MFB : [DESIGN BRIEF]

June 2009

Camp Rock! friends imagine what "*walking on water*" would be like (Disney, 2008)

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Version 1.1

bhpbilliton

resourcing the future

Executive Summary

This design brief is for the construction of a Modular Floating Bridge (herein referred to as the "MFB") for the region of Tonle Sap, Cambodia. We have used the Product Development Lifecycle (PDLC) model to detail the complete process of bringing the MFB to the Cambodian market.

An attempt has been made to combine the most up-to-date Civil Engineering techniques, with the latest Harvard Business School analysis, to come up with a solution that is both innovative as well as achievable. With superior knowledge of Cambodia, we structured a solution to bring a bridge that would be easily understood, as well as manufactured by the people of the Tonle Sap.

Our engineering solution is best summarized by the Chinese proverb:

> "*Economical; Exquisite; Excellent*"

The MFB is supreme from the perspectives of price, exterior design, and interior design (manufacturing quality).

Brief Overview

The MFB Design Brief features the following:

- Outlines alternative options during the design process, and justification for the selected technology
- Provides detail of conceptual design, analysis, and final design
- Considerations for budget (design, construction, and maintenance costs)
- PESTLE Analysis (political, economic, social, technological, legal, environmental) of the Tonle Sap in Cambodia
- Ethics, long-term sustainability, and maintenance considerations
- Implementation strategy describing construction and operation advice to cast members

In short, the Modular Floating Bridge (referred to as the "MFB") is an independent floating/bridging system that "plug-and-play's" with existing Cambodian infrastructure, with "hot-swap" speeds, taking into account possible boats that may need to cross through the MFB. The design uses materials that are 100% native to Cambodia, with the exclusion of the steel brackets, which can nonetheless be manufactured in Cambodia.

Letter to the Stakeholders

I would like to personally thank you for taking your time to read the engineering design brief for the MFB. My team and I honestly believe this will absolutely revolutionize the Tonle Sap, Cambodia; and its success would inspire other Cambodians to dream big and achieve huge.

I do not think I could have found a more qualified team of engineers, who from their various backgrounds, have contributed well to this project.

The Modular Floating Bridge Inc team included:

Jerry Shum [CEO] B.S.E.E. LL.B B.Com(Acctng)

As Chief Engineering Officer, I felt that I could not have achieved what I have without my team of engineers, who I now call friends. Each person played a different but integral part; and at times had to put up with my spontaneity that is not a managerial style always appreciated! Nevertheless, I hope you appreciate the somewhat interesting integration I make of Engineering with Management, and inspire many engineers in years to come to do so too.

Operations team:

Jordan Ward [SVP] B.C.E.

Mr. Ward, Senior Vice-President of Operations brought an excellent amount of talent to the competition, having attained phenomenal matriculation results. I would like to thank him for his support and the large amount of administrative work he has done. His portfolio was sustainability, and studied and researched various techniques worldwide to come up with just the right solution in relation to sustainable engineering.

Alden Pascua B.S.M.E.

Mr. Pascua, as his final-year project, has treated this project with nothing short of that description. He was a driver for the PESTLE Analysis, deriving an in-depth analysis, outlining particular social and cultural constraints in the Tonle Sap, not well versed by Westerners.

Leigh Costello B.C.E.

Mr. Costello delivered a strong written evaluation in the area of ethics. He was also key in the Design and Production team. For a large portion of the project, he was my P.A. and provided much needed personal support for the project.

Design and Production team:

Marty Sellar [ESVP] B.S.M.E. Mr. Sellar, Executive Senior Vice President of Design and Production, delegated the role of editor over much of the design brief documentation. Without his support, I could not have managed such a large team, so I would like to personally thank him as a team member and friend, for his brilliant managerial skills.

Carmen Tkalec [VP] B.C.E. An excellent communications manager, Ms. Tkalec, Vice President of Marketing, worked well to deliver a strong team oral presentation. Furthermore, she did a phenomenal job drawing the various MFB renders you find in this design brief. Without her contribution, the MFB could not have been communicated with the clarity that it has.

Finally, I'd like to thank **Elizabeth Smith** for her efforts in coordinating and reviewing this engineering design project. Her help has been both tremendous and necessary.

The MFB Team hopes you enjoy our innovative solution and hope to see you face-to-face on November 6, 2009 as one of the six outstanding teams at the EWB conference.

Jerry Shum – B.S.E.E., B.Com(Acctng), LL.B

President, Chief Engineering Officer

Disclaimer

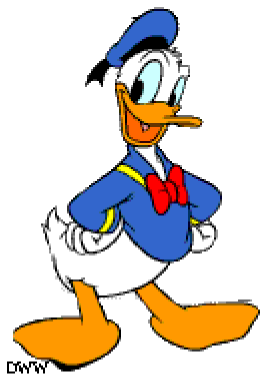
The team made all sketches originally with no external assistance. Images used under the Fair Use, for the educational and critic purposes.

In the EWB Project, we did not seek any external support provided to the design team. All work is attributable to members within the design team.

Acknowledgments

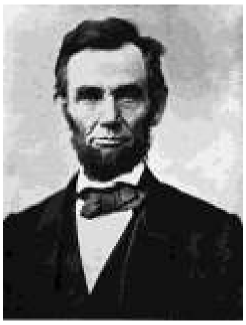
We would like to thank Donald Duck for inspiring us of this idea to "**Walk on Water**".

Furthermore, we would like to thank BHP Billiton for sponsoring the competition we find ourselves in.



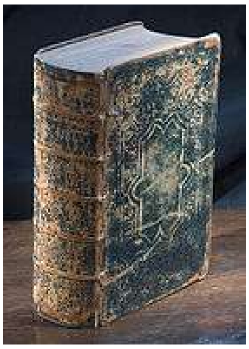
"Paddle, Paddle, Quack, Quack. Let's float on water!"

(**Donald Duck**, who didn't really make the quote, but nevertheless inspired us in our Modular Floating Bridge design)



"My dream is of a place and a time where America will once again be seen as the last best hope of earth."

(**Abraham Lincoln**, 16th President of the United States)



"Speak out ... for the rights of the destitute. Speak out ... defend the rights of the poor and needy."

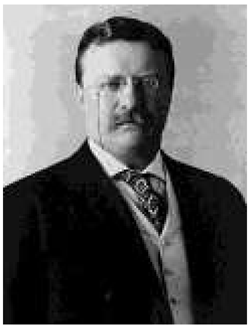
(**Proverbs 31:8-9**, King Solomon, son of King David)

"Change will not come if we wait for some other person or some other time. We are the ones we've been waiting for. We are the change that we seek."

(**Barack Obama**, 44th President of the United States)

"You can find Calcutta anywhere in the world. You only need two eyes to see. Everywhere in the world there are people that are not loved, people that are not wanted nor desired, and people that no one will help, people that are pushed away or forgotten. And this is the greatest poverty."

(**Mother Teresa**, Roman Catholic nun)

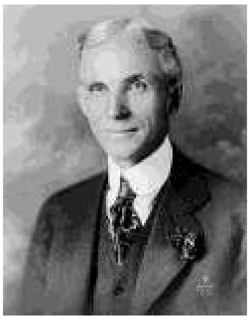


"This country will not be a good place for any of us to live in unless we make it a good place for all of us to live in.

(**Theodore Roosevelt**, 26th President of the United States)

"... Let us love, not just in word or speech, but in truth and action."

(**I John 3:18**, John the Evangelist)



"To do more for the world than the world does for you - that is success."

(**Henry Ford**, Founder of the Ford Motor Company)

"You get the Best of Both Worlds."

(**Hannah Montana**; we thought, if a tween like her can, why can't the people of the Tonle Sap, Cambodia?)

Selah.

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INTRODUCTION

It was Lewis in **Meet the Robinson**'s who said "*I mean there are so many things in the World that can be improved, just think of it; moving side walks, flying cars; the possibilities are endless!!!*" (Disney, 2006)

1 Introduction

Cambodia is located across the Pacific Ocean from the West Coast of the United States of America, a bit further than Australia, as shown in **Figure 1.1**. It is the successor of the once powerful Hindu/Buddhist Khmer Empire between the 11th and 14th centuries (The Phnom Penh Post, 2009), but Christianity is rapidly expanding and shaping culture (Back to Jerusalem, 2006).

Figure 1.1: This is where Cambodia is located in context of the World (University of Texas, 2009)

The Tonle Sap, Cambodian for "Large Freshwater River" (Geotimes, 2007), or "Great Lake" (Articles Base, 2009), is located in central Cambodia, and expands and contracts depending on the time of the year, as shown in **Figure 1.2**.

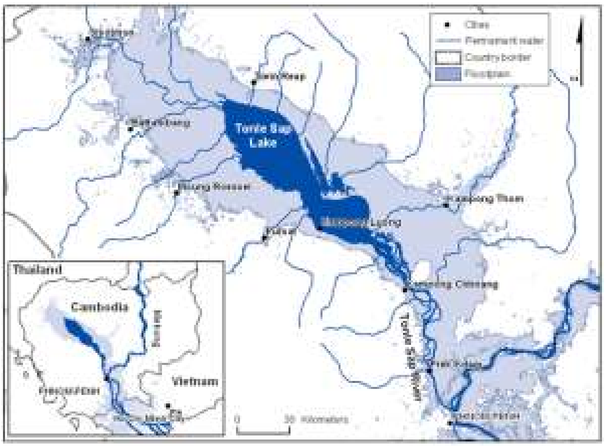


Figure 1.2: This is where the Tonle Sap is located in context of Cambodia (Helsinki University of Technology, 2006)

Because the Tonle Sap region is susceptible to rising water levels (Food and Agriculture Organization of the United Nations, 2001), Cambodians mostly live in stilted (The Phnom Penh Post, 2009) or floating houses (Angkor Travel, 2009), predominantly travelling by boat. **Figure 1.3** shows a modern-day example of a stilted house.

Figure 1.3: An example of a stilted house, from Disney's *Bridge to Terrabithia*

Unfortunately, travelling in this manner restricts movement, and ultimately, geographical freedom. A modern-day equivalent would be requiring all Beverly Hills residents to use a vehicle when navigating the roadways, rather than allowing residents to walk freely through the roads. Obviously, requiring so would be somewhat limiting. The fundamental idea of a bridge was proposed to allow Cambodians to freely walk their "land", or more semantically correct, freely "walk on water".

As shown in **Figure 1.4** however, even a Beverly Hills road is truly complex, everything from construction (Lay, 1992) to routing (Lexico Publishing Group, 2007) to transport economics (Nobel Foundation, 2000). It truly astonishing to see just how many Westerners take their roads and other civil infrastructure for granted.

Figure 1.4: A Beverly Hills road is complex in way of both design and construction.

Furthermore, unlike much of the Western World (including Venice in Europe), Cambodia faces a unique problem in relation to continuously changing water levels that differ vastly depending on season and time of year (Food and Agriculture Organization of the United Nations, 2001). In other words, the distinctive question that applied to Cambodia was what way was there to create a bridge that firstly, could stay stationary despite it was a large distance away from land; and secondly, could adjust for changing water levels.

The only solution was the Modular Floating Bridge (herein referred to as the "MFB"), which in its preliminary level has previously been used in the United States and around the World in defense, usually referred to as "pontoon bridges" (Brook, 1998). The MFB team's task was ultimately transposing this Western idea to suit the Eastern environment that the Tonle Sap finds itself.

1.1 SWOT Analysis

The **Strengths** of Cambodia lies in the public perception it needs help, thus attracts attention from various agencies (Engineers Without Borders UK, 2004). Although this is counteracted by lack of access to capital (World Vision Singapore, 2007), it means that the MFB project has at least *some* start-up capital.

The **Weaknesses** of Cambodia lies in its inability to access capital, due to its bad credit rating (although slowly improving) (Monster's and Critic's, 2008), low aggregate country income (Bharat Book Bureau, 2005), and public perception (World Federation of Public Health Associations, 2005). Thus, the MFB budget was severely limited as a result. As a result, materials were also limited to those that were commonly available within Cambodia, rather than importing materials from overseas that would likely be comparatively more expensive, not even considering freight (ASENA Secretariat, 2009) and tariff charges (World Bank, 2008).

The **Opportunities** in Cambodia lie in its underdevelopment (Foundations Pour Des Actions Concretes, 2007), thus there are huge opportunities for investment in infrastructure (Government of Cambodia, 2009), which could potentially attract advertising revenue (Beyond Madison Avenue, 2008), as well as business-government partnerships (Asian Development Bank, 2005), and government funding (Economic Institute of Cambodia, 2004).

The **Threats** to Cambodia are that because the country is slowly gaining momentum, many companies may already be investing in Cambodia (Government of Cambodia, 2009), which could attract huge completion, which could ultimately lead to a price war (Ryckman, 1994).

1.2 Problem Definition

The problem the MFB team faced was creating a civil infrastructure, which would assist persons residing in the Tonle Sap Lake and River in Cambodia.

The proposal outlined is a response to the EWB Challenge, which hopes to help the lives of people living in poverty and disadvantage. The aim is to respond to the disadvantaged communities living on and around the Tonle Sap Lake and River in Cambodia, by presenting a sustainable human development solution (United Nations Development Program, 2007). It is truly hoped the Live & Learn and EWB community partners will find the MFB solution innovative and beneficial for new trials and pilot tests.

The various conceptual designs include an integrated design solution, including physical infrastructure, machinery, equipment and appropriate technologies. The design aims to assist Live & Learn to support the local communities in their own efforts to improve the quality of their lives from a social, environmental and economic perspective.

In short, the aim is to build a bridge that differentiates itself from the current pontoon bridges on the market because of its extendibility. Whereas current pontoon bridges are built to specific lengths, the MFB idea is to create a pontoon bridge that can be extended and shortened like the aggregating and disaggregating of Lego blocks.

BACKGROUND

Hilary Duff has great brand recognition, but we hope MFB will gain even more (Disney, 2006)

2 Background

2.1 Political

The Political environment of Cambodia, which was once unstable, but now somewhat improving, affected the development of the MFB Conceptual Design in numerous ways.

