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Spatiotemporal Population Dynamics Based on a Location Survey in Taal Volcano Island, Philippines

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Abstract:- Population distribution is necessary for disaster mitigation initiatives such as evacuation planning. Where technology is insufficient, traditional methods such as actual ground survey of people is still the best option in areas. A location-based survey method to gather hourly distribution of people was utilized to map the population distribution in Taal volcano island. Results show that afternoons during weekdays and weekends are very crucial periods in Taal volcano island. There was also a small margin of difference between weekday and weekend densities. The identification of highest density areas and time periods through the survey was foreseen to supplement evacuation planning and disaster mitigation initiatives in Taal volcano.

Keywords:- *Spatiotemporal; Population Dynamics; Taal.*

I. INTRODUCTION

Dynamic population distribution an important factor to pay attention to in developing an evacuation strategy [1][10]. Human behavior and micro-scale modeling analysis requires detailed information of population in urban areas [3]. Detailed population is essential in understanding exposure to hazards and will have a direct effect on disaster response [2]. Temporal analysis of the population distribution still a huge gap in evacuation research. Previous researches have used location data from mobile phones and train cards [4][6][9]. In situations and areas where these technologies are not available, such as unavailability of transportation cards, smartphones and GPS equipment, a survey is still a good approach to achieve high temporal population distribution.

This study aims to estimate the hourly population density in a volcanic area through a location-based survey, and to determine the densest time periods which would be crucial for evacuation planning in hazard-prone areas.

II. MATERIALS AND METHODS

A. Study Area

The study area is in the volcano island of the Taal Caldera, Philippines. It is the second most active & hazardous in the country, and one of the "Twelve Decade Volcanoes" of the world which means, these have been the top priorities for studies and research due to their activity and high number of population living within its vicinity. Taal is popular for hiking and tourism - sightseeing & recreation, as it is near the country's capital, the Metropolitan Manila. In the Taal volcanic island where around 5,000 people are living, majority of the residents have tour- and horse-guiding and boat-driving as their main source of income. The area was in Brgy. Tabla of the Taal volcanic island. It was selected as it is the welcoming area for tourists who go hiking and horseback riding.

B. Data Collection

Questionnaires were administered to one hundred fifteen (115) respondents in the area during a field survey conducted on 2017 February. Questionnaires with incomplete answers were not disregarded. After reviewing the questionnaires, thirty-nine (39) questionnaires were answered by males, and sixty-nine (69) were by females, ranging from 18 to 71 years old.

Fig. 1a-b shows the location map and survey sheet for the time-location survey. Rows correspond to the days of the week while columns represent the hourly time period. For convenience in answering the survey, letter codes were written in the map. The places outside the defined area (K) were assumed to be in the hiking trails up to the volcano's crater since 50 percent of those that answered the questionnaire work as horse guides or tour guides.

C. Data Analysis

Hourly locations of each 100 person for Weekday (Monday) and Weekend (Saturday) were pinned in Google Earth. The pins were saved as .kmz file to create point-based vector data or shapefiles. The shapefiles were used as input data for creating heatmaps. The heatmap plugin feature in Quantum GIS was utilized to determine the density of points in an area where the default eight-degree radius was used. Distance formula and standard deviation computation from each location to the evacuation area in order to determine the differences between weekend and weekday locations.

