Tsunami Impact Assessment and Evacuation Strategy for Grand Sable Village, Mauritius, Using Remote Sensing and Geographical Information System (GIS)

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Abstract

Tsunamis generated in the Indian Ocean pose a great potential threat to all the countries of the Indian Ocean. Islands such as the Maldives, Mauritius, Reunion Island, the Seychelles and the low lying small atolls are mostly vulnerable. With the decline of Sugar export during the last decade, the Mauritian economy has diverted mainly towards the Tourism Industry. According to Statistics Mauritius, 1,390,000 tourists have visited Mauritius in 2018. Most hotels are located along the coast making the country's backbone vulnerable to the least tsunami threat. It is a fact that although awareness campaigns have been carried out in the island of Mauritius, most coastal villages and hotels do not have proper evacuation procedures against a tsunami warning. This project highlights the vulnerability of the coastal region in Mauritius using a case study of the Grand Sable Village. The objectives of this study is firstly to save the lives of people in the case of an eventual tsunami. All 2223 inhabitants have to be evacuated to a safe area within an adequate time frame after a tsunami alert. Development of Shelter zones can be planned accordingly with integrated resources. The methodology includes the digitalisation of Grand Sable village in the GIS ArcMap software, showing the coastal area with geospatial and attribute data. The raster geo-referenced image of the village was carried out using Google Earth pro. As the village is longitudinal with settlement along a main road, safe Shelter areas have been located after analysis in the GIS Software after overlaying attributes, land use and topography maps. The assembly areas can also provide planning strategies for the setting up of camps, social centres or emergency units.

Keywords: *Tsunami impact assessment, remote sensing, GIS map analysis*

I. Introduction

A. Grand Sable Village, Mauritius.

Mauritius is an island nation off the southeast coast of the African continent in the southwest Indian Ocean. It is located east of Madagascar with latitude 20.35 South and longitude 57.55 East. The country includes the islands of Rodrigues, Agalega, St. Brandon and two other disputed island territories. The population of Mauritius is 1,264,887 with a growth rate of 0.1% (SM, 2016). The area of the country is 2,040 km^2. The capital and largest city is Port Louis. The nation's exclusive economic zone (EEZ) covers about 2.3 million square kilometres of the Indian Ocean, including approximately 400,000 km^2 (150,000 sq. mi) jointly managed with the Seychelles. The main island is of volcanic origin and is almost entirely surrounded by a coral reef that poses maritime hazards. The Village of Grand sable is located along the East South East shore of Mauritius closed by the Bambous mountain range. It is one of the 23 villages of Grand Port administrative district. The population of Grand Sable is 2,223 (SM, 2015). Locals of the village have dwellings in reinforced concrete on both sides of the B28 road of 3.04 km stretching in length (Google earth, 2016) that has been upgraded from an unplanned access road. The houses are located within a range of 1m to 700m from the shore line making the inhabitants vulnerable to any types of sea surge.

B. Tsunami generation

A tsunami is a series of waves travelling at speeds of over 800 km/h in the deep ocean where they go unnoticed. Once the waves reach the shallow waters of the coast, the energy of the huge water body manifest themselves as they crash with devastating force across the shore and penetrates inland, particularly low lying areas, causing mass devastation in terms of lives and property on its way.