2.1.1 Increasing Use of Own Resources

The argument that Cambodia's natural resources, particularly it's valuable timber, is being exploited by the likes of Thailand, Vietnam, Malaysia, Singapore and Australia (Asia Sentinel, 2007), predominantly because Cambodia cannot utilize its resources is an interesting one. As a result, the MFB attempts to use, still on a basis of need, Cambodia's own resource industry, to help improve its own civil infrastructure. As the old saying goes:

"The person who can best help you – is yourself"

Despite deforestation will remain a Cambodian plague (Butler, 2005), the utilization of Cambodia's resources by their own people for their own use, will increase demand for the same output supply, thus reducing price, as shown in **Figure 2.1**.

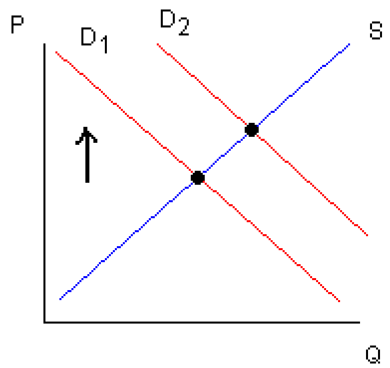


Figure 2.1: For the same Supply curve, if the Demand of Cambodian wood increases, the price will increase, thus deterring "exploit" pricing of Cambodian wood.

2.1.2 Dealing with Misappropriation

Because of the some-what corrupted Political climate of Cambodia (BBC Asia-Pacific News, 2006), aid from the United States is sometimes being misappropriated into private accounts (High Beam Research, 2005). This is a real concern to charitable civil engineering projects such as the MFB, because the primary source of funding for these projects are international aid funds. As a result, MFB was not only built using mostly local Cambodia materials, but also materials that needed to be exported (such as steel brackets), were manufactured in such a character, as so to make it almost impossible to misappropriate.

2.2 Economic

2.2.1 Access to Debt Finance

In terms of financing, in the past ten years, because Cambodia's economic growth rate has been reasonably strong, as shown in **Table 2.1**, with its GDP averaging 6.9% between the years of 1994 and 2004 (Assean Affairs, 2009), obtaining financing from debt (rather than equity) will become increasing easy. Despite the MFB's lead in price (hyper-)competitiveness and labor efficiency, because of the strong reliance on labor and natural resources, as the Cambodian economy continues to strengthen, debt financing will become essential. Note however, the Return-on-Investment (Frontier Investments and Development Partners, 2008) should eventually well offset the initial investment, particularly in terms of civil usability (and thus taxes as a result).

Cambodia Economy at a Glance	
GPD (US$)	$357
GPD growth rate	6.9%
GPD Composition by Sector	
Agriculture	20%
Fisheries	9%
Forestry	2%
Industry	29%
Services	34%
Per capita HFCE (in '000 Riel's)	1,091
Unemployment rate	0.8
Labor force participation Rate	74.6%
Poverty rate	36.1%

Table 2.1: NIS Statistical Year Book 2005, CDHS 2000, State of the Environment Report 2004

2.2.2 Benefits to Industry

The MFB introduction would come in perfect timing, particularly as the once-flourishing agricultural, fishery, and forestry industry of Cambodia begins to deplete (IPS Inter Press, 2008). Unfortunately, as the World Climate changes, and continues to change, this gentle erosion of Cambodia's traditional industries is looking unlikely to impede. Fortunately, because of International Free Trade Agreements (Bilaterals, 2008), Cambodia can in some ways move away from primary industries (natural resources) to secondary (manufacturing and construction) and even tertiary (services) industries. Interesting to observe is the production of the MFB in itself is classed as the much-heralded secondary and tertiary industry production, which the West has previously dominated (Chen, 2001). Furthermore, by inference, civil infrastructure development will increase access to labor, which will increase labor supply to already-huge export industries such as textiles, garments, and footwear (Cambodia Garment Industry, 2006), which on a larger scale could inflate GDP.

Furthermore, the MFB supports well the Tourism industry, already reaching two million per annum (China Post, 2008), by providing foreign travelers with, despite a unique experience, one that is more "close to home" or free, than merely travel-by-boat.

2.2.3 Benefits to Community

Increased public infrastructure also means reduced barriers of entry, whether that be in relation to schooling, or work-related. In other words, because a boat would be a private possession, person(s) who cannot afford a boat will be limited in their travelling ability. However, the introduction of public transport (the MFB) would mean that person(s) who cannot afford a boat would not be limited in the same way as if public transport were not present.

In terms of education, the MFB Training Sessions will also provide workforce with invaluable skills and working culture, which will greatly benefit the community, providing workers with hands-on experience that they can use for their own private enterprises.

2.3 Social

2.3.1 "Free Lunch"

One of the benefits for some of working for some big corporations in the West is whether the employment package includes a "free lunch" (Google Inc, 2009). Similarly, in Cambodia, the United Nations has introduced a "Food for Work" program (Friends of the World Food Program, 2009) that encourages low-skilled laborers to work for healthy and yummy food. After all, even Westerners long for a taste of Khmer cuisine – fermented fish, sticky rice, curry dishes (ifood.tv, 2009).

2.3.2 Population Growth

As the population of the Tonle Sap River grows, the MFB needs to extend, take greater capacities, and deal with network economics. The MFB took into consideration all these factors, and in many respects, delegated much of the planning roles to dedicated "Town

Planners" who would know the demand for the MFB more than Westerners'' from a different cultural and geographical context would.

Nevertheless, the MFB components were chosen for strength-to-cost ratio and durability, to account for the expanding Cambodian population.

Even at the current population of fourteen million people (CIA, 2008), and a growth forecast of nineteen million by 2020 (JICA, 2007), the MFB was designed and simulated based on:

- Individual /Tourist use (one to seven person)
- Household use (4.1 people (Population Reference Bureau, 2003))
- Community use (estimation of between fifty to five hundred families)
- School use (estimation of fifty to five thousand pupils)

Another consideration is average population density, which is around 67 people per square kilometer (PopulStat, 2004). This is compared with say 90.40 people per square kilometer in the State of California (United States Census Bureau, 2006). Increasing population density will only mean increased economies of scale of production (Sullivan, 2007).

2.3.2.1 Elderly Population

As the elderly population increases faster than other market segmentations (United Nations Economic and Social Commission for Asia and the Pacific, 2007), Cambodia must find ways to provide health care facilities and housing to improve their wellbeing. Because the MFB decreases barriers to entry (as discussed in **2.2.3**), it increases access (as well as presence) of health facilities.

2.3.3 Culture

In designing the MFB, special considerations were made into cultural elements of Cambodia that were key to the Country; such as music, dance, and the arts (Encyclopedia Britannica, 1998). Because of decreased barriers to entry, there is increased access to celebrations and festivals that take place throughout the year. Particularly in areas of Cambodia with low income per capita, this will revitalize dying cultural industries.

2.4 Technological

As an engineering design solution, the technological environment of Cambodia was critical to the assessment of materials, as well as tools and labor knowledge, which were available. The

MFB successfully utilizes natural resources derived from within Cambodia, with the only element that needs to be imported being the steel bracket.

2.5 Legal

Conducting business in Cambodia means complying with Cambodian labor law (iFrance, 1997).

Furthermore, because there are likely to be no laws or regulations on the dimensions of walkways and length of handrails, in the capacity of a professional engineer, it is a vital role that the highest level of safety is attained. Thus incorporating the United States standards of construction, a safe ethical design can be achieved.

Handrails in United States are required (Eng-Tips, 2003) to be made of steel tubing or timber with a minimum diameter of 40mm with support posts to be maximally spaced at 1.8 meters. United States standards consider stainless steel wire (minimum diameter of 3.2mm) below the handrails to be at a maximum of 100mm apart. However, in this design, it is necessary to keep cost low and therefore rope will be used for the support rails below the main handrail.

Walkways in the United States are required (Worldwide Cleaning Industry Association, 2009) to be at least 120 centimeters wide (two feet per person, for a walkway that allows for a two-way lane).

2.6 Environmental

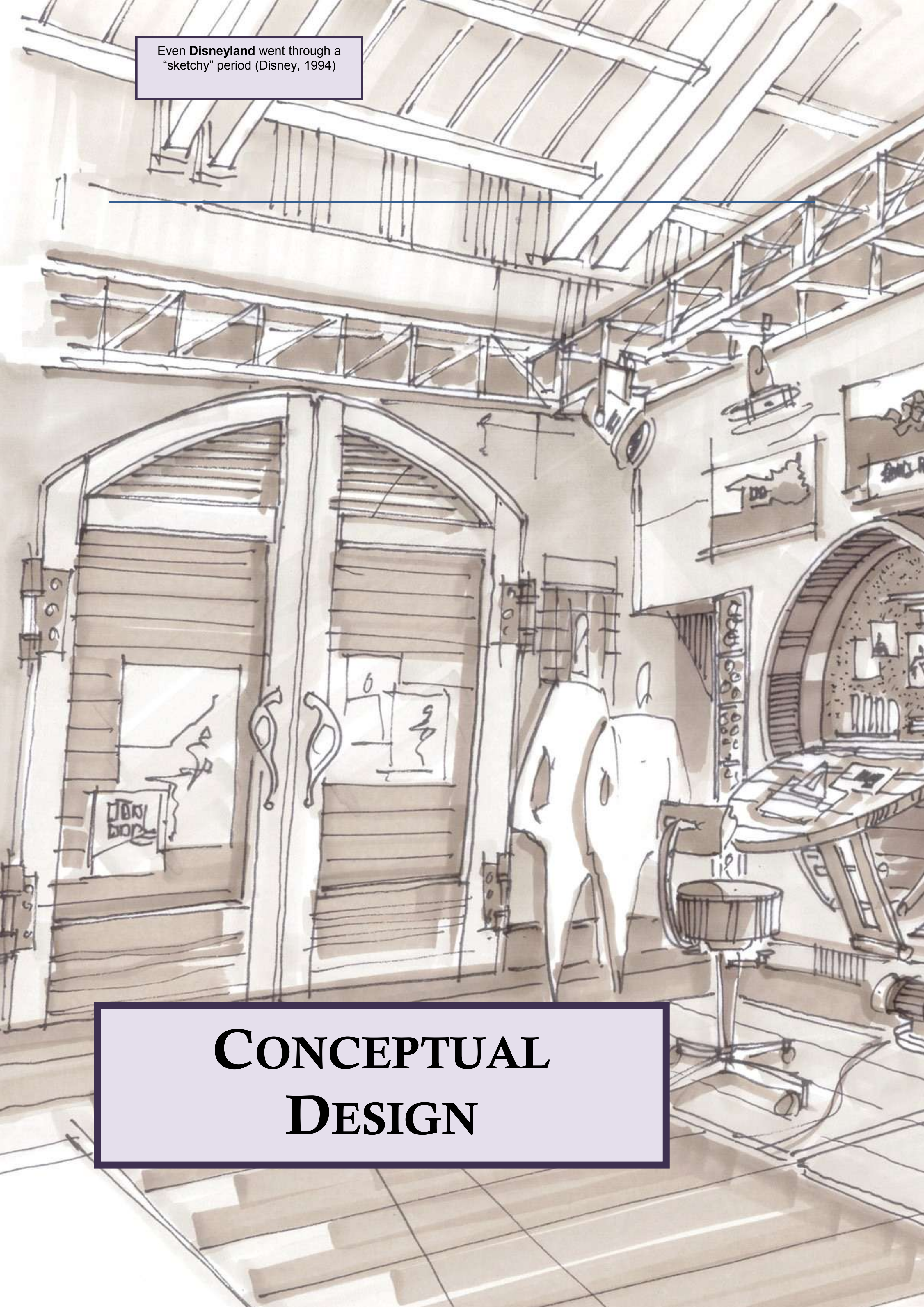
2.6.1 Climate Weather

Cambodia, in particular the Tonle Sap region, goes through annual monsoonal cycles (Cambodia Travel Guides, 2009), resulting in alternative wet and dry seasons, thus rising and falling water levels. Over the June to October period, the Tonle Sap Lake increases by five times in land coverage with respect to the dry season and gains a depth of up to ten meters (GIS Development, 1998). This rapid extension of the Lake's land coverage is a direct result of the Tonle Sap's flat landscape (Australian National University, 2008).

Due to this annual cycle, which results in adversely different landscapes, the design of the MFB was designed to be compatible with the Cambodian lifestyle throughout the seasonal changes, of both the wet and dry seasons.

For instance, a series of small detachable bridging sections were employed in preference to a large fixed bridging unit. This accommodates with portability and extendibility during the wet season in areas where most required, as well usability throughout the dry season in areas still covered by water.

