U_{ch}+U_{fh}}} \tag{5}$$

$$P_{fh} = \frac{e^{U_{fh}}}{e^{U_{ph}+U_{ch}+U_{fh}}} \tag{6}$$

To assess whether the predictive ability of the QC model using the data from Marikina households, the results were evaluated using two types of pseudo R^2. These are the Count R^2 and Tjur R^2. These are used in evaluating the destination choice model direct transfer of regression parameters. The goodness of fit of the variables from Marikina City used as inputs to the QC models was computed using absolute goodness of fit. According to the Institute for Digital Research and Education Statistical Consulting (2011), count R-squared does not measure the goodness of fit as compared to other ordinary least squares (OLS) regression approaches. It transforms the predicted probability into a binary variable on the same scale as the outcome variable. It then evaluates whether the prediction is correct or not. It treats the predicted probability of greater than or equal to 0.5 as 1 and treats less than 0.5 as 0. The number of correct counts was determined by obtaining the number of predicted outcomes that matched their respective actual outcomes. Count R^2 is computed by dividing the correct predicted count by the total count. It measures how well the model predicts the correct value of the dependent variable using known values. Values of the computed predicted probability greater than 0.5 govern whether a household will choose public shelters or homes of relatives/family. The equation for R^2 for count is shown in Equation 7 where C is the number of correct counts and T is the total number of counts. R^2 values closer to 1 mean QC model predicts outcomes from Marikina City.

$$R^2 = \frac{C}{T} \tag{7}$$

Moreover, Tjur R^2 or Tjur's coefficient of discrimination is a fit statistic that only applies to logistic regression. Tjur R^2 is the distance or absolute value of the difference between the two means of the predicted 0's and 1's. It is a type of pseudo R^2 for multinomial logistic regression shall govern since it provided the average fitted probability for the binary outcome that was correctly predicted, and the average fitted probability for the binary outcome that was incorrectly predicted. It compares the average fitted probability of the response outcomes. It is the difference between the average fitted probability coded to 1 and the average fitted probability coded to 0. Outcomes coded as 1 are success outcomes while outcomes coded as 0 failed outcomes (Tjur, 2009). The equation for Tjur R-squared is shown in Equation 8 where $\hat{\pi}$ is the average fitted probability. Values of R-squared closer to 1 indicates the QC model is transferable to Marikina City.

$$R^2 = \frac{1}{n_1}\sum \hat{\pi}(y = 1) - \frac{1}{n_0}\sum \hat{\pi}(y = 0) \tag{8}$$

The more an R^2 value is closer to one, the better is the transferability of the model. According to Moore *et al.* (2013), R^2 values less than 0.3 are generally considered very weak transferability. R^2 values between 0.3 and 0.5 mean the transferability of the destination choice models is weak. Values greater than 0.5 but is less than 0.7 indicate that the transferability of the model is considered moderate. Lastly, R^2 values greater than 0.7 shows that the destination choice models are strongly transferable.

4. RESULTS AND DISCUSSIONS

This chapter discusses the ability of the QC flood evacuation destination choice model to predict the travel behavior of households in Marikina City. It evaluates the degree of error when using the destination choice model and compares the two methods of transferability assessment that were used.

4.1 Data and Variable Correlations in the Model

From the 326 observations from households in Marikina City (shown in Figure 4), the majority of households, with 74.5% of the total data set went to public shelters provided by the local government. A total of 23% of the households chose the homes of their family/family as their evacuation destination choice. A small percentage (2.5%) of the respondents went to churches or seminaries during the flood disaster.

