

**THE SIGHTS AND THE RISKS OF INUNDATION
IN THE AGGLOMERATION OF ANTANANARIVO**
A concrete case of the risk management related to the road infrastructures

DIRECTION GENERALE DE L'APIPA
Antananarivo – Madagascar.
plainedetana@wanadoo.mg

SUMMARY

The sights

Nowadays, Antananarivo, a hill city of the XVIIth century, becomes a sprawling agglomeration of the plain crossed by Ikopa and its three tributaries. Not only is Antananarivo the capital of Madagascar economically speaking, but also its perimeter is about 6000 hectares. That's why it can provide several activities on which the economy of the country depends.

The risks and the different problems

Several successive measures have been set up in the order to face the almost continuous inundation of the city. In fact this threat of inundation results from the atmospheric disturbances and people's activities.

Many embankments have been created and reinforced, but not only does the damage of the big areas involve a rising of beds but it also causes alluvial deposits.

Nevertheless, the extraction of these alluvial deposits requires an artificial dredging of beds which can erode the dykes. Therefore, an appropriate regulation is imperative.

The different protection systems

Due to the damages of the strong rain in 1959, some measures of protection have been adopted:

- Infrastructures of protection;
- Regulations so as to prevent the different risks;
- A Risk estimating;
- Institutional reinforcement;
- Methods to tackle the plans.

The risk management and road infrastructures

Actually, new road infrastructures illustrate this risk management: the Dyke Road and the By-Pass.

1- THE DIFFERENT SIGHTS OF THE PROTECTION FROM INUNDATIONS IN ANTANANARIVO

1.1. The population and the economic activities

Antananarivo, the economic and politic capital of the Republic of Madagascar is an agglomeration with 1 700 000 housings. Localized on the highlands and at an altitude of 1245 m in general, Antananarivo is a city perched on hills (Manjakandriana, Faravohitra, Ambohijanahary, Antaninarenina ...) created at the beginning of the XVIIth century. The city overhangs the vast agricultural plain of Betsimitatatra and Laniera whose irrigation systems have been undertaken by Andrianampoinimerina who reigned in Imerina from 1787 till 1810.

Despite the strong Constraints of the site, the modern city has been developed since 1930 with the driving of two tunnels and the construction of many trunk roads which have shown the urban motivation at this time. Moreover, either the construction of the administrative zone of Anosy (ancient marsh) or the one of the big stadium of Mahamasina have reinforced the roles of the different district of the capital.

It has been the same for trades, department stores, banks, hotel infrastructures, craft enterprises, industrial firms and commercial firms which have spread in the north of the city (the north and the northwest industrial estate), in the south (the rail zone of Soanierana). All these news installations seem to form the real city centre divided in 6 administrative districts with 1 100 000 residents and a surface area of 85 km².

In addition to that, the horizontal development of Antananarivo includes about thirty peripheral rural districts with 600.000 residents and a surface area of 340 square kilometres. Speaking about the prospects on the future, they form the "big Antananarivo" and should be considered when developing the city.

Globally speaking, the economic activity of the agglomeration of Antananarivo generates the 55% of the national Gross Domestic Product. Concerning industries, the expansion of the industrial estate competes with the agricultural area of 100 square kilometres, about twenty of which are localised in the urban area.

1.2 The chronological account of the city development:

Built on a chain of hills at an altitude fewer than 1800 metres, at the beginning of the XVIIth century, Antananarivo have a vast alluvial plain crossed by the river of Ikopa and its three tributaries: Sisaony, Andromba and Mamba. Historically speaking, due to the multitudes of aggressive "little kings" of the feudal period, the site of Antananarivo was deeply coveted because of security reasons and the geopolitics. One of these reasons is the fact that not only is it a steep hill, the access of which is difficult for the invaders but also it is located in the middle of the six provinces of the merina kingdom.

Besides, the vast extent of the alluvial lands which borders the river of Ikopa and its tributaries provides a strategic interest because they guarantee the success of the wrestling against the famine, the first people's enemy. Finally, we cannot deny that the first builders' choice has been justified by the beauty of the landscape.

So, not only was the plain consecrated to the agriculture dominated by the rice growing, but also the setting up and the spread of the housings which are below the hills began at the end of the merina kingdom. It was the advent of the different areas such as Soanierana, Mahamasina, Isotry and Analakely. During the colonial period, the construction of the road infrastructures like tunnels, roads, civil engineering structures and the railway which links Antananarivo to the other provinces, has definitively contributed to the status of Antananarivo as the capital.