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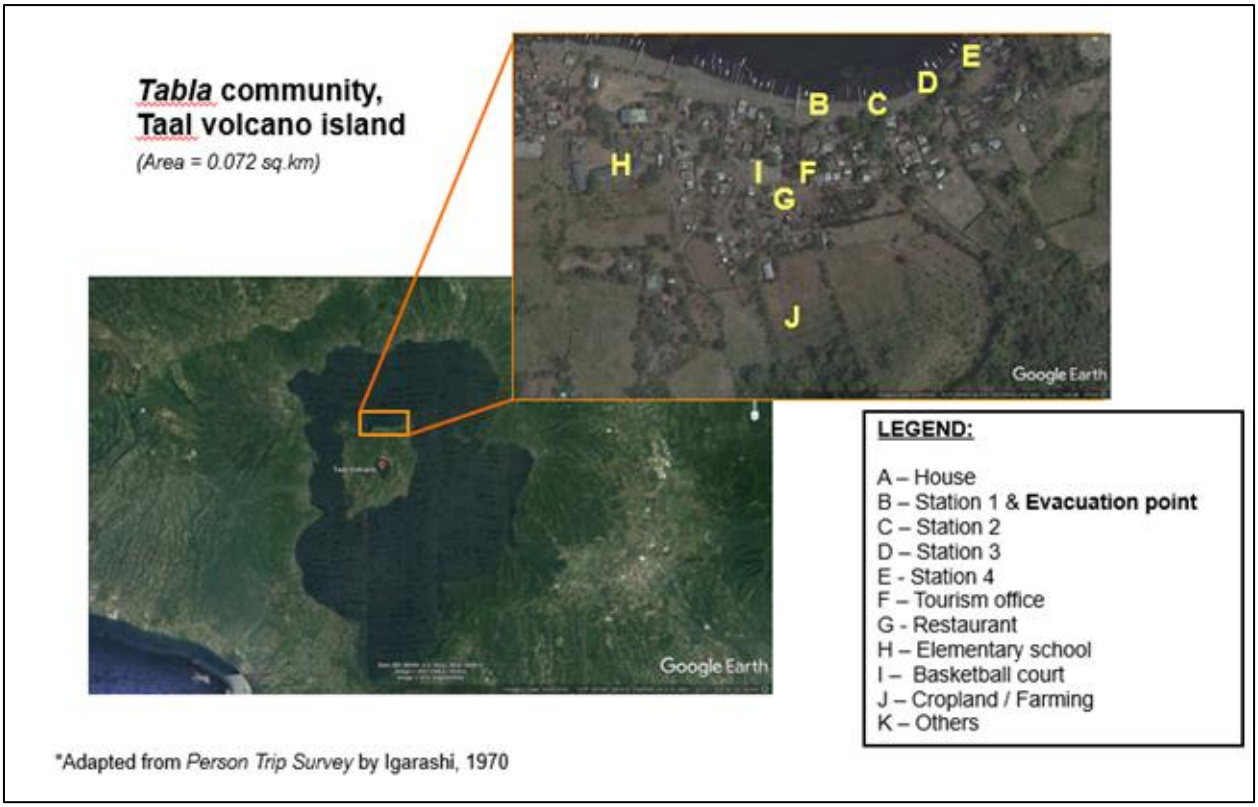
III. RESULTS AND DISCUSSION

A. *Weekday Heatmaps*

Weekday heatmaps (Fig. 2.a-r) show the population distribution in the Taal volcanic area per hour, from 06:00 to 22:00. At 06:00, 7:00 and 08:00, the highest density of people is at homes with 3 to 4 people per 8-degree radius. From 08:00 to 12:00, the highest density is in tourism areas such as shorelines and basketball court, with 3-8 people per 8-degree radius. From 12:00 to 13:00, the highest density is at the canteen and basketball court area. From 13:00 to 18:00, there were around 7-8 people in the basketball court area, but it decreased into 3-4 people from 16:00 to 17:00. From 18:00 to 22:00, the highest density of people is at homes with 3 and 4 people per 8-degree radius.



Base sa mapa sa ikalawang pahina, pakilagay ang letra ng iyong lugar o lokasyon base sa araw at oras na nakatakda.
(Based on the map on the second page, please write the letter of your location based on your activity per day and time)
Halimbawa (example): Kung sa lunes ng 8:00 ng umaga ay ikaw ay nasa basketball court, isulat ang letrang I sa loob ng kahon
(If you will be at the basketball court on Monday at 8:00 a.m., please write I at the corresponding box)

	U M A G A (a. m.)								(nn)	H A P O N (p. m.)					G A B I (p. m.)							(a.m.)
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Lunes (Monday)																					
Martes (Tuesday)																					
Miyerkules (Wednesday)																					
Huwebes (Thursday)																					
Biyernes (Friday)																					
Sabado (Saturday)																					
Linggo (Sunday)																					

Fig 1:- a.) Map of key locations and b.) answer sheet for the time-location survey in Tabla community, Taal volcano island

B. Weekend heatmaps

Weekend heatmaps (Fig. 3.a.-r.) show the population distribution in the Taal volcanic area per hour, from 06:00 to 22:00. Similar to the weekday situation, the highest density of people from 6:00 to 8:00 is at homes with 3 to 4 people per 8-degree radius. From 08:00 to 12:00, the highest density is in tourism areas such as shorelines and basketball court, with 3-8 people per 8-degree radius. From 12:00 to 13:00, the highest density is at the canteen and basketball court area. The afternoon period from 13:00 to 18:00 had the highest density per 8-degree radius with 7-8 people in the basketball court area, but it decreased into 3-4 people from 16:00 to 17:00. Around 3 to 4 people per 8 degree radius are at homes from 18:00 to 22:00.