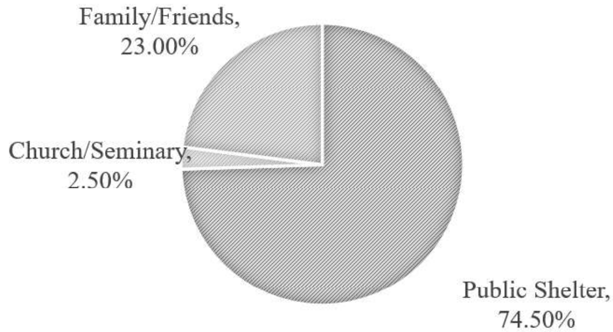

Figure 4. Destination Type Choice of Marikina City Households.

Table 4. Variables used in assessing the transferability to Marikina City.

Variable	Description	Frequency	% In Data
Destination Choice (DDEC)	Public Shelter	243	74.5
	Church/Seminary	8	2.5
	Family/Relatives House	75	23
	Capacity Related Characteristics		
Monthly income of the household (in Philippine peso, PHP) (INCOME)	1,000-5,000	139	42.6
	5,001-10,000	150	46
	>10,000	37	11.3
Presence of prepared equipment/materials for flood (EQUIP)	No equipment	311	95.4
	With Equipment	15	4.6
	Hazard Related Characteristics		
Distance from the Source of Hazard (DIST)	0-10m	94	28.8
	11-20m	84	25.8
	21-30m	23	7.1
	>30m	125	38.3
Source of Evacuation Warning (SWARN)	Family/relatives/television/radio	71	21.8
	Sub-district/village official	255	78.2
	Destination Specific Characteristics		
Cost for food and water while staying at the destination (DCOST)	No cost incurred	157	48.2
	Cost ranged from PHP 100-2,000	169	51.8
Distance Travelled to Destination (EDIST)	10-200 meters	80	24.5
	200-400 meters	141	43.3
	>400 meters	105	32.2
Duration of Stay at the Destination (DUR)	1-2 Days	190	58.3
	3-4 Days	72	22.1
	>4 Days	64	19.6
Total Number of Observations used in Analysis, N		326	100

Further, Table 4 shows the variables used. Almost half (46%) of the respondent households have a household income between PHP 5,000 and PHP 10,000. 42.6% of the households have a household income of less than PHP 5,000. Only 11.3% of the households have a household income greater than PHP 10,000. Based on the response of the Marikina City residents, 95.4% of the households do not have equipment or materials against flood, and only 4.6% of the households prepared equipment.

Under hazard-related characteristics is the distance of households from the source of hazard (DIST). From the results, 38.3% of the respondents are more than 30 meters from the source of the flood. The rest of the respondents are composed of households from 0-10 meters (28.8%), 11-20 meters (25.8), and 21-30 meters (7.1%). The source of evacuation warning (SWARN) is mostly received from the local authorities or the barangay officials (78.2%). The remaining 21.8% of the respondents received the source of evacuation warnings from the television/radio or family/family.

Destination-specific characteristics considered are cost while staying at the destination (DCOST), traveled distance from the origin to destination (EDIST), and duration of stay at the destination (DUR). 48.2% of the household respondents did not pay for their needs in the destination while 51.8% of paid for their stay. Also, households that traveled for less than 200 meters are 24.5% and households that traveled between 200 meters and 400 m is 43.3%. The remaining percentage traveled for more than 400 meters. The residents in the highly susceptible areas mostly stay for 1-2 days at the destination. Only 22.1% of the households stayed for 3-4 days and only 19.6% stayed for more than 4 days at their respective destination choice.

4.2 Model Transferability Assessment

The utilities and probabilities of outcomes using the QC Models with the Marikina data as inputs, were first calculated. Tables 5 and 6 show the sample results for determining such utilities and probabilities, where the number codes used are according to the variable codes presented in Table 3. Due to the many data calculated for each type of destination, only a few sample calculated results are presented here. After calculating the utilities and probabilities based on equations 1-6, the predicted outcomes were determined. Table 5 shows the resulting utilities and probabilities calculated for the public shelters. The predicted choice calculated using the probability equation 4 was compared to the actual destination choice of those that went to public shelters. These results were then used to determine how many percent of the data was predicted using the QC model for the destination choice. On the other hand, Table 6 shows the resulting utilities and probabilities calculated for those that went to church/seminaries. Like the process conducted for the public shelter model, the predicted choice was calculated using the probability equation 5. This was then compared to the actual destination choice of those that went to church/seminaries. These were also utilized in determining how much of the data was predicted using the QC model for the specific destination. Table 7 indicates the number of correct and incorrect outcomes after the comparison with the actual outcomes of the public shelter model and church/seminary model, respectively.

