Paring flexible infrastructure with adaptive planning
Case Study: Can Tho, Vietnam

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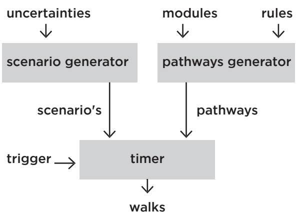

Figure 1. Methodology.

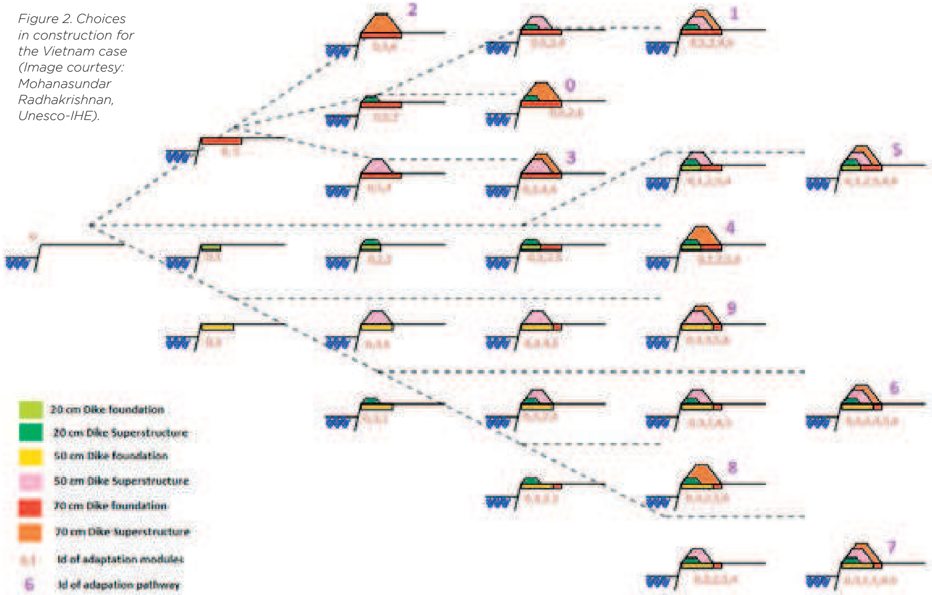

Figure 2. Choices in construction for the Vietnam case (Image courtesy: Mohanasundar Radhakrishnan, Unesco-IHE).

Tushith Islam

PARING FLEXIBLE INFRASTRUCTURE WITH ADAPTIVE PLANNING

CASE STUDY: CAN THO, VIETNAM

Dr. Tushith Islam was a Postdoc at the faculty of Technology, Policy and Management, Delft University of Technology. For the MFFD program he was part of the project 'Integrated design. Adaptivity and Robustness'.

The large-scale deployment and maintenance of infrastructure is time consuming and expensive. Over time, with changing demands and threats, these artifacts need replacement, upgrades or removal. Designing these objects assuming a fixed life or for perpetuity, neglects the reality of mutability of our built environment and variations in natural systems (Milly 2008). Consequently, in locations where there is a great degree of uncertainty, it may be worthwhile to consider modular structures and systems.

Pairing flexible infrastructure with preplanned adaption opens the door for new forms of infrastructure systems. This is in contrast with the current ad-hoc adaptation techniques. With simulation and robust optimization methods, it is possible to create policies that attempt to meet the multitude of values and constraints of stakeholders, with a possibility of minimizing costs in the long term (Haasnoot et al. 2013). To date, real options analysis (ROA) has been one of the leading methods for adaptive decision-making.

The application of the state of the art in ROA faces difficulties on two fronts (Neufville et al. 2006):

1. The methods of modeling trinomial lattices and stochastic dynamic programming are challenging and laborious, and the resulting full nodal connectivity does not map to the built environment; where assets are hard, if not impossible to sell.
2. Sourcing the probability information for constructing the aforementioned decision trees is difficult, if not impossible.

Furthermore, the exercising of one option can prohibit the application of other options. The inability to account for path dependence, makes the use of standard real options representations, inappropriate for infrastructure. To summarize, this research aims to advance the use of modular systems for strategic planning of infrastructure systems, while addressing the need for simplifying the modeling of path dependence and integrating the use of a multiple of sources of uncertainty. The methodology allows for a simple yet explicit modeling of uncertainties and the path dependence of decisions. Next, it enables the activation of these decisions in a user specified time domain (cf. Figure 1).

The case study of Vietnam highlights the use of the method and analysis the results of method. The methodology is illustrated, by applying it to the feasibility analysis of a multifunctional dike system in the city of Can-Tho along the Mekong River The project has a time window from 2016 until 2100 with an annual time step for the analysis (river level simulations are monthly). The exogenous scenarios used in the application are: sea level rise and gross domestic product growth percentage.

The sea level rise scenarios are combined with historic river level variation to generate potential river level futures. A transformation factor of .74 is used to transform the potential rise in sea level to river level (Wassmann et. al. 2004). The historic data is decomposed into an underlying (and rising) trend, seasonal variation, and residual noise. The trend can in turn be decomposed (using a hilbert-huang transform), into a smoother sigmoid, and a pair of chaotic oscillations. As no compelling causal explanation or regression was found for the noise or the oscillations, the curves were combined, and are used as a lookup table for generating the noise component of the future scenarios.

The GDP growth percentage data is from OECD and IIASA free data sources. The sea level rise scenarios are sourced from the latest IPCC report on the south east Asia region. The pathways of modules (the choices in construction) are visualized in Figure 2. There are six different modules under inspection of two categories; three different foundation sizes, and their associated dike heightening (50 cm, 70cm and 120 cm). Dike heightening can only be constructed if a base greater or equal to their pre-requisites exist. Once an artifact of a particular size has been constructed, it cannot be followed by a smaller artifact.

By increasing the safety factor, the building of the next module will be triggered, when the river level is some fraction below the maximum river value. However, as the river values are non-monotonic, floods can still occur if the dike height is insufficient. Furthermore, as the construction of the defense may take multiple time steps, floods can still happen during the building process.

The outcome of this application shows the consequences of different choices in construction; for example the difference in risk of the strategy 'do nothing', and the strategy 'build dikes with extra height of 120 cm.'