C. Comparison between Weekday and Weekend

Fig. 4. shows the variation of distances of the population's hourly location from the evacuation point which is the shore area of the Taal volcanic island. The time periods at 13:00 to 17:00 have the highest values at 0.30 to 0.34 km. The higher standard deviation value indicates the varied distance from people's locations to the evacuation point. These values imply that there are areas which are more concentrated and there are not, and there are people who are far away from the evacuation point. Meanwhile, the periods from 18:00 to 22:00 have the lowest values at 0.1 to 0.4 km. There is less variation in the distance of people from the evacuation point which means the distance of people's locations from the evacuation point are almost the same.

D. Spatiotemporal dynamics and implications on evacuation

Dynamics of population distribution in the Taal area depends on the major activities of people in the area. These areas where concentration of people is high show the specific activities of people depending on schedule and type of work. In the case of Taal, plenty of people concentrate in the basketball courts and shores as these are the areas where they accept tourists and hikers to the Taal main volcanic crater. These highly concentrated areas may be prone to congestion and bottlenecks during evacuation especially if routes and collection points are unclear and road routes are not in the best condition for people and vehicles [7].

The differences of population per hour may offer a different point of view in terms of evacuation time estimates for each person in the sense [3][8]. People in uplands are at risk of reaching the evacuation point slowly due to large distance and slope. During high density periods, other routes towards the evacuation point might be considered, and more evacuation points and shelters must be established near the hiking trails and the crater.

IV. CONCLUSION

This study proposed a method on mapping the distribution of population through a time-location survey. The findings were utilized to aid in planning of evacuation activities in Taal volcano. It was found that the areas where there is a high density of population depended on the common source of income activities such as hiking and tourism. There was also no significant difference in the population distribution between weekday and weekends. The time-location survey can be a good option for evacuation planning for high risk areas without access of technology.

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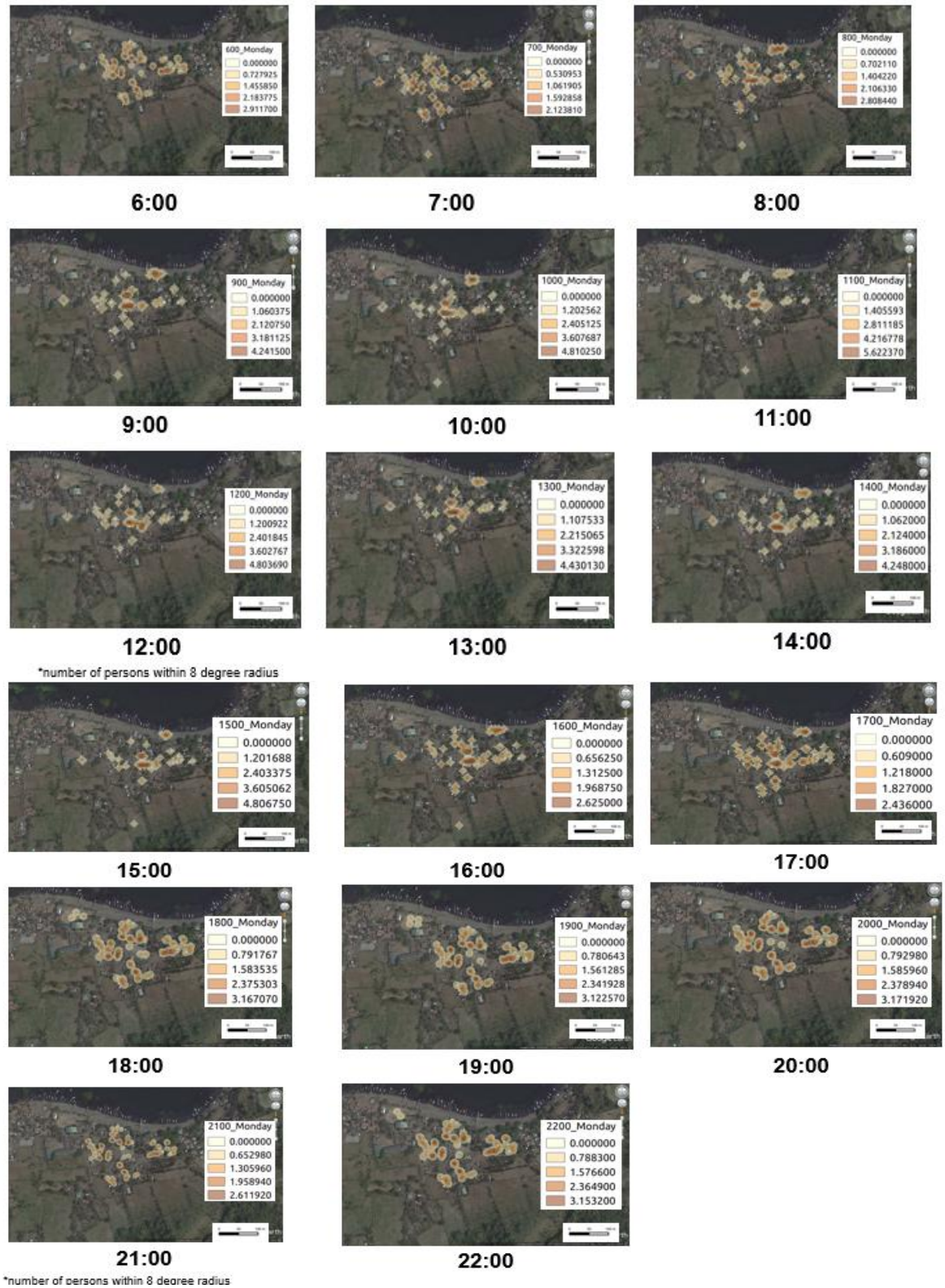