Based on the actual calculations, there were 284 households that went to public shelters while 35 households went to the homes of family/relatives. However, as shown in Table 7, only 221 of these predictions matched the actual outcomes and 98 were failed predictions. The church/seminary actual calculations show that there were 39 households that chose church/ seminaries while 43 households went to the homes of friends/relatives. However, only 44 of these predicted outcomes matched the actual destination choice and 38 of the predicted choice were incorrect. Table 8 shows the transferability assessment of the directly transferred public shelter model and the church/seminary model using count R^2 and Tjur R^2. Both QC destination choice models were directly transferred to Marikina City household data.

Table 5. Sample Utility and Probability Calculated for Public Shelter Model

UTILITY		PROBABILITY			
Public Shelter	Family/Relatives	Public Shelter	Family/ Relative	Predicted Choice	Actual Choice
-2.095	0	0.110	0.890	3	1
3.208	0	0.961	0.039	1	1
3.208	0	0.961	0.039	1	1
3.208	0	0.961	0.039	1	1
2.54	0	0.927	0.073	1	1
1.649	0	0.839	0.161	1	1
1.849	0	0.864	0.136	1	1
-5.458	0	0.004	0.996	3	1
4.189	0	0.985	0.015	1	1

Table 6. Sample Utility and Probability Calculated for Church/Seminary Model

UTILITY		PROBABILITY			
Church/ Seminary	Family/ Relatives	Church/ seminary	Family/ Relatives	Predicted Outcome	Actual Outcome
0.149	0	0.537	0.463	2	2
-2.094	0	0.110	0.890	3	2
-2.094	0	0.110	0.890	3	2
1.149	0	0.759	0.241	2	2
1.096	0	0.750	0.250	2	2
0.114	0	0.528	0.472	2	2
-5.121	0	0.006	0.994	3	2
-5.937	0	0.003	0.997	3	3
-0.543	0	0.367	0.633	3	3

Table 7. Predicted Outcome Results using the Probability Function

	Correct Predicted Outcomes	Incorrect Predicted Outcomes	Total Outcomes
Public Shelter	221	98	319
Church/Seminary	44	38	82

The assessment of the QC Public Shelter Model showed that it is moderately transferrable to Marikina City using count R^2 since the value is between 0.5 and 0.7. The model predicted 221 correct destination choice outcomes out of 329 total responses from households. Using Tjur R^2, the public shelter QC model strongly predicts the decision of Marikina City households. This is because it obtained a 0.7079 value which is greater than 0.7. The difference of both R^2 values is due to Tjur's ability to clear separation between the predicted values for the 0's and 1's. The strong transferability of the public shelter model can be supported by the claims of Zalzal *et al.* (2019) that models are transferrable between cities with similar features. In the case of this study, Marikina City and QC are adjacent cities in the same region of the Philippines.

Table 8. Model Transferability Assessment using Count R^2 and Tjur R^2.

	Count R^2	Tjur R^2
Public Shelter	0.6928	0.7079
Church/Seminary	0.5366	0.0855

On the other hand, the result of the transferability assessment of the church/seminary model using count R^2 showed that the model is moderately transferrable since the value R^2 of 0.5366 is between 0.5 and 0.7. The predicted outcome was then compared to the actual destination choice of the household. The 44 correct predicted outcomes of the model using Marikina City household data are divided by the total number of households that chose church/seminary of 82. Although through the count R^2, the church/seminary model predicted more than half of the total data, Tjur R^2 confirmed that the model was not transferrable using the limited data. Using Tjur R^2, the value obtained was 0.0855. This R^2 value is below 0.3 which indicates that the model is very weak when directly transferring the QC Model to Marikina City. One major reason for poor results from the church/seminary model is the limited number of households that went to churches or seminary during the Tropical Strom Yagi in 2018. As shown in Table 4, there were very few households (2.5%) that went to the church/seminary. This greatly affected the results of the study.