CONCEPTUAL DESIGN



Even **Disneyland** went through a "sketchy" period (Disney, 1994)

3 Conceptual Design

Guided by the PESTLE analysis of the Tonle Sap, in considering the Conceptual Design, the MFB was modeled based on these questions:

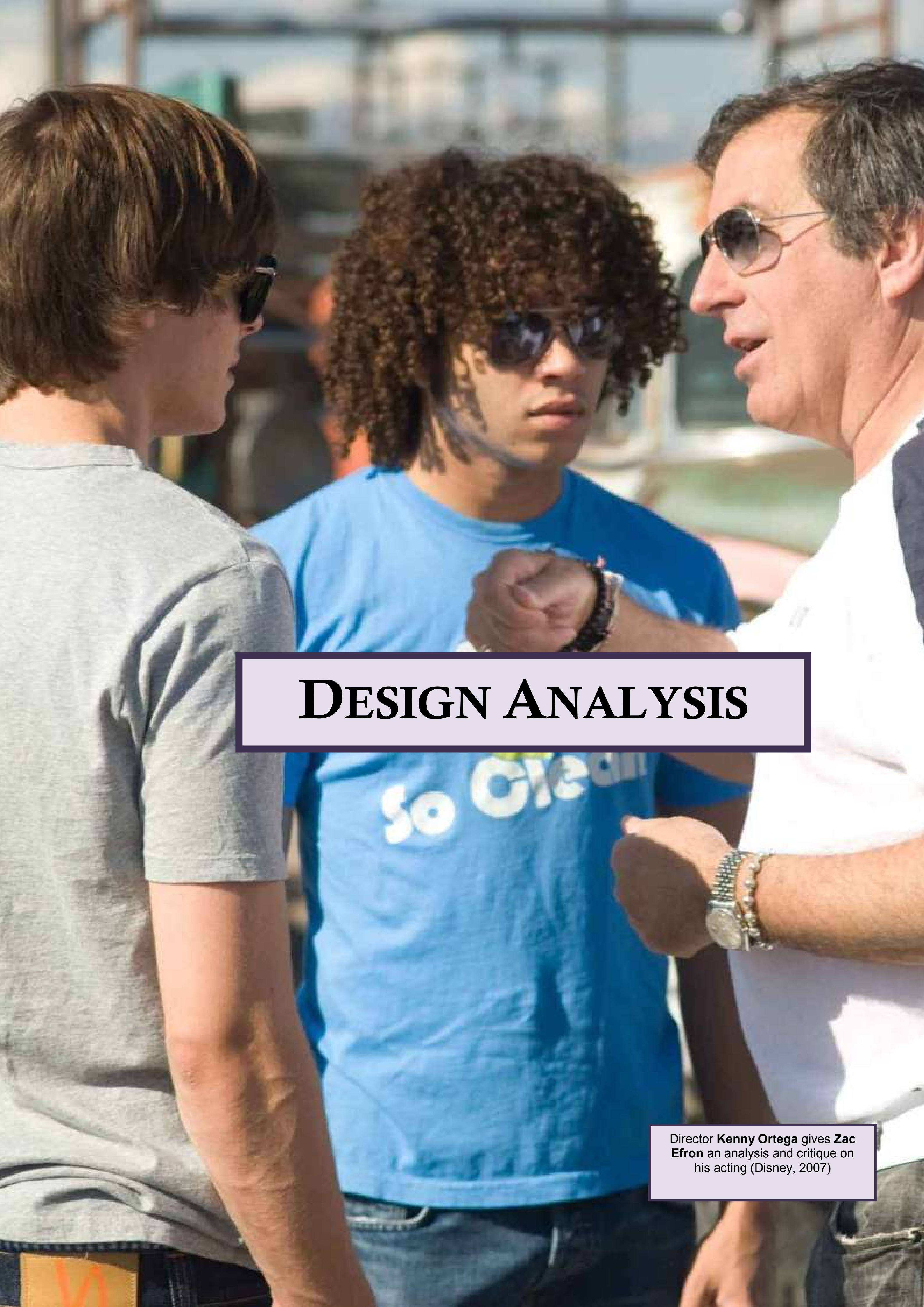
- **What product features must the product incorporate**? As per the definition of "bridge", the fundamental aspects must be met, namely that the structure spans a body of water, providing passage over (or in this case through) an obstacle (Merriam-Webster Dictionary, 2009). Furthermore, it must be suitable to both the economic climate of Cambodia; as well as the environmental climate of Cambodia. In short, the optimal design will use componentry native to Cambodia (as discussed in **2.1.1**), and takes into account the changing water levels (as discussed in **1**).
- **Will the market segment (people living in the Tonle Sap, Cambodia) benefit from the product**? As outlined in **2.2.2** and **2.2.3**, the benefits of the MFB are will occur directly, in way of reducing cost of travel (sometimes referred to as barriers to entry), as well as indirectly, on other industries that prerequisite civil infrastructure.
- **How will the market segment react to the product**? Despite the size of the Monivong Bridge, Cambodia responded well to the heavily trafficked bridge, despite it was a multi-lane concrete bridge with fully equipped lights and other modern features (The Phnom Penh Post, 2009). Thus, the prospect of Cambodia's smaller towns not accepting the introduction of the MFB is unlikely. Particularly considering the lowering of costs of travel that will occur as a result, the MFB will be tremendously welcomed by locals, even simply in the form of "building the nation".
- **What is the size and growth forecast of the market segment**? The growth rate of the Tonle Sap is 2.21% (Keskinen, 2003). This is very similar to that of California's (California Legislative Analyst's Office, 2000). Also projected to be similar to that of California, is the civil infrastructure participation rate (Hanak, 2006), near or close to 100%, which justifies funding from taxation.
- **What is the current or expected competitive pressure for the product**? There is currently little-to-no competitive pressure for the introduction of bridges into the Tonle Sap, Cambodia. The only noticeable competition was:
  - **Prek Kdam Bridge** over the Tonle Sap which Cambodia Prime Minister Hun Sen stated would be the "transportation hub of Cambodia", financed by the Shanghai Construction General Company (Xinhua News Agency, 2007), which is projected to cost $207 million. Whereas the PK Bridge is a nation-

wide project, the MFB, although attachable to the PK Bridge, is an intra-communal project.

- **25m Collapsed Bridge** was a Tonle Sap Lake bridge that infamously collapsed, decimating the Tonle Sap tourism industry. The MFB takes into account this horrendous accident, and thus at its core, values safety, and is United States and Europe Engineering Civil Engineering Standards-compliant.

- **What are the industry sales and market trends the product is based on**? The MFB assumes the continued expansion and contraction of the Tonle Sap freshwater lake. There seems to be no indication this cycle is about to impede (PD Activity, 2004).
- **Is it technically feasible to manufacture the product**? The MFB was specifically designed in such a manner as to be technically simple, to not confuse low-skilled laborers. In fact, the engineers took to it to design a mini-model, which was tested to demonstrate technical feasibility.
- **Will the product be economically feasible when manufactured to the market segment at the target price**? The MFB takes into account the low GDP per capita (International Monetary Fund, 2009). From both the componentry and labor cost level, all was done to triumph on a price hypercompetitive basis.
- **How will the product be produced most cost-effectively**? The MFB is designed in such a manner as to best utilize natural resources, and limit waste. Furthermore, componentry was designed in such a manner to allow compact packing, thus reduced shipping density, and therefore carbon footprint.
- **Proof of feasibility through computer-aided rendering and rapid prototyping**? As a part of assessing technical feasibility, a prototype was designed to demonstrate workability.

There is no doubt the concept behind the MFB is producing supply to meet demand. The cost-effectiveness and proof of feasibility simply outline the commercial viability of the MFB, and the many different ways, directly and indirectly, the MFB would benefit the economy (both quantitatively and qualitatively).



DESIGN ANALYSIS

Director **Kenny Ortega** gives **Zac Efron** an analysis and critique on his acting (Disney, 2007)

4 Design Analysis

4.1 Alternative Analysis

4.1.1 Pontoon Alternatives

4.1.1.1 Pontoon Structure

Because the MFB would be subject to both physical forces and corrosion from both the atmosphere and the solution the bridge will float on, selection of the correct pontoon design and material was important. Furthermore, the pontoons would have to provide the buoyancy force and stability that a MFB requires. The materials available for the pontoon in the market are both vast and differ predominantly depending on environmental and social environments (as discussed in **2**).

4.1.1.1.1 Barrel Design

Figure 4.1: Poly Drum
(ADCO Services, 2003)

Sealed short cylindrical drums, like that in **Figure 4.1** and **Figure 4.2**, also known as barrels are regularly used in the construction of small rafts and pontoons (SookeRotary.com, 2009). These drums are readily available as many industries utilize these containers for the transportation and storage of liquids (Newcastle City Council, 2006). Barrels are available in different sizes and but the more common sizes are the 20L, 120L, 205L and 220L volume drums (Schutz DSL, 2009).

The physical size of a barrels provide little buoyancy and stability but do provide a streamline shape if orientated end into wind and water currents.

Using the Barrel Design for the MFB would mean using a product that had gone through the "test of time", previously used for small rafts and pontoons, and was a readily available resource in Cambodia.

Figure 4.2: Steel Drum
(Global Industrial, 2009)

4.1.1.1.2 Cigar Design

Cigar-shaped pontoons are physically similar to barrels but have rounded ends and an elongated shape as seen in **Figure 3.3.** The elongated shape provides superior levels of stability if orientated perpendicular to a bridge span (Fidler, 2008). The increased displacement of this design over barrel design offer larger buoyancy forces, which can be utilized to support heavier bridge designs with fewer pontoons. The streamline shape of this design limits the effects of water and wind turbulence if orientated end onto the current flows and thus reduces the load on the anchoring system

Figure 4.3: Canary North Quay Bridge, West India (Darkwaters, 2009)

Although the superior levels of stability that the Cigar Design could provide, because the shape was unavailable in Cambodia, unless it was manufactured out of synthetic (and costly materials), this structure was left for reconsideration for second-generation MFB’s.

4.1.1.1.3 Box Design

Box design pontoons are commonly used in calm water environments (Alaska Department of Fish and Game, 2006) and are frequently installed in boat mariners. The design consist of a square or rectangular box section which provides the vessel for displacement on top of which is attached a flat surface used as the deck. The large area of displacement of this design provides large load bearing capacity with the trade off to large susceptibility to surface currents and wind loading. The stability of this design is poor due to the narrow displacement surface and so is generally installed between steel piles, which are used to locate and brace the bridge section.

Unfortunately, both the poor stability, and uncommon shape meant it was incompatible with both the environmental climate, as well as the environmental resources of Cambodia.

4.1.1.1.4 Displacement Design

The displacement design bridge is not regularly used in practice but does overcome the need to suspend a carry way, as seen in **Figure 3.4**.

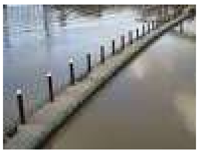


Figure 4.4: Vera Katz Eastbank Esplanade and Floating Bridge
(Bridge Stories, 2009)

Unfortunately, this design is unsuitable for Cambodia due to the large effects water and wind currents would have on this structure due to its large longitudinal area.

4.1.1.1.5 Selection

Although the Cigar Design does provide increased superiority in terms of both stability as well as load, because of the unusual shape, considerations for this design will only be made for the 2nd generation MFB. Thus, because both the Box and Displacement Design are inappropriate for the Cambodian environment, the classic Barrel Design is selected by default.

4.1.1.2 Pontoon Material

The materials used in the construction of floats available on the market internationally are vast and vary greatly in their cost and availability. Not all materials listed in the conceptual analysis are appropriate for the use in the Tonle Sap, and is eliminated as necessary.

4.1.1.2.1 Concrete

Concrete is used in the construction of pontoons and offers good resilience to the effects of ultraviolet radiation (Hota, 2006). Concrete is a versatile material, which can be cast into complex shapes (Concrete.com, 2009) but is reliant on reinforcement steel to provide enough toughness in an environment such as the Tonle Sap.

Unfortunately, the density of concrete is approximately 2300 kg/m^3 (Jackson, 1996) and thus limits both the size of a pontoon, and the load bearing capacity.

4.1.1.2.2 Steel Drums

205L steel drums are generally the standard in the petroleum industry (Perth Petroleum, 2009). It is appropriate for the buoyancy device used for the MFB, but is disadvantaged to the plastic barrel because plastic is generally less reactive to seawater than steel. However, the advantage of steel does not have the disadvantage of degeneration if exposed to ultra-violet light for prolonged periods (Askeland, 2008).

Despite the Tonle Sap is a freshwater lake (World Wildlife Fund, 2009), because of the reactivity of steel with salt water (Hall, 1997); the metallurgic process of converting steel into inox would increase the price above that which is accessible to Cambodians.

4.1.1.2.3 Non-Recycled Plastic Drums

Like steel drums, polyethylene (plastic) drums are often used in the construction of floats. Plastic barrels are generally used in the chemical industry, which require a corrosion resistant storage container (IndiaMart, 2009).

The selection of polyethylene drums, which have been treated with UV stabilizers, would extend the lifespan of the product (ASM, 1995) and provide a more sustainable design. Compared with other materials, plastic drums are one of the lightest (yet cheapest) materials (Hansma, 2007) and therefore can be transported easily, thus reducing cost of freight.

Since the price of treating polyethylene drums with UV stabilizers (ASM, 1995) would be far cheaper than that of treating steel in metallurgic process (Hall, 1997), plastic drums would be preferred over steel drums.

4.1.1.2.4 Recycled Plastic Drums

Among the more environmentally sustainable materials, which could be considered suitable for the construction of pontoons, are recycled plastics such as polyethylene terephthalate, high-density polyethylene and polyvinyl chloride (Lenau, 2003). These plastics are currently recycled and used to produce wheelie bins, which are comely, used in Europe for rubbish collection (Wheelie Bin Skins, 2009).

The production of recycled plastics relies on the collection of plastics currently thrown in waste deposits such as landfills (Waste Online, 2006). The plastic is then subjected to various chemical and mechanical processes in specialized facilities. Although this process has high initiation costs and logistics (Hinkley Center, 2002), increasingly complex and interlocked environmental regulations (AllBusiness.com, 2005) will mean increased demand in the long-term, thus good Return-On-Investment.

Fortunately, recycled plastic drums are readily available in Cambodia (EWB Australia, 2009).

4.1.1.2.5 Fiberglass Drums

A common composite material used in the marine environment for the construction of buoyancy devices such as boat hull design is fiberglass (Wiley, 1988). Fiberglass is a matrix of thermosetting resin in which a reinforcement mat of glass fibers is laid (Techstreet, 2004). Composites such as this require a mould in which the composite is laid into which determines the dimensions of the final product, as shown in **Figure 3.5**. Fiberglass has the advantage of being super-lightweight and can be filled with low-density foam, which strengthens the product as well as providing buoyancy.

Figure 4.5: Vera Katz Eastbank Esplanade and Floating Bridge
(Bridge Stories, 2009)

Unfortunately, the expense of fiberglass (Taunton Press, 1997) restricts access to such material. Nevertheless, consideration was given for second-generation MFB to include such materials.

4.1.1.2.6 Selection

Concrete was inappropriate as a floating device because of its restrictive density. Steel drums proved to be less potent (and readily available) than Plastic drums in the Cambodian economic and environmental climate. Fiberglass was another effective option, but was expensive.

Thus, recycled plastic drums were chosen by default.

4.1.2 Bridge Alternatives

A number of constraints limit the design of the bridge structure, which is supported by the pontoons. The most influential component on the bridge structure design is the pontoons as these provide both the buoyancy and stability to a non-pile tethered bridge designs.