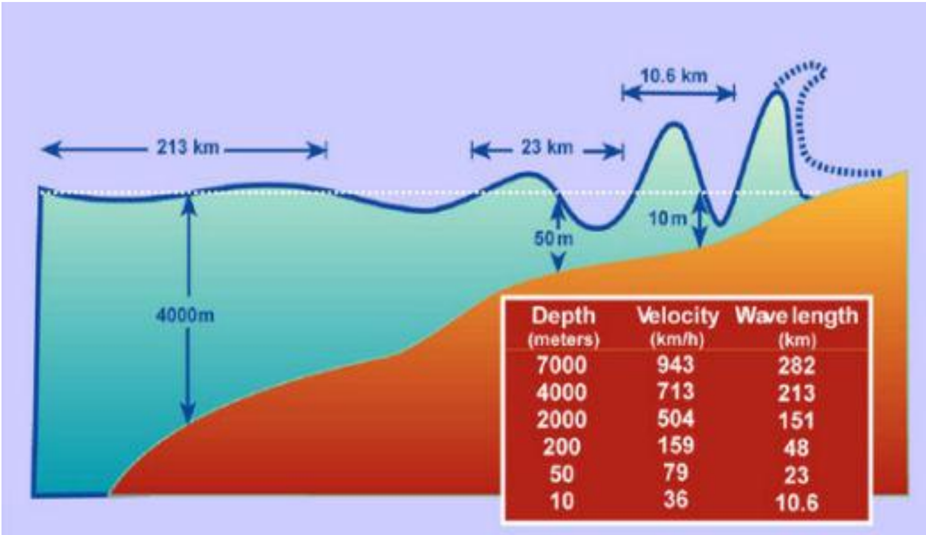

Figure 1.2: Tsunami amplitude reaching shore
(*Source: http://www.nea.gov.sg, 2017*)

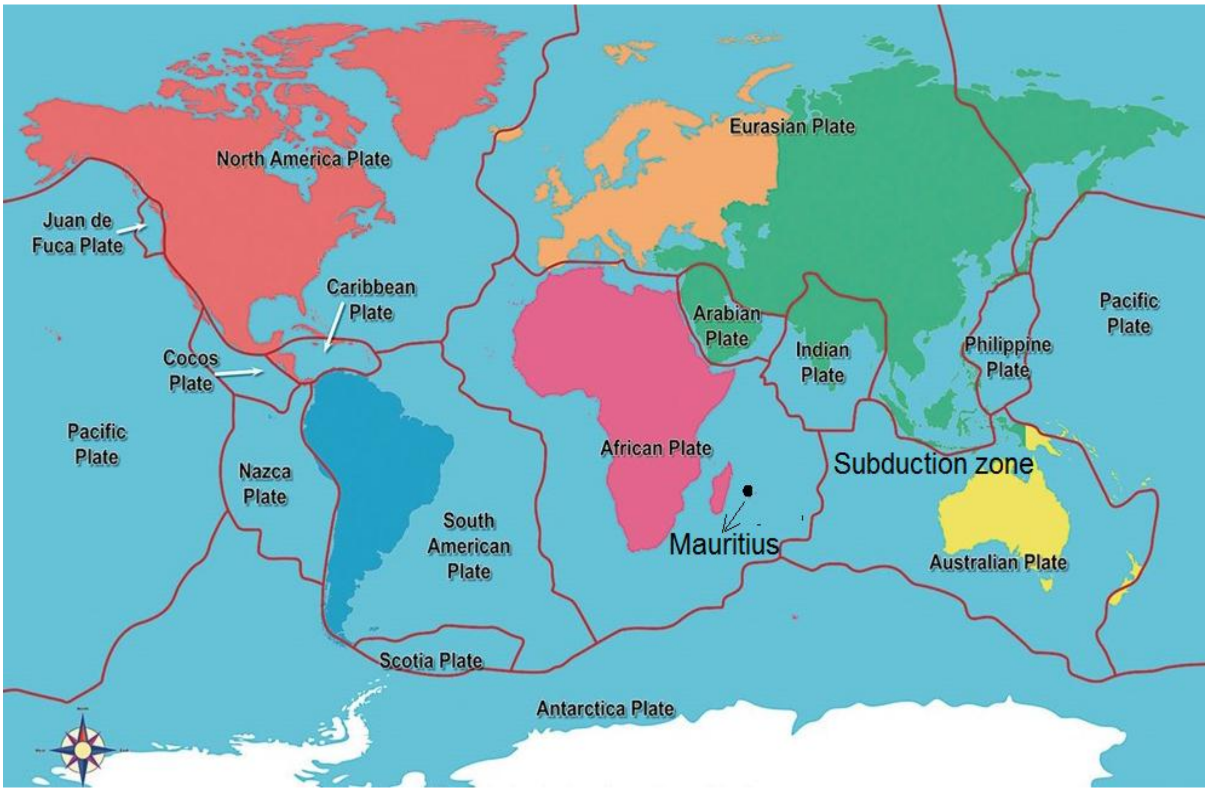

Figure1.3: Tectonic Plates Boundaries Map *(source: https://www.findel-international.com/ (2019))*

Though Mauritius is located far from the subduction zone, minor inundation was experienced from the Tsunami of December 26, 2004 while the island of Rodrigues (620km from Mauritius) was more affected showing that the risk though, of low probability can be of high magnitude. Eventually, the coastal settlements and the hotels are all threatened. The Tsunami Warning System managed by the Mauritius Meteorological Services (MMS) has taken into consideration the degree of risk as well as the time factor. In virtue of its geographical location, Mauritius and Rodrigues have a lead-time of 5 to 7 hours before tsunami waves are likely to reach their coasts from either the Sumatra or the Makran source (*MMS, 2017*). However, in the event of the epicentre of the seism being closer to Mauritius, the lead time will be eventually less than that expected.