After the independence, the urbanization of the plain has progressed rapidly along trunk roads and news areas. For example, we can refer to the north industrial zone along the Hydrocarbon Road in Ankorondrano (the petrol storage depot downstream of the city terminal of Toamasina), the northwest industrial area around the edge of the Dyke Road, the rail zone in Soanierana (the agricultural and industrial complex of Antananarivo), the administrative area of Anosy, the "Ampefiloha city", the "67 hectares city" and the industrial area of Tanjombato in the major bank of Ikopa.

This kind of urbanization has been achieved until now in a more or less regulated manner. In fact, the persons in charge of the embankment are used to proceeding by referring to the laws in force (n°95-034 on the 3rd October 1995). Then, this urbanization has improved since the 90s due to the migratory flux of the neighbouring regions, the revival of the industrial investments (free industrial zones) and the property development (for highlands).

Table n°1: The evolution of the construction of new roads in the urban plain:

| Period | 1900-1960 | 1960-1990 | 1990-2007 |
|---|-----------|---|---|
| The length of the different roads crossing the area | 19km | National road 1 Ampefiloha 67 hectares The Dyke Road | Little boulevard Little bypass (Masay) |

2- THE RISKS OF INONDATION AND THE DIFFERENT PROBLEMS :

2.1. The natural risks:

The surface area of the big area of Ambohimanambola in the eastern entrance of Ikopa is about 1500 km². At 50 km downstream of the channel of Bevomanga, an estuary of Ikopa facing Betsiboka, the area covers a surface area of 4250km². This difference is constituted by the accumulation of the areas drained by the tributaries of Ikopa such as Andromba, Katsaoka, Sisaony and Mamba.

That's why, the only outlet of the five rivers and their overcharges during the rainy season explains the vulnerability of the areas of Antananarivo which is increased by rocky shelves of about fifteen kilometres between Bevomanga and the waterfalls of Farahantsana. It can also provide bad influences on the flow of the affected rivers, the alluviums and the sedimentation in their banks.

Normally, the plain emerges at the bottom of a mountainous area where the banks of the waterways are deeply embanked before joining the plain. Besides, the slope of the flow is not so more than 17cm per km. After the cyclonic rain, not only does this natural handicap aggravate the situation, but it also causes the rapid inflow of water in the polder of Antananarivo, even an inundation with different strengths because the flows are not drained off enough due to the narrowing of the banks.

2-2 The different problems:

As we said, the memorable inundation on the 29th March 1959 in the agglomeration of Antananarivo with 2 metres of water in general, brought a lot of devastating water, especially for Ikopa. Furthermore, it takes about 50 years for Antananarivo to get over this problem. And such a rapid flow (about 1000m³/s) toward Ambohimambola causes certainly a bursting of dykes with a submersion and an undermined bank of Ikopa.

During the last twenty years, the inundations of the plain of Antananarivo on the 8th February 1994, after the passage of the cyclone Geralda, showed the weakness of the protecting infrastructures set up because of the inundation in 1959 and the real impact of the extensive urbanization of the plain of Antananarivo. At that time, the dykes were still submerged and the National Roads (NR 7- NR 1) were unfit for a long time: the most rapid flow was the one in Ambohimambola (440m³/s).

We'd like to precise that the delimitation of the plain of Antananarivo includes other peripheral districts except for the thirty districts we have already seen. Therefore, they are in possession of the main rice fields which are liable to flooding. Actually, due to the last inundations, not less than 10 000 hectares of rice fields are regularly swallowed up. What's more, with an average productivity of 2t/ha, the lack gets to 20 000t easily during the period of inundations.

3- THE DIFFERENT MEASURES OF PROTECTION

3.1. The dykes

3.1.1. The existing initiatives:

In order to reinforce the security of the old city of Antananarivo, the first constructions of the dykes in Betsimitatatra and Laniera caused a strong mobilization of people. Certainly, the first objective is not to protect Antananarivo from inundations because the city is built on hills. In fact, it consists of controlling the irrigation of the regions suitable for cultivation so as to get a good rice harvesting.