As the supporting force of a MFB is solely supplied by the pontoons, the bridge structure and the load intended for the structure cannot exceed the buoyancy force (AllExperts.com, 2006). Therefore, a practical bridge structure needs to be lightweight to ensure an efficient safe working load is achieved. The bridge structure is used both as a load-carrying frame, but also to locate the pontoons. The secure locating of the pontoons to the bridge structure is paramount to ensure a safe design.

In designing the structure of the MFB, the design had to incorporate a centre of gravity in proportion to the stability provided by the pontoons. Without properly addressing this issue, a bridge when loaded can become unstable and unsafe due to an increase in the height of the center of gravity (Gaudron, 1999). The designs of floating bridges are generally of low modular type construction but can be as extravagant as the rolling bridge designed by Heatherwick Studio, which utilizes hydraulic rams to curl the structure (**Figure 3.6**).

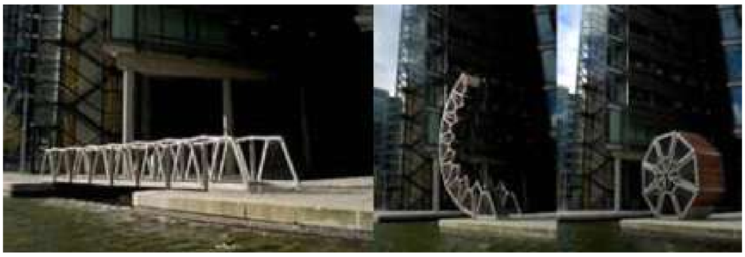


Figure 4.6: Rolling Bridge designed by Heatherwick Studio
Geekologie (2007)

Furthermore, handrails were carefully considered for the purpose of safety. The handrails of the MFB had to supply adequate support for users in the event the structure is hit by waves or wind (Bennett, 1999). Furthermore, the handrails needed to be designed in such a way that they do not inhibit the flexibility of the structure.

4.1.3 Component Fixing Alternatives

4.1.3.1 Component Fixing Structure

After establishing all the various componentry, the next important consideration was the structure of the adjoining module. In particular, because of the cyclic and fluctuating stresses caused by the constantly changing water levels (Food and Agriculture Organization of the United Nations, 2001), special consideration had to be made for the flexibility factor to ensure brittle fracture does not occur. This consideration of environmental conditions, as well as of the loading capacities, led to the "modular design" of the MFB.

The modular design commonly seen in boat marinas (MarineTek, 2009) ensures the bridge structure has a moderate level of flexibility both in its structure and application sense. A modular design consists of a long bridge span being constructed from many smaller individual modules, which allow for flexibility at the point where they connect to one another. The modular design also has the additional benefit of its USB-like "plug-and-play" nature, which allows individual short spanning modules to be used where a long span would be impractical.

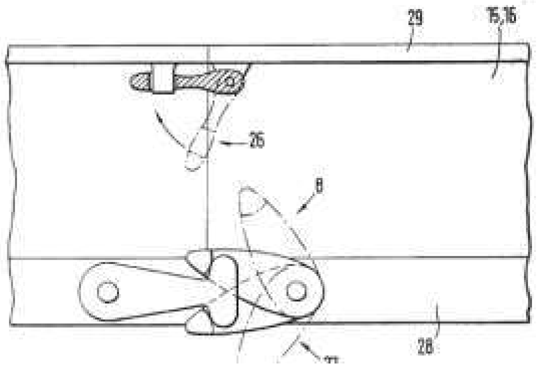


Figure 4.7: "Hot-Swap" Super-Fast Connectivity
(Scarlet Skunk Marine Services, 2009)

Furthermore, the connection of a modular design can also utilize "hot-swap" super-fast connectivity as seen in **Figure 3.7**, appropriate for a bridge that may need to be moved frequently, disassembled/reassembled quickly as seen in **Figure 3.8**.

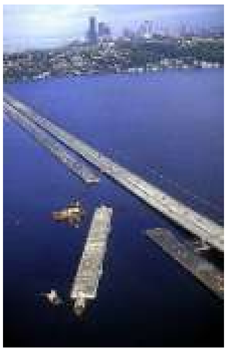


Figure 4.8: Lacy V Murrow Bridge
(Seattle Daily Journal of Commerce, 2009)

4.1.3.2 Component Fixing Material

Note that the material used in the bridge structure would generally dictate the method of fixing components together in the bridge. For example:

1) In relation to **concrete structures**, methods include **bracketing or bolting**
2) In relation to **plastic structures**, methods include **clipping, bracketing, or bolting**
3) In relation to **wooden structures**, methods include **dowelling, bolting, roping, or bracketing**
4) In relation to **metal structures**, methods include **welding, riveting, or bolting**

Since **3.1** established the use of **plastic drums**, and **3.2** established the use of a **wooden bridge**, both (2) and (3) would be relevant. Furthermore, in order to adjoin the plastic drum and the wooden bridge, steel brackets were introduced, thus the relevance of (4) too.

4.1.4 Anchoring Alternatives

Because the bridge was likely to "float" in the middle of a vast flood of water, consideration for anchoring was required.

Traditionally, the methods used to hold bridges in place were to either:

1) Fix the bridge to a solid structure at either end as seen in Canary North Quay Bridge, West India (**Figure 3.3**) or;
2) To tether the bridge to pylons which are driven into the sea floor (**Figure 3.4**)

Unfortunately, these methods are only useful if, for (1) either there is a solid structure at the termination points of the bridge; or for (2) the bridge is not required to be removable in the case of pylon-tethered designs. Otherwise, as with the MFB, an alternative anchoring system would have to be employed.

As a result, the MFB uses "heavy weights" (conventional marine anchors), which are attached to the bridge, locked on to an area of the seabed. Furthermore, because the MFB needs to accommodate to changing water levels driven by wind and tides in large bodies of water, a special method is devised (see **5.6**) to adjust for changing water levels accordingly.

4.2 Selection Analysis

4.2.1 Benefits

There are a number of benefits to the MFB bridge design, as finalized above, which makes it ideal for the communities living on and around the Tonle Sap.

4.2.1.1 Generic Parts

The componentry material is undemanding with generic parts for the construction of each section. This allows for standardized construction techniques (Berhow, 2005) to be used, which increase the economical benefits of this design by shortening the construction time needed.

4.2.1.2 Local Materials

The bridge uses materials that are easily sourced in Cambodia, including:

- Plastic drums (EWB Australia, 2009)
- Wooden decking (American University Washington D.C., 1996)
- Bamboo railings (Biodiversity International, 2009)

As discussed in **2.1.1**, locally sourced materials aid in reducing the material costs due to eliminating freight and tariff charges while providing the benefits of supporting the Cambodian economy.

4.2.1.3 Entrepreneurial Design

A key feature that differentiates the MFB from its competitors is its modular sections, which are joined together to form a long structure. This allows for the easy extension or reduction in length and shape as the needs of the user change during the year. As the engineers described it, the MFB allows for "plug-and-play" and "hot-swapping" (**3.3.1**).

4.2.1.4 Increased Safety

The use of short bridge sections in this modular design provides additional levels of safety and flexibility when compared to a longer more rigid structure. The many joints between short sections allow for the flexibility of the structure when adverse weather conditions are experienced. In the event of a wave affecting the bridge the multiple joints allow the bridge to flex and rotate in a variety of directions increases the stability of the structure when compared to a more rigid structure.

The placement of the drums on the ends of the cross section timbers allow for an increase in stability due to the wide footprint of the bridge structure. The location of the drums helps to lower the center of gravity of the bridge, which is vital to ensuring a safe and sustainable design.

The location of the anchoring system onto the midpoint between the drums on the cross section timbers was a safety conscious decision. The location of this ensures that the structure will not heel over when subject to a disturbed water state and decreases the swaying action of the bridge much like a keel on a boat.

4.2.2 Detriments

The MFB was designed in such a way as to be superior in every manner; nevertheless, because of the restrictive financial constraints on the project, several materials were chosen for the "first-generation MFB" that could be upgraded in the likelihood of a "second-generation MFB".

This includes:

- **Cigar Design**, rather than Barrel Design, which allows for increased stability and load; and

- ❖ **Fiberglass Drums**; rather than Recycled Plastic Drums, which allows for increased strength and buoyancy (thus load)

Nevertheless, the engineering team intends that the second-generation MFB will have full "back-compatibility", meaning it will integrated perfectly with first-generation MFB's, thus reducing operational redundancy.

4.3 Budget Analysis

For a project of the immense size that the MFB aimed to be, and the suitability of the project on a far smaller scale, meant that cost estimations were made based on two criteria (Taylor, 1999):

1) **Precision**: High level of repeatability, because if the MFB cost estimations were not precise, despite the project may be financially sustainable in the production of mass quantities, it would lack the consistency required for the production of smaller quantities of MFB's; and
2) **Accuracy**: Degree of closeness to the true quantitative value, because if the MFB cost estimates were inaccurate, the project may not have the funding to properly expand, if not implemented at all

In coming up with a budget proposal, we kept in mind the following qualitative characteristics in drawing up one:

- ❖ **Reliability**: Synonymous with "Accuracy", as described above; thus has representational faithfulness, and not biased;
- ❖ **Consistency**: Synonymous with "Precision", as described above;
- ❖ **Relevance**:
  - ➢ To provide a forecast of revenue and expenses, as well as assets and liabilities
  - ➢ To provide a forecast of how the business may respond from certain strategies, and events (expected and unexpected)
  - ➢ Have both predicative and feedback value
- ❖ **Comparability**: To enable actual financial operations of the business to be measured against the forecast;
- ❖ **Understandability**: Stakeholders, without prior accounting and engineering knowledge, can understand and apply the budget in a systematic manner. Obviously,

this criterion assumes its users have a reasonable knowledge of business and economic activities and are willing to study the information with due diligence; and

- **Decision Usefulness**: The budget must be provided in a timely manner as so not to inhibit decision usefulness. This characteristic must be weighed up against the reliability criterion; since increased time would mean increased reliability, but may mean reduced decision usefulness.

For each independent (that is, separately funded) implementation of the MFB, there are three stages of product development:

1) **Business start-up**: In this period, working capital and labor service must be established. Since the bridge is Do-It-Yourself, assuming no labor costs (other than those of training staff at EWB), working capital is the predominant levy.
2) **Business establishment**: Once a community has established various MFB, it becomes established, and has a cash flow. Because of the franchise-nature of the MFB system, the franchisor would receive a fee, which would go towards a marketing budget. Note that economies of scale (with the exception of the steel bracket) is unlikely to be achieved because of the independent and autonomous nature of the MFB production system.

In order to increase perceived (as well as actual) professionalism, annual reports should be drawn up yearly, outlining the financial position, performance, and cash flow of each autonomous MFB system, and a consolidated report for the entire network of MFB's (including the corporate head).

Because of the varying prices of componentry in Cambodia, the use of its own natural resources, and volatile economy, cost estimations could not be accurately provided in the design brief. Nevertheless, price minimization was the objective at every stage of analyses.

FINAL DESIGN

This **General Motor**'s car is the "new thing" in Disney's **EPCOT**. When will we see the MFB there? (Disney, 1999)

5 Final Design

As established in the **Design Analysis**:

- Barrel Pontoon Structure
- Recycled Plastic Drum Material
- Component fixing using (depending on material of to-fix structure):
    - **Plastic structures**, methods include **clipping, bracketing, or bolting**
    - **Wooden structures**, methods include **dowelling, bolting, roping, or bracketing**
    - **Metal structures**, methods include **welding, riveting, or bolting**

From the analyses of existing designs and available materials, a **Final Design** was created for the MFB that would be used to as civil infrastructure in the Tonle Sap area.

There are a number of key parts to the design, which include:

1) Polyethylene (Plastic) Drums
2) Steel Brackets
3) Wooden 4”x6” Timbers
4) Wooden Decking

5.1 Polyethylene (Plastic) Drums

Polyethylene drums are used as the bridge's buoyancy devices. The 220-liter drums are used as they provide suitable buoyancy levels for our MFB design (as discussed in **4.1.1.2.3**) and are readily available in Cambodia for the reasonable cost of two dollars per unit (EWB Australia, 2009). The drums are 220 liters in volume, which provide a buoyancy force capable of supporting approximately 220Kg when fully submersed in fresh water (Marine & Industrial Distribution Ltd, 2009). The external dimensions of the drums are 580mm in diameter and 910mm in length, as shown in **Figure 5.1**.

One section of the bridge will have four drums attached to it, two on each end, which will result in a theoretical gross maximum load of 880 kg, reducing safety issues. To extend product life, the polyethylene drums will ideally be manufactured with UV stabilizers to reduce the decomposition of the material when exposed to ultra-violet light for long periods (as discussed in **4.1.1.2.3**).

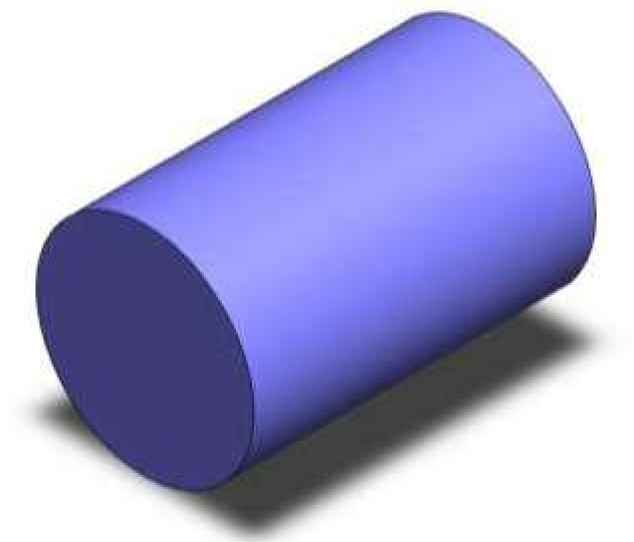


Figure 5.1: Artist's Visualization of a Polyethylene Drum

5.2 Steel Brackets

Steel brackets are manufactured to allow the secure attachment of the drums onto the bridge structure. The steel brackets are comprised of two halves, one standard bracket and also a modified bracket that are bolted together when placed around one of the drums, as shown in **Figure 5.2**.