II. Research Interest

As a result of the December 2004 tsunami, and the consequences in the Asian countries, much emphasis have been made in the awareness program by the United Nations Office for Disaster Risk Reduction (UNDRR). As a small island, Mauritius must be well prepared to mitigate the impact of a possible tsunami. A general approach to possible solutions is primarily to localise the vulnerable areas and work from part to whole to fine tune evacuation strategies. Grand Sable village has been taken as case study as it falls among the vulnerable areas of tsunami threat. Dwellings in Grand sable village occupies mainly both sides of the main road lining the coastal front at an elevation of 0 to 15 metres AMSL. The lagoon width varies from 300 to 600 m (Google Earth, 2017) within a maximum depth of 3m. In the event of a tsunami alert, all the inhabitants must be evacuated by local authorities designated to intervene within a specific time frame.

From the Grand sable case study, the following research question was formulated:

- Is there an adequate spatial information system available to the local authority for the evacuation of the inhabitants of Grand Sable to a safe assembly area during a tsunami threat?
- What is the impact on the existing infrastructures of the village when subjected to a certain magnitude of surge?

A. Research Objectives

- The main objective of this project is to save the lives of people living along the coastal village of Grand Sable.
- This research hereby aims at providing the local Authorities with maps showing inundated zones of the village relative to certain magnitudes of tsunami.
- Another objective is to calculate damages and their financial implications to Residential Buildings and road structures, using approximation rates from Mauritian Authorities.

This study ultimately can map appropriate evacuation routes and shelter zones to accommodate facilities for the 2223 inhabitants in an eventual tsunami.

III. Methodology

This chapter describes the methodology adopted to achieve the project objectives. This study has been carried out by remote sensing. All features and elementary calculations regarding distances, altimetry, settlements (buildings), agriculture zone, and road networks have been taken from Google Earth as the raster image. The flow chart in figure 3.1 illustrates the methodology adopted for this study.

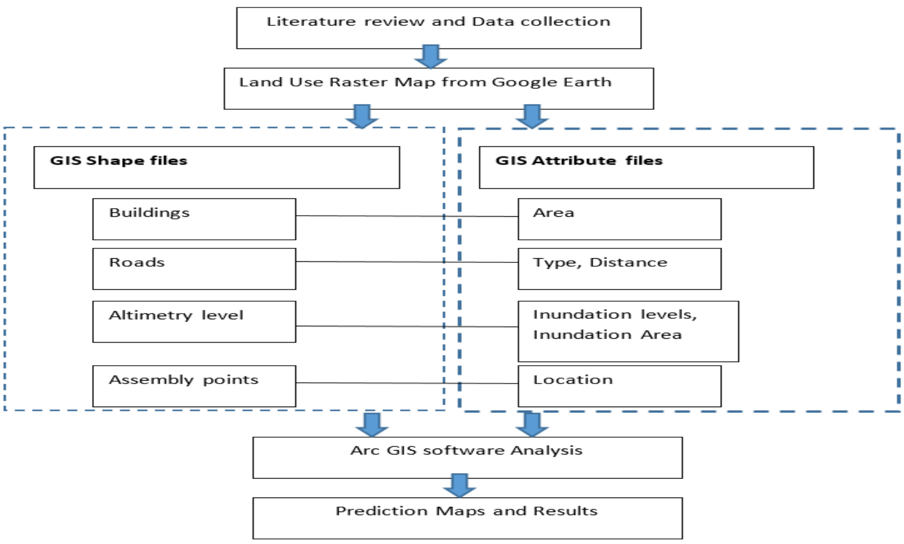

Figure 3.1: Project Methodology flow chart

With locations of specific features on the map, the image has been geo-referenced in Arc Map. Then, layers have been created to digitize the specific features on the map as per figure 3.2.