Fig 2:- a-r. Weekday hourly population dynamics in Tabla community

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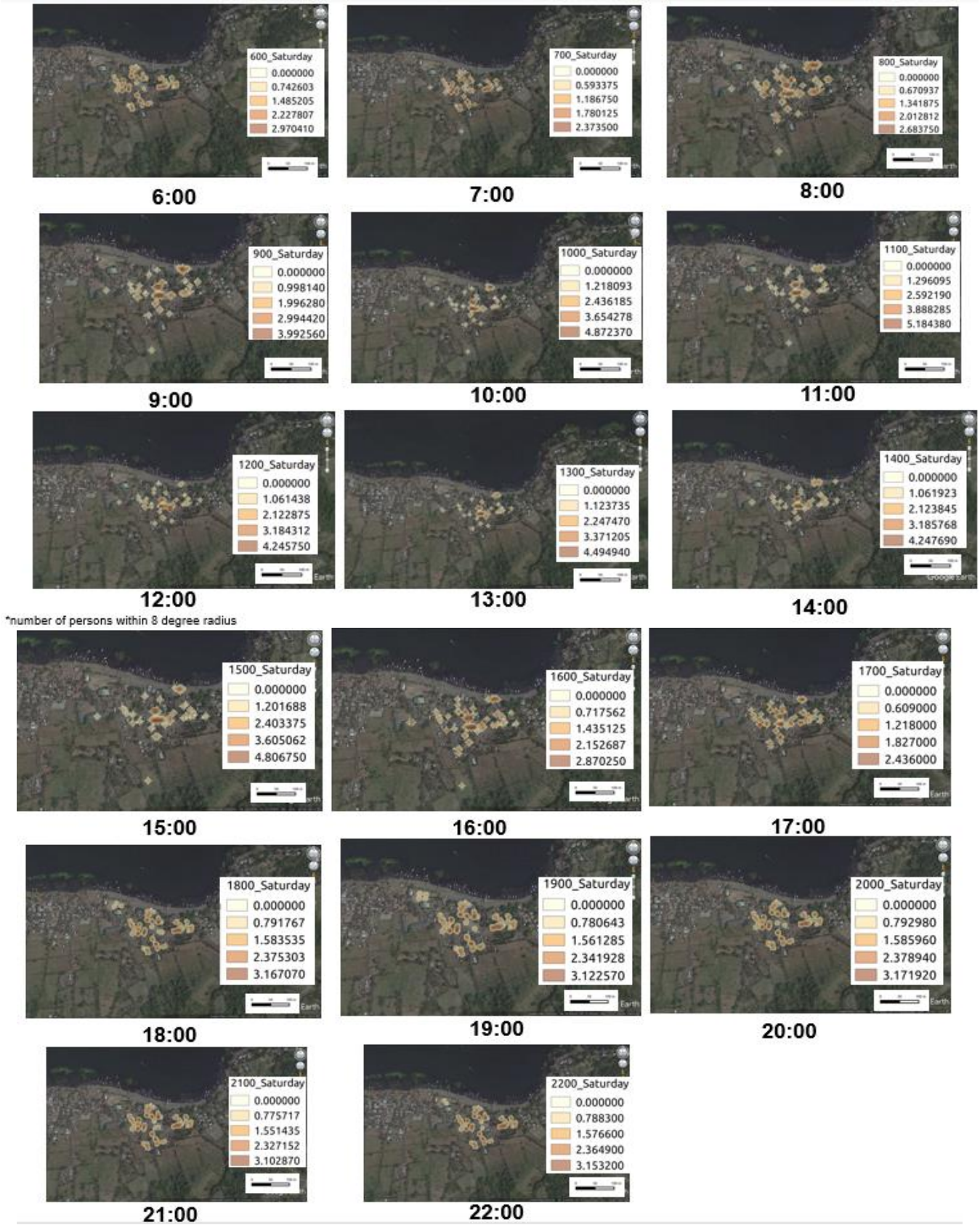