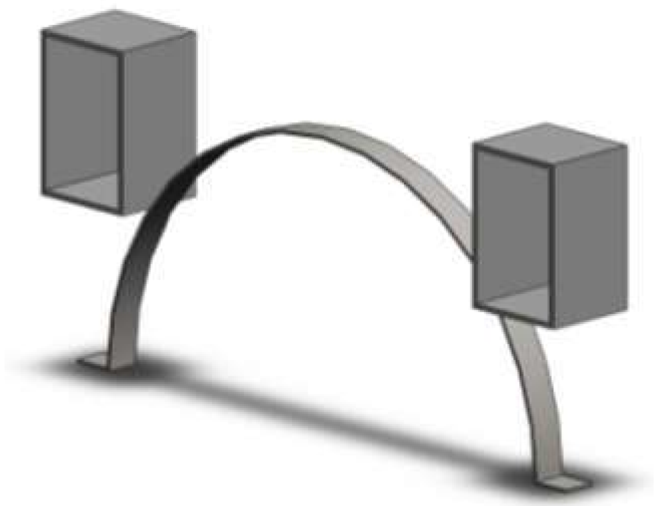


Figure 5.2: Artist's Visualization of a Modified Bracket

A key feature of the modified brackets is the two hollow rectangular boxes that are attached by gusseting and welding to either side. The attached boxes are used to locate the drums onto the cross timbers which locate the drums and provide the support for the bridge structure. One section of the bridge will have eight of these brackets, two being around each of the plastic drums, as shown in **Figure 5.3**.

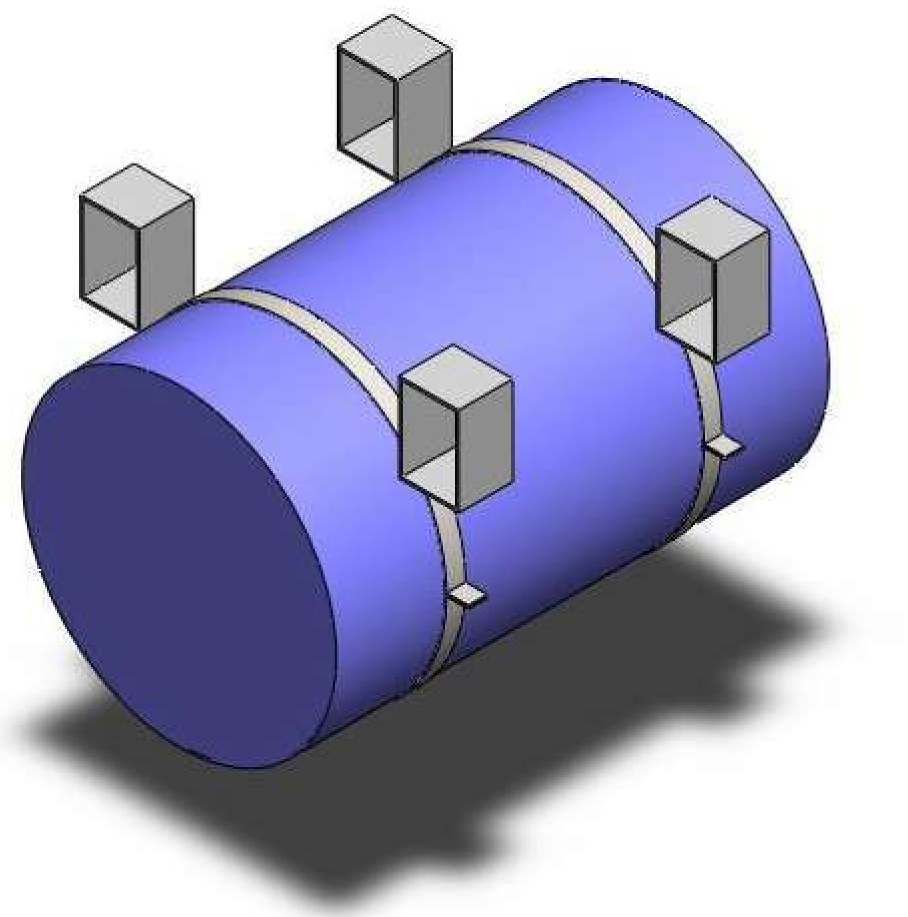


Figure 5.3: Artist's Visualization of a Drum Assembly

5.3 4"x6" Timbers

A standard sized timber of cross sectional dimension, 4 inch by 6 inch (4"x 6") is used throughout the design. Standard sized timber was purposely used to simplify the design and construction and increase the flexibility of the final design. The use of generic material throughout the design has large economic benefits, as discussed in **4.2.1**.

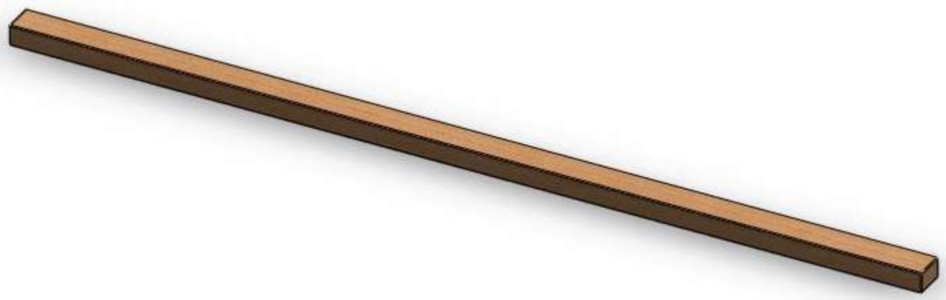


Figure 5.4: Artist's Visualization of a 4"x6" Timber

The timber used in this bridge design will be treated to ensure protection from material decay because of water exposure. During the construction of the bridge, the timbers are first used to hold the two drums at a set distance of 1480mm apart. Next, they are slid into the rectangular boxes on the brackets where they can then be fixed into place. This creates the end drum piece.

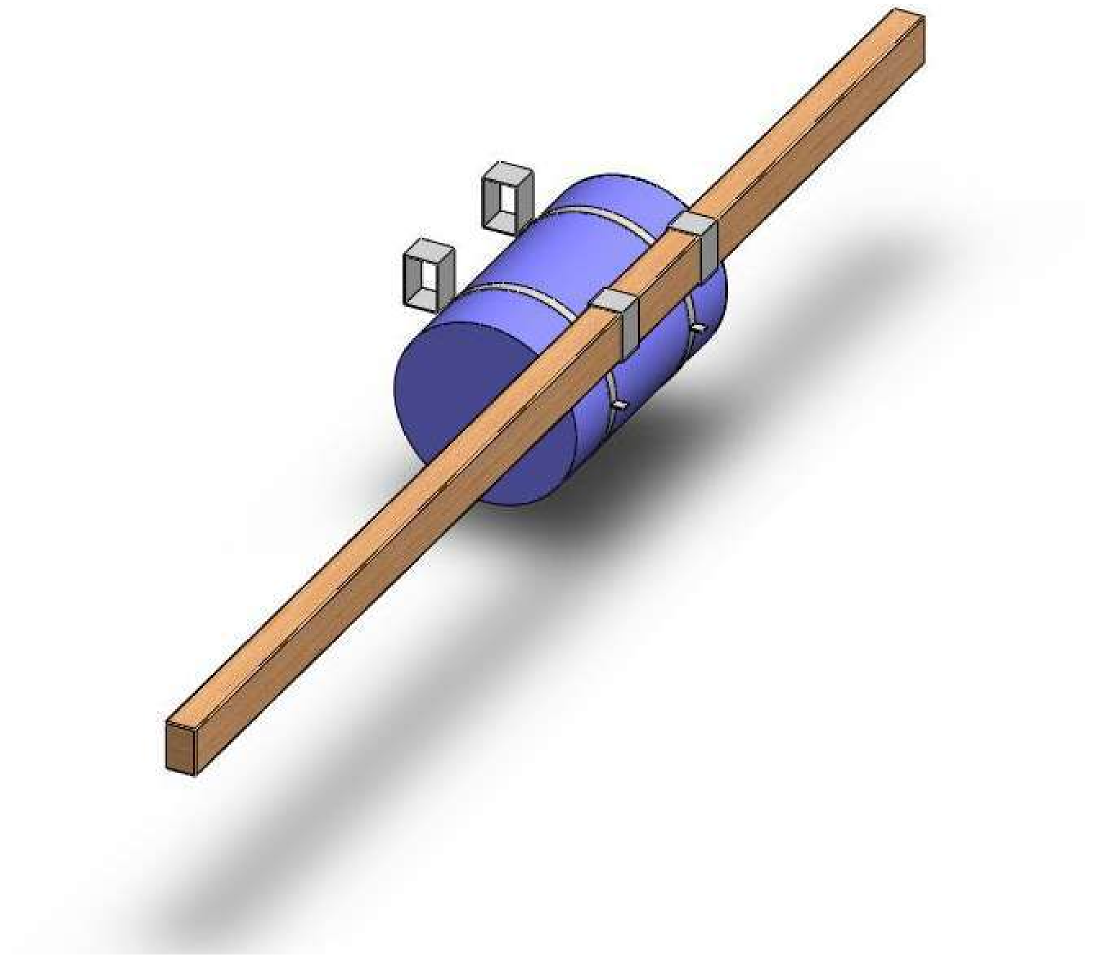


Figure 5.5: Artist's Visualization of how a Timber fits into a Bracketed Drum

The second circumstance where the timbers are used in the design are to set the distance in between the two end drum pieces, which provides a platform for the deck to sit on. To construct this, a water treated 4"x6" wooden timber of standard length (6000mm) has two 800mm sections cut from it. The cut offs are then notched and become the connecting component between the cross sections and bridge span. The notches measure 4" x 1" that allow for the location of these components securely to the cross timbers. The notched pieces are then reattached to the underside of the remaining 4400mm timber at each end. Several large cylindrical dowels are used in the connection of these two pieces, which create notched timber sections. There are four notched timber sections per bridge module. To ensure a high level of safety the notched timbers will be secured onto the cross timbers by a small recess and dowel between these two components.

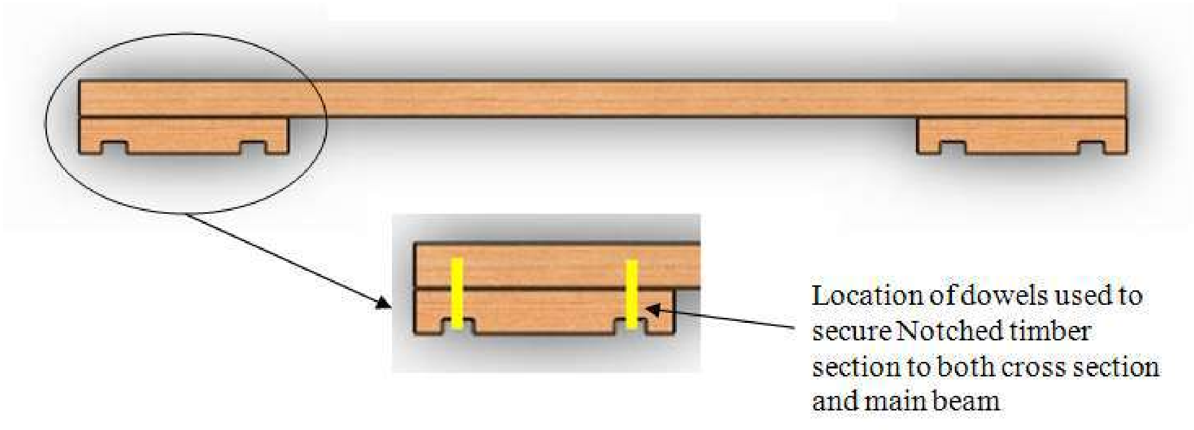


Figure 5.6: Artist's Visualization of a notched timber section

The combination of a completed **Figure 5.5** and **Figure 5.6** is the underlying framework for the MFB, shown in **Figure 5.7**.

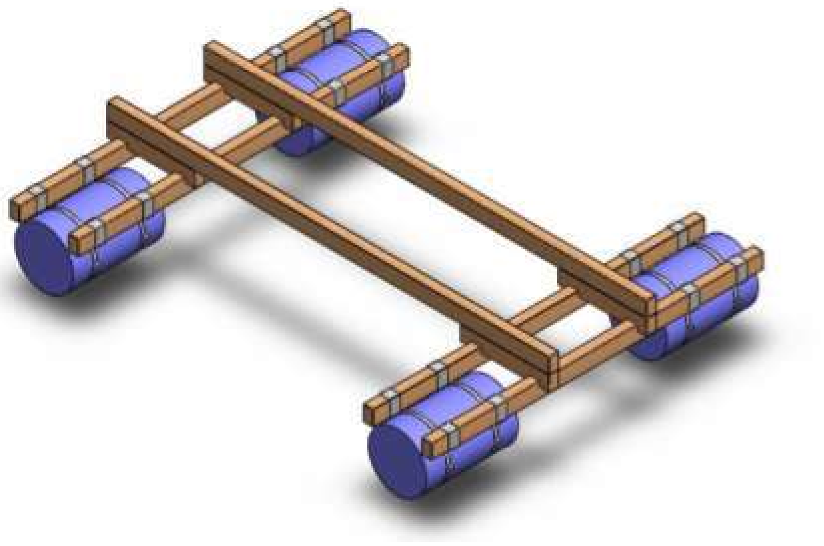


Figure 5.7: Artist's Visualization of an assembly bridge module

5.4 Wooden Decking

The decking for the bridge is constructed of a resource readily available in Cambodia: it is made of wooden tree trunks that have been treated to ensure suitable protection from water exposure. The supplied tree trunks are 150mm in diameter and 5000mm in length. The trunks are then cut through their length and sanded smooth to give two halves that are 5000mm in length. The semi-circular tree trunks are then cut into pieces of 1100mm in length to be used as the decking. The resulting width of the walkway is 1100mm and there are 29 pieces of deck spanning between the two end drums. The wooden decking (unaccompanied) can be seen in **Figure 5.8**.