5. CONCLUSIONS AND RECOMMENDATIONS

Approximately 31% of Metro Manila's land area is prone to flooding. In Marikina City alone, almost 90% are considered flood-prone areas. Seven out of sixteen barangays in Marikina City are highly susceptible to flooding. These barangays include Malanday, Industrial Valley Complex, Tañong, Jesus Dela Peña, Sto. Niño, Nangka, and Tumana. Evacuations are done to reduce disaster risks and damages in households. One of the evacuation decisions that a household resolves is the destination choice. Despite its importance, destination choice modeling has not been widely investigated. To deal with the tediousness of data collection for future evacuation planning and forecasting, the transferability of developed models is evaluated. Transferability is the extension of research in which results in one study are applied to another context. This study evaluated the ability of the QC flood evacuation destination choice model to predict the evacuation behavior of households in Marikina City.

The flood evacuation destination choice models from QC developed by Lim (2016) include a public shelter model and a church/seminary model which was developed using family'/relatives house as the base of model estimation. The destination choice model considers household income, presence of flood preventive equipment, distance from the source of hazard, source of evacuation warning, cost of stay at the destination, distance traveled to the destination, and duration of stay at the destination as significant variables when choosing the destination of choice. Face to face survey was conducted with households affected by Tropical Storm Yagi in Barangays Malanday, Nangka, Santo Niño, and Tumana, Marikina City. The data from the Marikina City households were used as inputs to the QC models directly transferred to the QC flood evacuation destination choice model using the corresponding destination choice utility function and probability function. After calculating the utilities and probabilities accordingly, the predictive ability of the QC models was assessed.

The public shelter model correctly predicted 221 outcomes and incorrectly predicted 98 outcomes. The church/seminary model has 44 correct outcomes and 38 incorrect results. The predicted results and actual results were evaluated using count R^2 and Tjur R^2. The more an R^2 value is closer to 1, the better the transferability of a model. R^2 values less than 0.3 are considered very weak transferability while values between 0.3 and 0.5 are considered weak transferability. R^2 values greater than 0.5 but less than 0.7 have moderate transferability and values greater than 0.7 are generally considered strong transferability. The public shelter model showed a promising transferable result of 0.6928 in count R^2 and 0.7079 in Tjur R^2. However, the church/seminary model showed poor results of 0.5366 and 0.0855 in count R^2 and Tjur R^2, respectively. The result of the church/seminary model assessment is likely because of the limited responses obtained from households that chose churches or seminary during tropical storm Yagi. This can be further investigated by ensuring more data that captures a balanced number of evacuation choice categories. More data were not collected by the researchers due to face-to-face restrictions during the pandemic and time constraints.

Although the results in this study need further investigation due to data limitations, the potential transferability of the QC model to the Marikina City is put to light. Results show the potential use in planning for future evacuation destination needs. Further study is also recommended to compare the directly transferred model to a recalibrated model using the data from households in Marikina City. Specifically, it is recommended to build a new model by transferring and adjusting the coefficients of the old model to obtain a new model that is more appropriate for Marikina City households. Moreover, it is recommended that the assessment of QC models using data from other cities be conducted as an extension of this research. Also, assessing the generalizability of the QC flood evacuation destination choice model to a greater population like the National Capital Region can also expand the purpose of the destination choice models. Further, assessing the generalizability of the destination choice model by directly transferring the model or by recalibrating the model for the greater population can be done in the future.

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