In addition to that, the feudal authorities resorted to community works. That's why, about thirty kilometres of dykes have been set up around Ikopa in accordance with the norms, the availabilities, the techniques, and the expertises at that time. Consequently, these age-old works were not able to resist of climatic risks and the intensity of strong rain. Moreover, some kilometres of infrastructures had to be improved in accordance with the norms in force.

As it is stated, the news infrastructures reinforced before 1959, were not able to resist of the inundations which caused the submersion of almost the whole plain of Antananarivo.

3.1.2. The materials of construction extraction:

With the aim of controlling the bank rising of the main rivers which cross the plain of Antananarivo, the extraction and the exploitation of sands and clays have been encouraged under the Administration control. Nonetheless, since ten years, not only does this method become excessive (boom of the real estate) but also it has involved a general lowering of the water level and the collapse of dykes.

Another vision shows that not only does the deepening of the ways of the flow have a good impact on the low water but it also reduces the risks of inundations. So, new measures have been recently taken to extract sands and clays. On the other hand, we should reinforce the training of the explorers of sands and clays.

3.1.3. The procedures of protection:

Antananarivo has seriously suffered from the damages of 1959. That's why, these following different measures of protection have been taken due to this inundation:

- Infrastructures of protection: a reinforcement of dykes and a construction of other dykes setting the limits of the plain of Antananarivo which are the river of Ikopa, Sisaony and Mamba. It is the same for the channels of drainage and the areas of flattening such as Andriantany, the north buffer area, the north C3, the buffer area of the lake Anosy, the south areas and channels, and all the supply works from the Canal GR. Other measures of protection have been recently taken like the construction of 100 hectares of areas, the one of Masay downstream of the east Valley and the pumping station of Ambodimita.

Picture3- The pumping station of Ambodimita.

With the purpose of controlling the streaming water flow of the plain of Antananarivo by preserving the water table, other urgent interventions should be considered in the short/ medium/ long term: i) the bank of waterways dredging and drainages leading into the areas of Antananarivo which are liable to flooding, ii) the re-checking of dimensions especially for the confluence from the four rivers till the threshold of Bevomanga and finally, iii) the regulation of Bevomanga such as an enlargement of channels, an extraction of rocks and a construction of barriers which can control the flow. Generally speaking, this barrier can reach easily 15km but it is more effective.

Then, socially and economically speaking we can get many results on behalf of the population of Antananarivo and Malagasy people:

- A reinforcement of the capacity of the present and the future infrastructures with regard to the protection of the plain of Antananarivo from inundations;
 - A draining of 350 km² areas;
 - A preservation of 7000 hectares of rice fields from inundations;
 - An amelioration of the yield of the rice field;
 - A sustained growth of the agro-business;
 - An amelioration of the life conditions of 1 700 000 residents , especially 130000 families, residents of the low plains ;
 - A fight against poverty;
 - A strong amelioration of the future objectives of development.
- The rules to prevent the risks: the law n° 95-034 on the 3rd October 1995 allows the creation of organizations which are in charge of the protection from inundations and fix its licence fees. It concerns also the text related to the protection from the inundation of Antananarivo, a public administrative organization which is in charge of the exploitation and the maintenance of the present and the future equipments aimed at the protection against inundations.
 - Forecasts and evaluation of the risks: in close cooperation with the Direction of the National Meteorology, the forecast equipments and the ways to announce the inundation have been brought up to date.
 - An institutional reinforcement carried out by the promulgation of the law n° 95-034 on the 3rd October 1995, its texts of applications and the reorganization of the authorities in the protection from the inundation of Antananarivo. Furthermore, news arrangements concerning the urbanism management have been prevented so as to master the occupation of the ground or principally the preservation of zones designed for possible inundations and the arrangement of the hydro-agricultural edge.

The Ministry in charge of the country planning has undertaken the drawing up of the texts tending to actualize the urbanization methods of the national area in order to protect the zones designed for possible inundations and to master the hydro-agricultural edge. As a result, each decentralized organization (region, district or group of districts) will have its own master plan of planning which comprises an occupation plan of the ground (OPG).

Picture 4- A master plan of planning of Antananarivo

- Methods to tackle the plan: from these news states concerning the prevision and/or the protection from inundations such as the instructions of a detailed urbanization diagram equivalent to a Detailed Urbanization Plan, the technical arrangements should be respected concerning the setting up of plans. The case of the construction of a little bypass is the best example of methods.