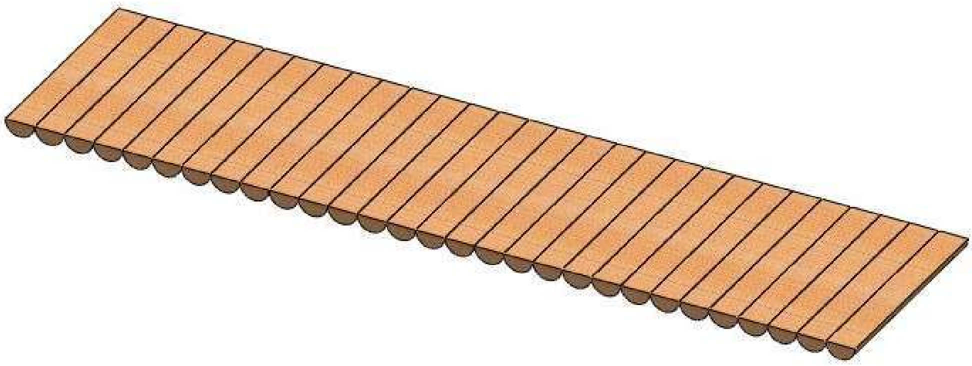


Figure 5.8: Artist's Visualization of a wooden decking

These individual pieces of deck are then nailed to the notched timber sections, convex down which creates a secure and sustainable deck surface, as shown in **Figure 5.9**.

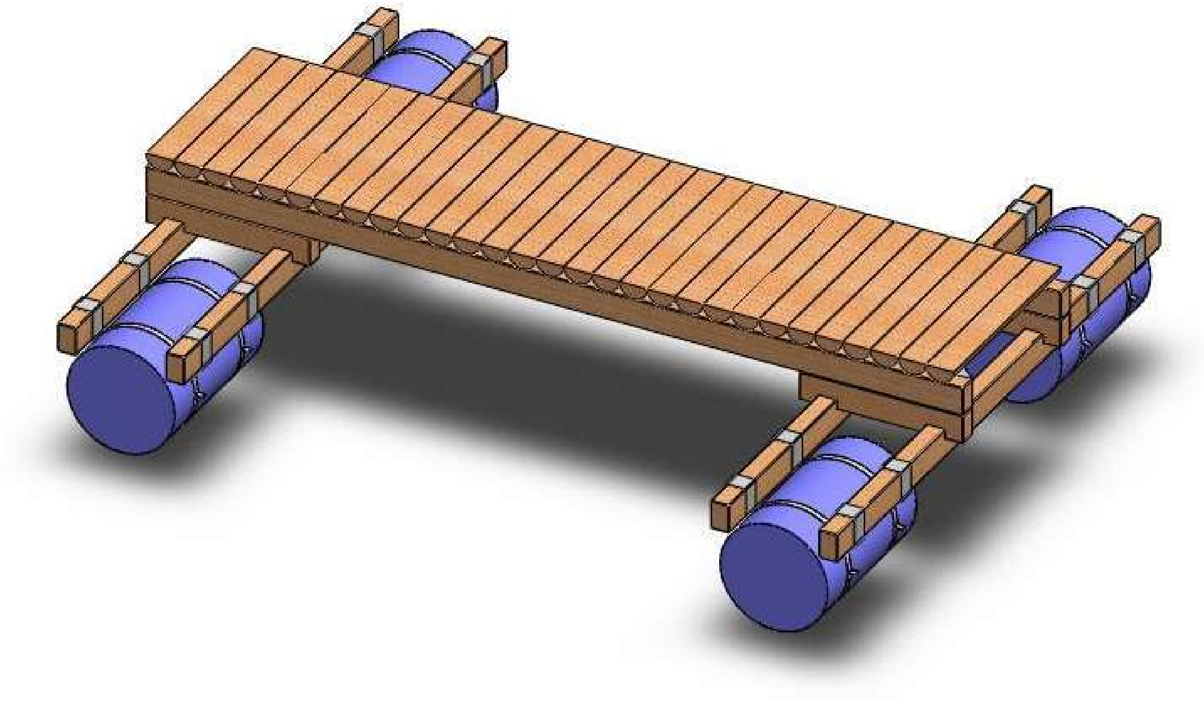


Figure 5.9: Artist's Visualization of an assembly decking onto bridge module

5.4.1 Extension Pieces

A key feature of this design is the use of extension pieces as every second segment of bridge. These extension pieces have a similar design as the segments described above; however, they have no drums attached to them. The notched timber sections are spaced further apart, resulting in a wider deck; 1300mm compared to 1100mm. The extension piece fits on the outside of the standard decking and is located onto the cross timbers in a similar fashion.

These extension pieces, shown in **Figure 5.10**, are constructed with 6 pieces of decking missing from each end to ensure the there is no overlapping of the decking materials. The generic design of the notched timber sections allows the use of this component in the construction of both the standard and extension pieces.

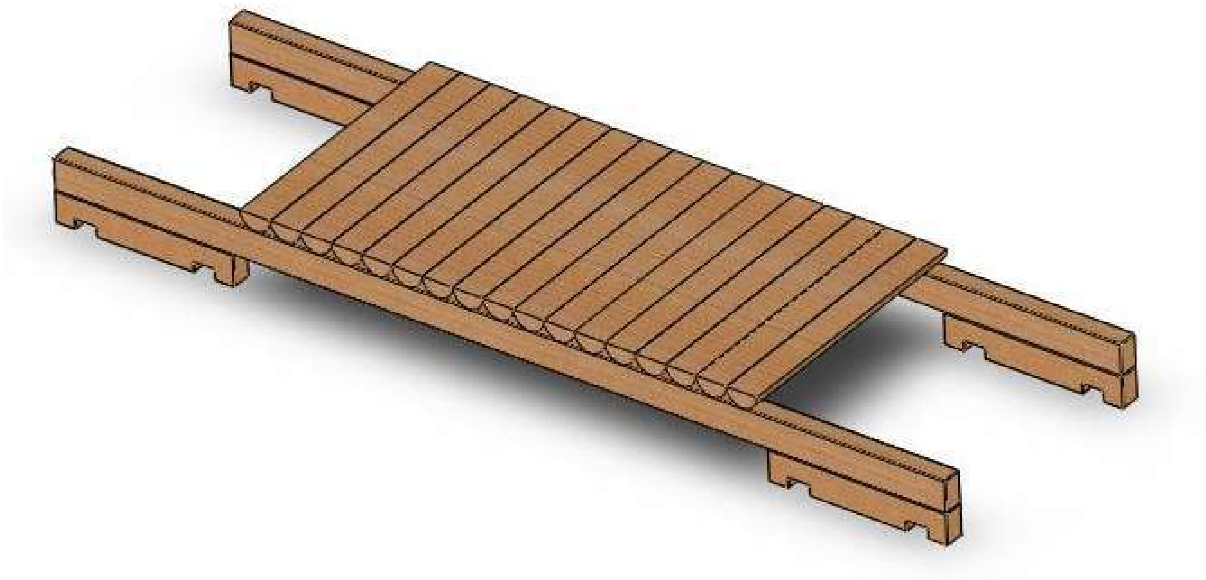


Figure 5.10: Artist's Visualization of an extension piece (note wider decking is the only modification)

The use of these extension pieces reduces cost as it allows the use of one cross section with barrels for every two "bridge sections", as shown in **Figure 5.11**.

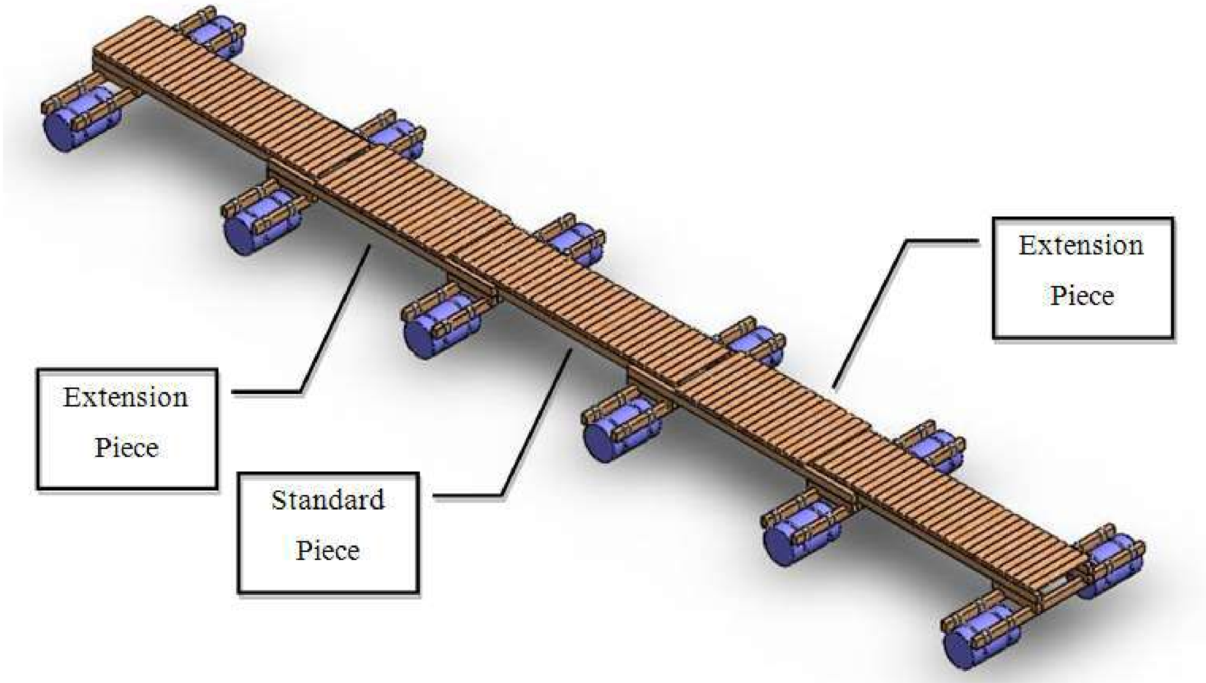


Figure 5.11: Artist's Visualization of an extension
piece and a standard piece interoperating

5.4.2 "Branching" Pieces

The construction of shortened end drum pieces which only have one drum attached in the middle allow for the addition of branched bridge sections perpendicular to the main span. The branches are attached by several short lengths of rope secured between the branch section and the main bridge span, as shown in **Figure 5.12**.

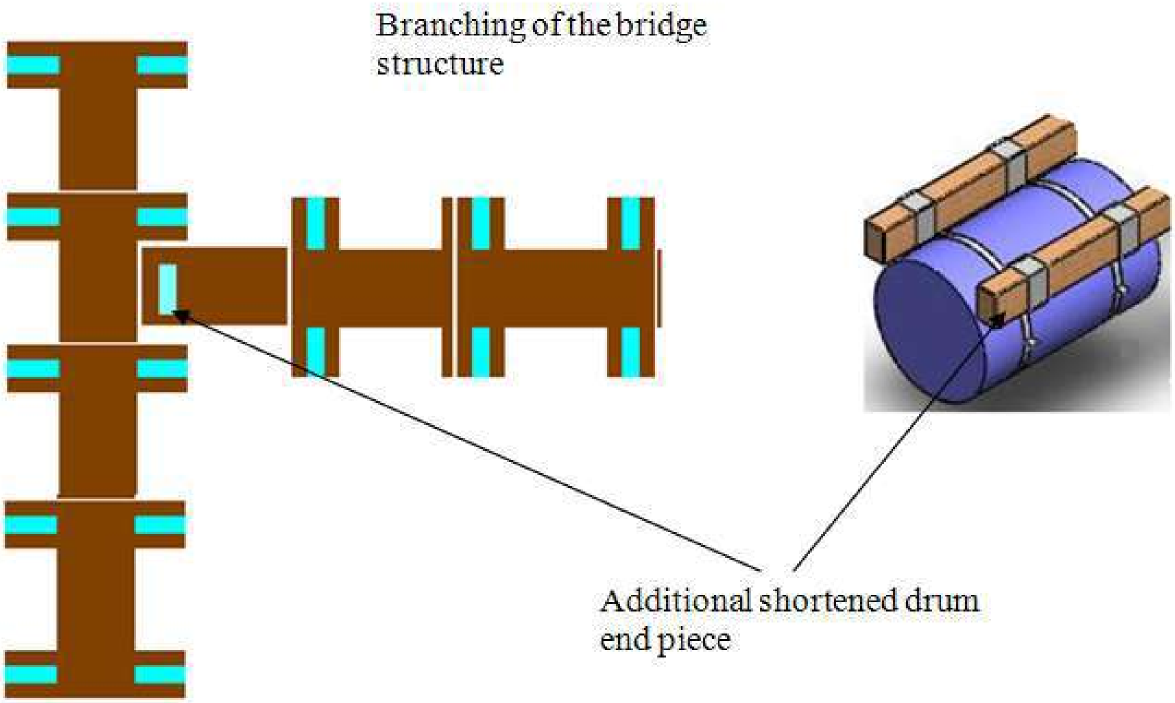


Figure 5.12: Artist's Visualization of a bridge branch piece

5.5 Handrails

Handrails are also to be included on the bridge to improve safety. The handrails are made of bamboo and are 1300mm in height. Eight bamboo poles are attached to the bridge segments (four to each side) and rope is strung from one to the other. A singular rope section can be removed if a bridge section is to be joined perpendicular to another.

5.6 Anchoring

To locate the bridge in position a weighted pulley system is used. This anchor system provides the lateral stability needed in an environment with changing water depths. The system comprises of a two concrete weights, which are located onto the lakebed, either side of the bridge and are referred to as the dead weights. Secondly a rope is attached to each dead weight and run through a common steel eye, located on the middle of the cross sections of the bridge structure, and then to a counter weight which is suspended under the bridge.

As shown in **Figure 5.13**, as the water level changes, the counter weight changes height as the bridge floats up and down which changes the length of the anchoring rope appropriately.