Layers	Feature	Details
Study area	Polygon	Area of Grand Sable village defining the research project
Road	Line	Paved and unpaved road networks of at least 3m wide on the map.
Buildings	Polygon	Inhabited areas
Cluster	Point	Point (on road) showing the centre of a specific inhabited area
Level5	Polygon	Area showing inundation with 5m height of tsunami
Level10	Polygon	Area showing inundation with 10m height of tsunami
Level20	Polygon	Area showing inundation with 20m height of tsunami

Figure 3.2: Digitised layers on Grand Sable map

The elevation levels were obtained from Google Earth using the terrain view. Line layers were traced on Google earth each showing specific elevations with respect to the mean sea level. The lines with specific altimetry values were then uploaded to the geo-referenced Grand Sable map on Arc Map.
"level5" and "level10" layers were then digitalised as polygons each showing areas affected after a 5 m and a 10 m heights tsunami event respectively.
The Assembly point spatial data illustrates the centre of a specific settlement where the residents should converge and meet before moving towards the safe zone. Distance between two respective cluster points does not exceed 500m for the manageable and quick evacuation of the residents. Distance between each cluster (Assembly Point) were set up for 500 m in the GIS Map. This resulted in a maximum walking distance that equals to 250m for the inhabitants to assemble at the cluster for a preliminary control check.

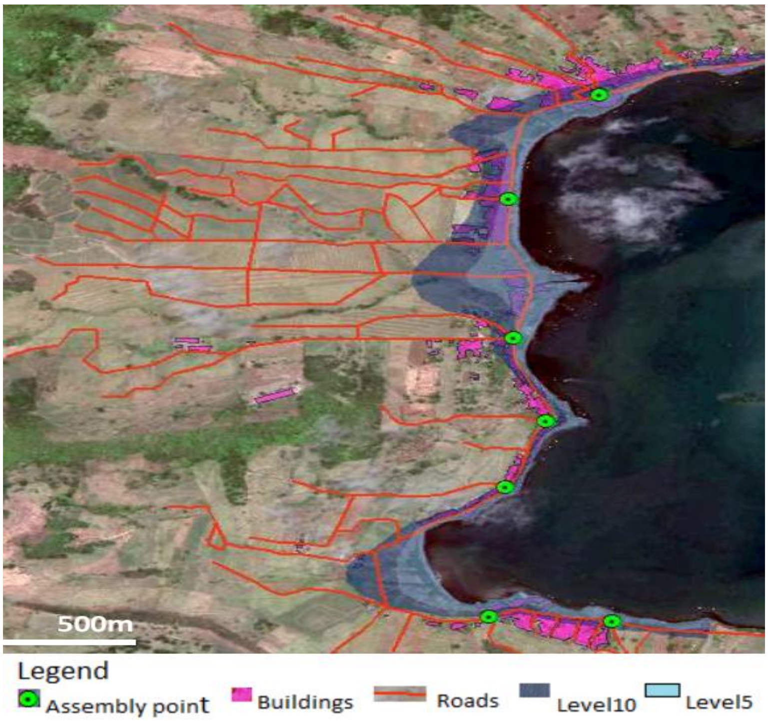

Figure 3.3: Study area with digitalised layer

IV. Analysis and Results

The digitalised layers were then interpreted on the spatial plane as illustrated below:

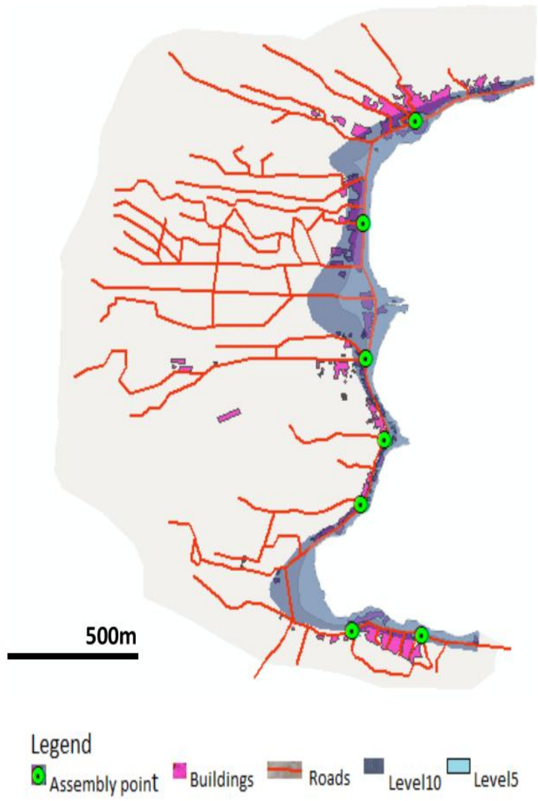

Figure 4.1: ArcMap image with inundation zones.

As a result of a projected 5m and 10m tsunami striking the Grand sable coastal village, the simulation in figure 4.1 illustrates the following affected areas including the main road.

Inundation level	Area of land affected
5	1.45
10	2.97

Figure 4.2: Simulated land area affected

Figures 4.3 and 4.4 illustrate the areas of buildings affected with respect to two inundation levels.
This enables an approximate computation of the loss in buildings and amenities computed in figure 4.5.

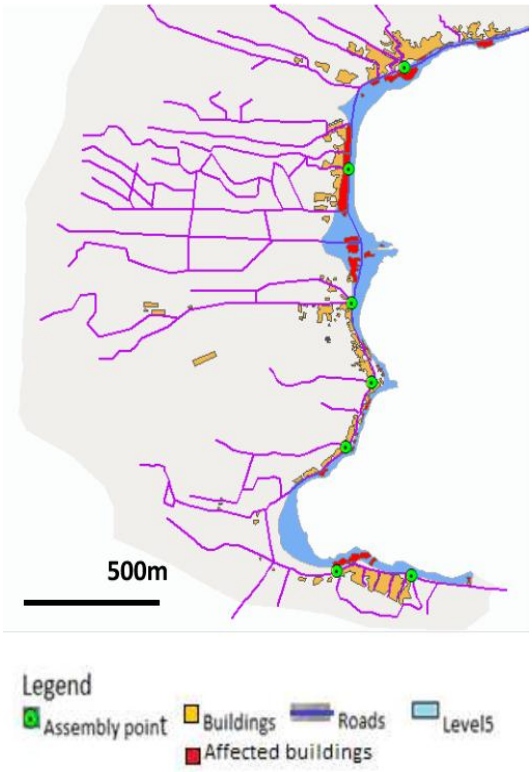

Figure 4.3: Projected buildings affected during 5m inundation

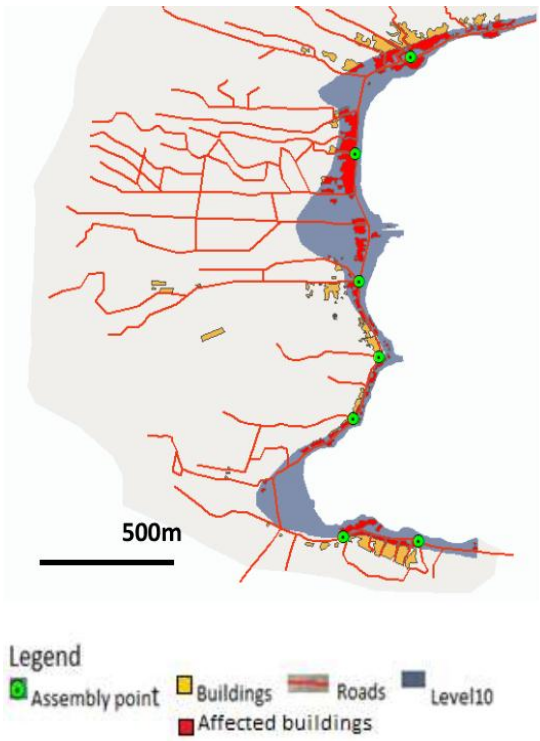

Figure 4.4: Projected buildings affected during 10m inundation

Inundation level	**Area of houses affected (m^2)**	**Estimated cost of damage to buildings in MUR** **(Rate of Rs 13000/m^2, *Mauritius Housing Company*)**
5m	23742 (24%)	308,646,000
10m	56939 (57%)	740,207,000
20m	100282 (100%)	**1,303,666,000**

Figure 4.5: Estimated cost related to affected buildings during inundation.