Fig 3:- a-r. Weekend hourly population dynamics in Tabla community

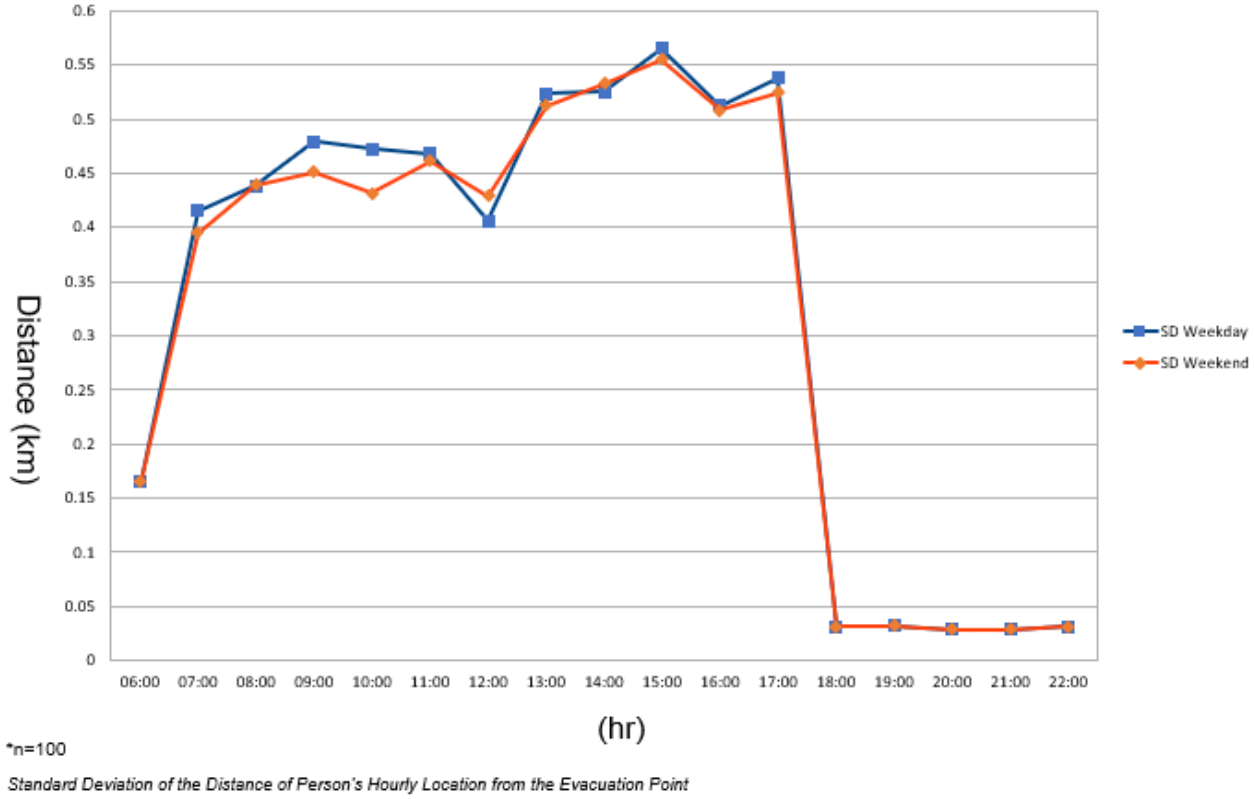

Fig 4:- Variation of distances of the persons' hourly location from the evacuation point