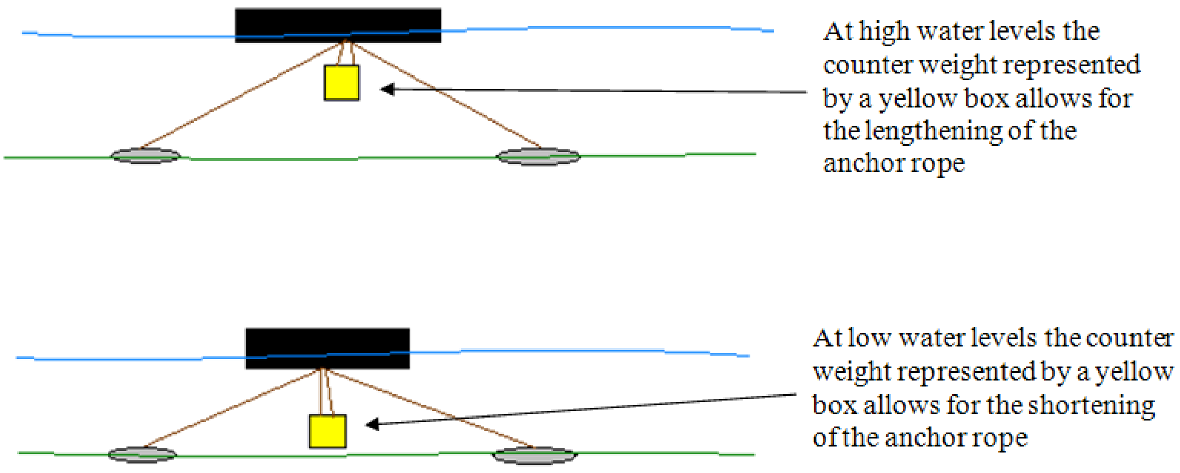


Figure 5.13: Artist's Visualization of how the Bridge reacts to changing water levels

Even when you're **Hilary Duff** you need "hair and make-up" maintenance. How much more would a bridge need it? (Disney, 2004)

SUSTAINABILITY & MAINTENANCE

6 Sustainability & Maintenance

6.1 Environmental Impact of Materials

6.1.1 Timber and Deforestation

Because the MFB uses wood from trees that is being sourced from Cambodia, deforestation will be a direct result of the selection of timber.

- Negative aspects of deforestation is that it destroys the natural habitats of local flora and fauna that are unable to survive in an adversely different localized environment, due to both the different habit and climate conditions that arise (Telepool, 2008). Deforestation results in an increase in ground temperature, as a direct result of there being no physical coverage provided by trees. Soil will become significantly drier compared to the original moist soil conditions. A lower extent of carbon dioxide to oxygen exchange will result. Note however, the negative aspects of deforestation can be counteracted by the growing of more trees (North Carolina Christmas Tree Association, 2008).
- Positive aspects of using timber (and re-growing trees once the trees have been chopped down) is that throughout its lifecycle, a tree intakes carbon dioxide and releases this as oxygen through a process known as photosynthesis (Smith, 1997). Even when the tree is eventually cut down, the carbon is "locked" in the tissue and wood of the tree, until it is burnt, when it will react with the oxygen in the air (Current.com, 2009). Thus, you're helping the environment!

Obviously, the issue is when deforestation occurs at a more rapid rate than forestation (which is a common occurrence since it takes longer to grow a tree than it does to chop it down). Nevertheless, in the long haul, as described in **2.1.1**, self-use of Cambodian resources will increase the demand for wood, thus increase the price of woods, reducing price competitiveness, thus eventually, demand for Cambodian wood.

6.1.2 Marine Impacts

There are no predicted long-term effects to the marine life through the introduction and construction of the MFB to the Tonle Sap. All construction of the bridging system will be based on land, thus eliminating any potential contaminants and reducing any waste material from entering into the water supply during the construction process.

All assembly materials have been specifically treated and selected for the MFB's construction, to minimize impact they pose to the sensitive marine ecology of the Tonle Sap, once the MFB implements.

Furthermore, the plastic barrels, which are the buoyancy device for our MFB design, are made out of recyclable materials and not severely distorted, thus will have no adverse environmental effects, and can be recycled and reused even at disposal of the MFB.

6.2 Sustainability of Materials

Due to the water exposure treatment, the wood can be immersed in water and will not show signs of warping and deterioration, as would if normal timber, if it were not treated. The long life expectancy of the timber is just one of the specifications of the MFB that make it a long-term sustainable advantage over its competitors for the Tonle Sap Region.

6.2.1.1 Polyethylene Drums

The drums used as the floatation devices have been molded from a polyethylene thermoplastic (River Lake Sea, 209), which exhibits exceptionally durability. These drums were selected, as they were very strong and lightweight, and furthermore would not rust, as it will be constantly subjected to water in the wet season.

However, since plastics will tend to breakdown from over exposure to the harmful ultraviolet light rays from the sun (Layfield Geosynthetics, 2009), and since the top of the drums will be above the waterline, an ultraviolet stabilized polyethylene material is used for the floatation devices in the bridge design.

It can potentially take centuries for Polyethylene (StateMaster, 2008) to fully breakdown, because of the synthetic polymers they are made from, thus their chemical stability; however if any faults were to happen to the drums, they can be recycled.

Thus, the material's inactivity will mean little-to-no adverse affect when introduced into the bridging system in the Tonle Sap, providing a long-term sustainable component for the bridging network. The UV stabilizers only enhance their sustainability.

6.2.1.2 Wooden Planks

Although the MFB is designed to allow the polyethylene drums to be fully submerged in the water, the wooden planks used as decking along with the support beams that hold the MFB together are not underwater, though it will be constantly subject to water through waves, as well as rain. The treatment of wood with Tung Oil is intended to increase its life, so can be used in an aqueous environment (Food and Agriculture Organization of the United Nations, 2007).

As this bridge is going to be used quite frequently throughout the wet season, a good oil that stands up to the harsh conditions needs to be chosen. Although there was a range of products that provided water resistance, only Tung Oil could do it at a relatively cheap price, as well as being easy to obtain (Sankey, 2009). Tung oil comes from the Tung tree, and is a part of the flora of Cambodia's neighboring country, Thailand (Thailand is directly West of Cambodia) (National Herbarium Nederland, 2009).

Tung oil enhances the toughness of wood and creates a hard durable surface (WoodBin Woodworking, 2009). Furthermore, it penetrates deep into the wood its fantastic waterproofing capabilities.

However, although a simple process, to maintain the water-resistance, the Tung oil needs to be reapplied every two to three months (Haymes Paint, 1998). The oil just needs to be re-applied to a clean surface and there is no need for the wood to be sanded down. Furthermore, pure Tung oil is a relatively safe product to use, as it is non-flammable and non-toxic (Refinish Furniture, 2009).

6.2.1.3 Steel Brackets

6.2.1.3.1 Corrosion Resistance

To connect the overall structure of the design, steel brackets were designed to connect the polyethylene drums to the wooded beams. Steel is a strong metal that is capable of doing its job well; however, steel can rust quite rapidly and will potentially be useless in holding the design together if this occurs. Steel will rust when subjected to moisture and oxygen (Holleman, 2001), thus the harsh wet condition of Cambodia and the oxygen in the atmosphere is the ideal climatically conditions for corrosion.

Thus, a layer of corrosion resistant paint is applied to the metal brackets (Suzuki, 1989), meaning the surface of the metal bracket is not exposed to the water. Therefore, the metal is unable to corrode and provides a sustainable join. Furthermore, the corrosion resistant paint includes rust inhibitive pigments, such as marine-grade primocon antifoul (MarineStore, 2009), ensuring that the steel lasts for the duration of the bridge's service. Furthermore, it only needs to be reapplied yearly, with an ordinary paintbrush against a mildly sanded surface (preferably 40-80 grip sandpaper), requiring approximately eight hours to fully dry before it can be subjected to water (Micron).

If rust does appear on the steel brackets they can be recycled to a scrap metal yard where a kilogram of scrap steel can be sold for approximately 500-750 riel (approximately 15-20c AUS) as "scrap metal" (CAMNET, 2004).

6.2.1.3.2 Weld

The weld that joins the steel brackets together, which supports the floatation devices, provides strength, comparable to the original strength of a metal (Du, 2000). This strong join will provide strength for the bridging system over a long period.

6.2.2 Disposal

6.2.2.1 Polyethylene Drums

As polyethylene drums can potentially take centuries to break down (StateMaster, 2008), there is no need for them to be replaced. However, if holes and cracks do appear in the drums, the polyethylene drums can be recycled accordingly (Concord CA, 2009).

6.2.2.2 Wooden Planks

To dispose of the wooden planks that are no longer capable of doing their job safely, it is best that either the wood is:

- Reused for other purposes that is suitable, but isn't dependent on the wooden planks being of paramount quality, such as small fences; or
- The treated wood can be recycled

It is strongly recommended that the treated wood must not be burnt in open fires. Although Tung Oil is non-toxic, it can potentially emit toxic chemicals in the fumes and ash when burnt (SWTOP, 2008).

6.3 Maintenance Strategy

The maintenance inspection will provide systematic guidelines that must be implemented in order to achieve the maximum functional usability of the bridging system and all it offers to the community.

Initial inspection will be conducted by qualified personnel, to ensure that the correct construction method and techniques are of a satisfactory standard. This will reduce stress on susceptible components of the MFB segments, once implemented into the community.

6.3.1 Inspection Methodology

6.3.1.1 Initial Material / Construction Inspection

The correct initial construction process is paramount in the long-term sustainability of the MFB segments.

The qualified personnel will review that:

- **All materials used are the correct material as specified by the design**: If incorrect materials are used for the construction of the MFB's, detrimental effects may occur, as the incorrect materials will be unable to adequately support the anticipated loads, and the environmental conditions without deterioration;
- **Defected materials will not be implemented in the construction process**: Material defects and incorrect sizing will produce a "weak point", which will be unable to support loading conditions, and hazardous environmental conditions. Despite it may be difficult to achieve, an optimistic target should be General Electric CEO, Jack Welsh's "Six Sigma Program" (Antony, 2008);
- **Materials dimension are made to the design specification**: Components must be assembled to design specification for functionality and strength purposes;

Any poorly constructed bridging system will likely be seen by the Tonle Sap community as disastrous, as seen with the collapse of the Tonle Sap's "25m Bridge". Inspecting materials and construction integrity will reduce the likelihood of material and assembly failure, thus preventing any consequential safety hazards, and complex public relations issues that may result.

6.3.1.2 Routine Maintenance Inspections

Routine maintenance checks will be completed three times a year once the bridging systems have been introduced into the Tonle Sap community. This strategy enables any repairs to be made to the MFB components before, whilst, and after they are most used (during the wet season). Furthermore, other maintenance's and adaption's can be made accordingly.

6.3.1.2.1 Inspection 1: Pre Wet-Season

All sections of the MFB are to be inspected before the wet season commences, for:

- Material integrity
- Correct assembly

6.3.1.2.2 Inspection 2: During the Wet-Season

Samples of the MFB, generally of a size square root of the population (Baldwin, 2007), are to be simple randomly sampled (Yates, 2008) and inspected from various areas within the Tonle Sap, for:

- ❖ Material deterioration
- ❖ Material joints

If from within the samples there are consistent maintenance problems, inspections of a larger sample may need to be made (even the entire population). However, general maintenance and repairs will be based on accessibility, and the extent of the damage.

6.3.1.2.3 Inspection 3: Post Wet-Season

Samples of the MFB are to be simple randomly selected and inspected from various areas of the Tonle Sap, for

- ❖ Material deterioration
- ❖ Material joints
- ❖ Design improvements / Alterations / Checks against ISO Standards (ISO, 2009)

Because the MFB will be less used post wet-season, more vigorous checks can be achieved at this time of the year. An annual design review will occur, with recommendations, possibly improvements and adaption's, to be made to the existing bridging system.

6.3.2 Special Maintenance Considerations for Susceptible Componentry

6.3.2.1 Weld Inspection

The weld will be inspected for join integrity upon all checks. This is vital in the construction of the bridging system as it provides the fundamental support for the buoyancy device. This will be maintained and repaired to ensure operational use of the bridging system.

The protective coating of the metal bracket is vital in corrosion prevention. This will be reapplied upon maintenance checks, subject to wear, to ensure the protection of the metal brackets, thus prevent rusting, hence material failure.

6.3.2.2 Bridge Loading

Despite the bridging system can only be subject to specific conditions (that is, only people and household items; and strictly no vehicle), because Cambodians may not follow civil regulations (European Commission, 2009), bridge loading has to be tested from time-to-time to ensure no safety issues will arise as a result of using the bridge.

6.4 Ethics

In designing the MFB, the engineering team faced little to no ethical dilemmas, riding on the back of a culture of "corporate social responsibility", also known as "CSR".

The MFB benefits Cambodia in terms of the "3 E's":

- **Economy**, both indirectly and directly, as mentioned in **2**
- **Environment**, by the use of carefully chosen materials
- **Entrepreneurship**, by directly encouraging and inspiring other Cambodians; and indirectly by lowering costs of travel, thus lowering barriers to entry (to education, or business)

Bill Gates is commonly referred to by Harvard Business School graduates as a best practices company. MFB did no less. (Microsoft, 2007)

IMPLEMENTATION STRATEGY

7 Implementation Strategy

The MFB was designed in such a way as to allow the community to repair, rebuild and replicate the design right throughout Cambodia. However, whereas in the Western World, we can do so through a range of product distribution lines, government organizations, and marketing; to do so in Cambodia, is not as straightforward. To put it simply, supply and demand alone is not what guides a third world country (Quinion, 2005).

7.1 Stakeholder and Customer Communications

Whereas in the America, Europe, Australia, and most other developed nations, a communications strategy can use existing media channels such as radio, television, and the Internet, third world countries often lack such communications infrastructure, which delivers those countries a comparative disadvantage to developed nations.

When assessing a suitable communications strategy, an essential belief of our team was to use communications strategies that were native to the Tonle Sap, Cambodia.

Since Cambodia is community-oriented, the fact that a new bridge is being built by the cooperation of locals and Westerners will already raise awareness. As the town planner begins to work with families to establish where the "main street" should go, there should be a community participation rate between 90-100%.

One of the most effective ways to train staff to build the MFB is to initiate a "Requirement Publication" which details the start-to-finish construction of the MFB.

7.1.1 Marketing Mix

The model used to assess the marketing mix is the 5P model (Borden, 1953).

7.1.1.1 Product

One of the foremost considerations we made for the production of the MFB was, in what ways, could we satisfy a want or need (Kolter, 2006) in the Tonle Sap region of Cambodia, but yet could do so in a way that was somewhat constricted by the low GDP of Cambodia.