4 – THE CONCRET CASES OF THE RISK MANAGEMENT RELATED TO THE ROAD INFRASTRUCTURES

Seeing that, on one hand, the road infrastructures are the main elements which structure the urbanization; on the other hand, the urbanization should not underestimate the risks and the stakes of inundations that we have seen at the beginning, it is necessary that the road projects lean on detailed urbanization plan relating to the Directing Town Planning of the agglomeration in question and maps showing the probabilities of inundations of the areas in question.

Consequently, each plan will not focus on the analysis of the environmental impact only. In fact, we should transform this environment so as to get a new stability considering the general interest. Speaking about the species, the hydraulic security of the agglomeration is worth bearing in mind on the whole.

4.1. The case of the Dyke Road

As it is stated at the beginning, the right side dykes of the river Ikopa have been set up since the merina kingdom. That's why this infrastructure was not strong enough to face the inundation in 1959. That is the reason why a new strategy of protection from inundations has been created. Thus, the Administration decided to reinforce the existing dykes by embanking the vulnerable parts, that is to say the whole right side dykes of Ikopa from Ankadimbahoaka till Ambodimita. What's more, this second embankment can be used as a semi-rapid traffic way linking Ankadimbahoaka and Ambodimita. Economically speaking, the Dyke Road called NR 58 A forms a short cut between the town centre and the international airport of Ivato. For the future years, an access road will link this "dyke road" to By-pass. Finally, this new reinforcement is supposed to be able to face the assaults of the future inundations.

In the middle term, this new procedure of reinforcement should be generalized for the others rivers which are threatening the plain of Antananarivo. Due to the fact that the protection system begins to get old, far-reaching actions should be planned rapidly.

That's why, a feasibility study will always be done in order to reinforce the left side dyke of Mamba which can also be used as a thoroughfare between Sabotsy Namehana (NR3) and the Dyke Road (NR 58 A). Considered as a peripheral road of Antananarivo, it can improve the urban traffic in Antananarivo and its surroundings. The success of this experience shows the importance of the road infrastructures in the procedures of the management of risks.

4.2. The case of the bypass Masay

Among the different plans of drainage of the “big Antananarivo” set up at the end of the 90s, a road called “little bypass” linking the Hydrocarbon Road and the NR 3 at Andranobeava with a probable extension to NR 2 at Ankadindramamy was inaugurated in 2006. It is a two-way embanked street of Marais Masay, a regulator and retaining basin with a surface area of 100 hectares.

Before the feasibility studies, the construction of this new road has followed the instructions based on the detailed urbanization diagram of the town of Antananarivo, the region of immigration. In the area considered as the prolongation of an halweg called” the East Valley” downstream of the big areas of the surrounding hills (Ampandrianomby, Betongolo, Mausolée, Ampasapito, Manjakaray), other retaining areas are built before the delivery into the channel Andriantany. This infrastructure requires an expropriation of about one hundred properties and/ or private buildings.

Apparently, all the solutions set up in 2006 seem to be efficient. Actually, although the rain intensity during the cyclonic season persists, there is neither rupture nor submersion of dykes. So, we can say that the inundation has been mastered because of this new road infrastructure.

Also, we can notice that the retention of water will be successful, if the drainage of the district of Andravoahangy becomes functional. Besides, it can contribute to the development of Masay.

4.3. The case of By- Pass NR2-NR7

In order to improve the traffic in the town, a two-way avenue with a length of 15km initiated in 2004 has just been inaugurated. This new road along the left bank of Ikopa links the NR 2 and the NR 7, from Ambohomangakely till lavoloha.

Crossing the decentralized areas of the peripheral suburbs of the Urban District of Antananarivo, the feasibility study of this road doesn't refer to any detailed urbanization plan as it is supposed to do because these spots still don't have this opportunity. However, a study of environmental impacts has been done. It confirms that any road should not impede the passage of water through the irrigation canals.

Nonetheless, it is crucial that we make rapidly a detailed urbanism plan specifying a strict rule related to the occupation of the ground. Moreover, it is evident that this new service road will be interesting for the property promoters and the tourists.

Conclusion

As it is proven through the case of the Dyke Road, the road infrastructures have an important role in the risk management. Therefore, according to these convincing results, either the civil engineers or all the new vision should not underestimate the importance of the road infrastructures in the procedures of the risk management.