As a result of a 5m tsunami strike, the inundation zone encompasses 24% of the housing units of Grand Sable simultaneously. This amounts to a loss of MUR Rs 308,646,000 in terms of houses and amenities only. Figure 4.4 showing a 10m surge, illustrates a 57% of affected housing units. The main road network (B28) of 5.5m wide and 3.2km long will be mostly damaged and left impracticable with a mere surge impact of 5m height as detailed in the following table:

Inundation level	**Length of B28 Road affected (km)**	**Estimated cost of road reconstruction in MUR** **(Rate of Rs 65,000,000/km, *Road Development Authority, Mauritius*)**
5m	2.74 (90%)	**177,840,000**

Figure 4.6: Estimated reconstruction cost related to affected road during inundation

From the assembly points, the inhabitants should be evacuated towards a safe zone at a walking distance of not more than 1.5 km. The safe zone with shelters, was projected at a buffer distance of not less than 400m from a 20m inundation event taken as the worst case scenario. The zones should be plain enough to accommodate clusters of the 2223 inhabitants. The GIS analysis resulted in the localisation of 3 shelter zones interlinked with access roads, under plain areas as illustrated in figure 4.6:

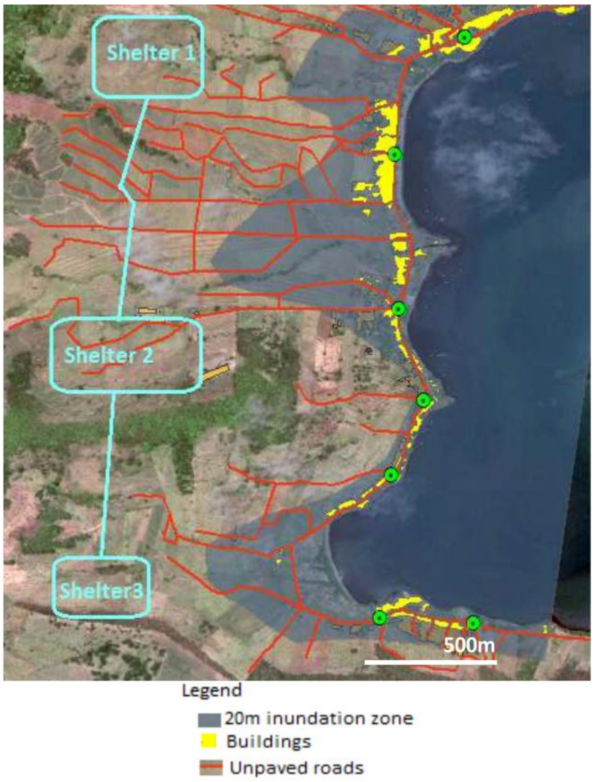

Figure 4.6: Proposed shelters location after analysis

V. Conclusions and Recommendations

The Grand Sable village digitised in ArcMap enables unlimited spatial and attribute analysis. The main objective of saving lives can be achieved if a proper management practice is involved under the guidance of the GIS Map with assembly points, evacuation routes and shelter zones well defined on site.

The GIS Maps can be a tool for decision making for concerned authorities, government and planners. The GIS analysis provides maps with spatial simulations of inundation zones at different surge elevations. Future development of infrastructures and dwellings can hence be planned in safe zones outside the vulnerable areas.

The GIS analysis helps in the projected calculations of damages to features and infrastructures around. A 10m height Tsunami can practically wipe out most of the dwellings and other infrastructures erasing the whole village. The GIS analysis showed that a 5m height Tsunami can be disastrous with an economic loss of more than 400 million MUR for a village of 2200 inhabitants. Mitigation measures involving sensitisation and awareness campaigns as well as provision of soft and hard measures should therefore be planned accordingly by authorities.

The results obtained in this study were processed from Satellite images of Google Earth. This project can therefore be upgraded with the acquisition of more geo-referenced detailed features using a GPS on site. An up to date high resolution map will eventually improve the results accuracy. Other influential attributes namely, land drainage data, soil characteristics, building conditions, etc. can be added as layers in the GIS to have an in depth calculation of vulnerability for this location.

This research should be extended to other places of Mauritius as well as for regional and international coastal zones since the risk of tsunami can never underestimated.

VI. References

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