As a tangible product, the MFB in the Cambodian economic climate interestingly does not work on an economies-of-scale production model. Instead, a better representation of the production model would be a "franchising system". In summary, this business philosophy has the franchisor granting its franchisee's the right to distribute products, techniques, and trademarks for a percentage of gross monthly and royalty fees. The franchisor additionally commonly also makes available advertising and training.

Reasons for why the franchise business model works include (Alon, 2005):

- The MFB is based on the infrastructure of the West which has a good track record of profitability (civil usability)
- The MFB is based around the unique concept of "walking on water"
- The MFB has a broad geographical appeal, for opportunities in other towns that struggle with flooding
- The MFB is relatively easy to operate, particularly considering the constant considerations we made for its lower level of labor education
- The MFB is relatively inexpensive to operate, made from environmentally friendly wood products, and recycled plastic drums
- The MFB can be easily duplicated around Cambodia due to its simplicity and its low cost appeal

7.1.1.2 Price

As the old saying goes "nothing is free"; there is a price involved in the construction of even the MFB. It may be cheap to the West's standards of pricing, but including assessment for Labor pricing and Value of time, it starts to become obvious that critical to the expansion of MFB is finance.

The method of funding and financing the MFB Roll-Out (network maintenance, improvement, expansion) are taxes and user fees. With Cambodia, this will derive from federal income tax (20%) (Asian Development Bank, 2008), as well as local (sales tax or CGT [capital gains tax]), variable (fuel tax), or user fees (tolls, congestion charges / fares).

In the West, the main form of financing is loans; bonds; public-private partnerships; and concessions. In principle, the dominant forms of financing available in the West (loans, bonds) are unavailable in Cambodia due to its low credit rating and GDP.

However, there are definitely innovative opportunities for sponsorship, such as "Coca-Cola" or "McDonald"-sponsored Cambodian bridges that could be a great source of advertising revenue, as already implemented by the Huajian Rice Industry on a Chinese Highway, shown in **Figure 7.1**.

Figure 7.1: Advertising Bridge by Sihun Highway
(Huajian Rice Industry, 2007)

The Cambodian Government could also provide tax breaks and guaranteed annual revenues to help rapid expansion of the MFB.

Furthermore, as a third world country, Cambodia also has access to international financial institutions who are dedicated to financing and technically assisting third world countries for development programs, usually including “bridges” and “roads”, with the role of reducing poverty. This includes:

- ❖ The World Bank (World Bank, 2008)
- ❖ International Monetary Fund (Sullivan, 2003)
- ❖ World Trade Organization (Encyclopaedia Britannica, 2009)

7.1.1.3 Place

There are three separate materials used in the construction of the MFB:

- ❖ **Waterproof (Tung oiled) wooden planks**: The planks are from the forests of Cambodia, so require little transport, but the waterproofing method requires considerations for the application of the Tung oil. Fortunately, this process is easy and can be applied at build time.
- ❖ **Recycled plastic drums**: The recycled plastic drums are available from within Cambodia
- ❖ **Steel bracket**: This is the primary consideration for the “Place” problem, in relation to distribution channels, et cetera. They will need to be manufactured overseas, or in factories in Cambodia. Fortunately, because of the compact size and relatively lightweight of these steel brackets, the outcome is reduced transport size, transport costs, and furthermore carbon footprint as a result.

7.1.1.4 Promotion

The promotion used for the MFB will predominantly be word-of-mouth (Grewal, 2003), due to the viral nature of this form of publicity which works well particularly in Cambodia, as well as more generally for public civil-engineering projects.

PR will also be used (Grunig, 1984), both in relation to raising awareness for the production of the MFB, as well as to address Green lobby groups who may want to diminish development of developing countries because of environmental impacts it may have (Sullivan, 2003).

Advertising will also have its place in the production of MFB, to raise awareness for the MFB in Cambodia, on the television stations, radio, and billboards of Cambodia. Billboard advertising may present itself to be rather effective.

Because of the franchise-like system used for the distribution of MFB, one of the issues facing this system is "control", particularly in face of lack of possible legal sanctions in the legal environment of Cambodia. For this reason, it is probably useful to establish an "**mfb**" brand, analogous to that of Hewlett-Packard ("**hp**"), as shown in **Figure 7.2**.

Figure 7.2: Users know they are buying "quality"
when they spot the Hewlett Packard "HP" Brand

As a result, bridges manufactured by "**mfb**" can be separately identified by that of a non-branded, non-certified nature. In some ways, the culture, as well as entrepreneurial ship in MFB bridges could be reflected in other aspects of business in Cambodia as a result.

7.1.1.5 Packaging

Because of the political nature of infrastructure building, public opinion may sway trends and knowledge, as well as political power. As a result, careful consideration must be given to:

- **People**, of which high-ranking officials of Cambodia should sit on the Board of the MFB
- **Process**, in that procedures, mechanisms, must be professional and understood well by Western businesspeople to garner their support
- **Physical evidence**, which may include customer treatment, cover letters.

7.2 Infrastructure Preparation

The existing civil infrastructure in Tonle Sap, Cambodia, is housing and transport. Houses are built on raised platforms to prevent flooding, and transport (during the wet season) is generally via self-made boats.

In order to maximize the usefulness of the MFB, a town planner must map out where families are residing within the community and a way in which to maximize access to the bridge.

7.3 Manufacturing Roll-Out

The metal brackets will be imported into Cambodian, funded by both Government and charitable organizations.

The Live & Learn staff, volunteers, and the Tonle Sap communities will be involved in the development of the MFB. When coming up with our manufacturing design, we had this fact in mind, and for these reasons, have only used materials that are easily obtainable in Cambodia.

Construction may occur during the wet or dry season, but once the main street is constructed, its use is not validated until it connects the housing infrastructure. Although some side streets may need to be constructed, in general, many shops, if not housing, can connect directly with the "main street". For privacy reasons however, the MFB's should not connect directly with housing. Rather, a boat of any kind, which can be docked at either the house or the MFB, should be used.

7.3.1 Quantity of Production

This design was not specifically constructed to connect an entire village together, thus a village would only have 2-3 MFB's connecting the major parts of the village together such as connecting the local trade markets together. Since the MFB is a very generic design and each section of the bridge is repeated every few meters, this allows the villagers in Cambodia to easily maintain the bridge and keep it in service for as long as possible.

7.4 Training

Training and education is key to the production of the MFB.

Both the Cambodians and Live & Learn staff workers should be taught basic skills in construction from DIY parts. Informal half-hour training seminars should be effective enough. The Cambodians could then teach one another once a critical mass has learnt how to construct the MFB.

The educational process must be:

- ❖ **Instructional**, facilitating staff towards learning objectives delivered by instruction
- ❖ **Taught**, refer to the actions of a real life instructor designed to impart learning to a student; that can be applied upon completion

The MFB Training Guide should include learning modules that are (Theroux, 2004):

- ❖ **Visual**, learning based on observation, such as drawings, images, and models of the bridge
- ❖ **Auditory**, learning based on audible instructions/information, such as the conveyance of the process to manufacture bridge
- ❖ **Kinesthetic**, learning based on hands-on work, such as actual construction of the bridge

7.5 Change Management

Traditionally, bridges in Cambodia are built with bamboo, water-permeable wood, and are typically non-movable.

In considering management of change, as consideration is made to the PDLC (product development life cycle), the question of how to deal with market decline. In particular, say if an entire network of MFB's were to be created, if it were to reach anywhere near the size of the United States network of roads, at 6,430,336 kilometers (CIA World Fact Book, 2009); how would such infrastructure deal with change?

Furthermore, as a result of the introduction of the MFB, an interesting network of effects on the economy will occur. Immediately, new jobs will be created:

- ❖ Bridge constructers
- ❖ Transport economists (Discrete choice modeling / Traffic flow) (McFadden, 2007)
- ❖ Town planners / regulatory agencies (RCW MRS Center of Washington, 2005)
- ❖ Businesses relating to tolls (IBTT Association, 2007)
- ❖ Pollution/health authorities

Figure 7.3: Bridge on Tonle Sap
(TravelPod, 2009)

With existing Tonle Sap bridges, as shown in **Figure 7.3**, the issue with such traditional design, is that when the water levels rise, the dirt loosens, and the structure falls apart as a result. The differentiating factor with the MFB is that the bridge attaches itself to infrastructure, rather than the ground, and can ascend and descend depending on the water levels. It is difficult to comprehend how Cambodians would not accept such transformational proposal, but may need some adjust from predominantly using boating to a combination of boating and MFB's for navigation purposes. This will be a change for the good however.

7.6 Problem Resolution

Because this project is a community project, individuals or certain groups may oppose construction methods, or in particular, how the town planner plans where to insert the "main street". The Vice President in charge from overseas should sort out any problems.

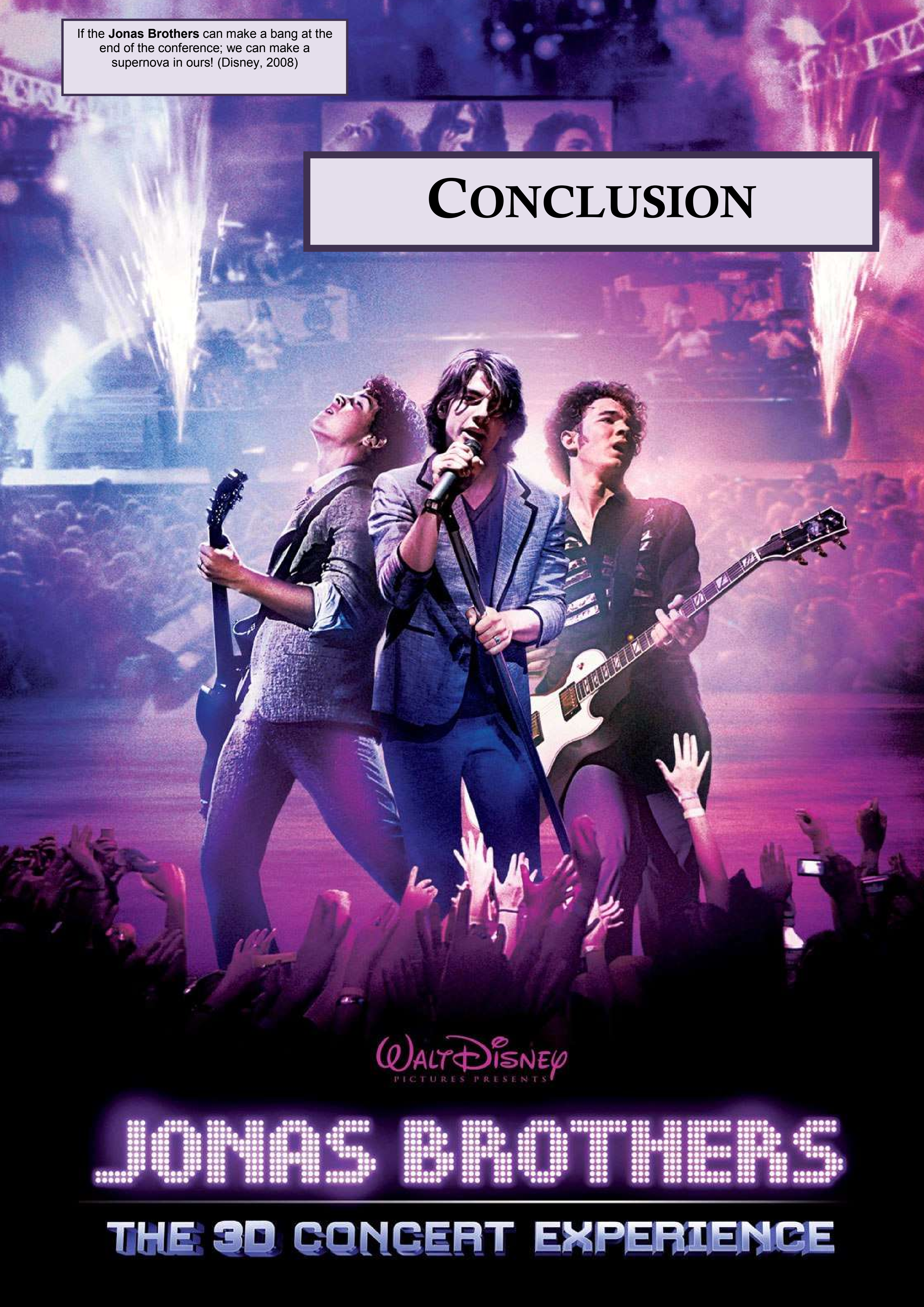
Although congestion is quite a big problem in the Western World (Small, Kenneth; 1998), this will not be considered in this design brief for now. There are ways however, to combat this issue, using congestion pricing (such as tolls).

One big issue with such a large project is "where to start?" Professional project appraisals and evaluators from the Western World should head these projects, and use their business tools in conjunction with their decision-making. In doing so, their coming to their decision should be transparent and clearly drafted and presentable to the Cambodian Cabinet. These analyses may include:

- Cost-benefit analysis (European Commission, 2001), analyzing cost effectiveness
- Social Return on Investment (SROI, which is the best targeted to NGO's) (Lingane, 2004)
- Value of time (Mackie, 2003)

If the **Jonas Brothers** can make a bang at the end of the conference; we can make a supernova in ours! (Disney, 2008)

Conclusion



8 Conclusion

In this assessment, the team felt that they effectively incorporated into the EWB Project various modern civil engineering techniques, as well as careful environmental consideration. The team also felt a level of passion for ethical action and social responsibility more than ever because of the project.

Furthermore, it was rather interesting to consider the different constraints on the engineering team because of the Tonle Sap context. Although the team was initially non-skeptical about an American perspective to a Cambodia solution, they soon understood what really was required was a multicultural, multitalented, and multi-technological solution.

As the Cambodian economy grows, so will the specifications of the MFB. As outlined previously, there is already some discussion on improvements of a possible second-generation MFB that uses even more lightweight material to increase buoyancy (thus load), as well as strength of material (thus product lifetime).

The MFB truly believes one person (or team) can change the world, and we hope the one which changes Cambodia, is the Modular Floating Bridge.

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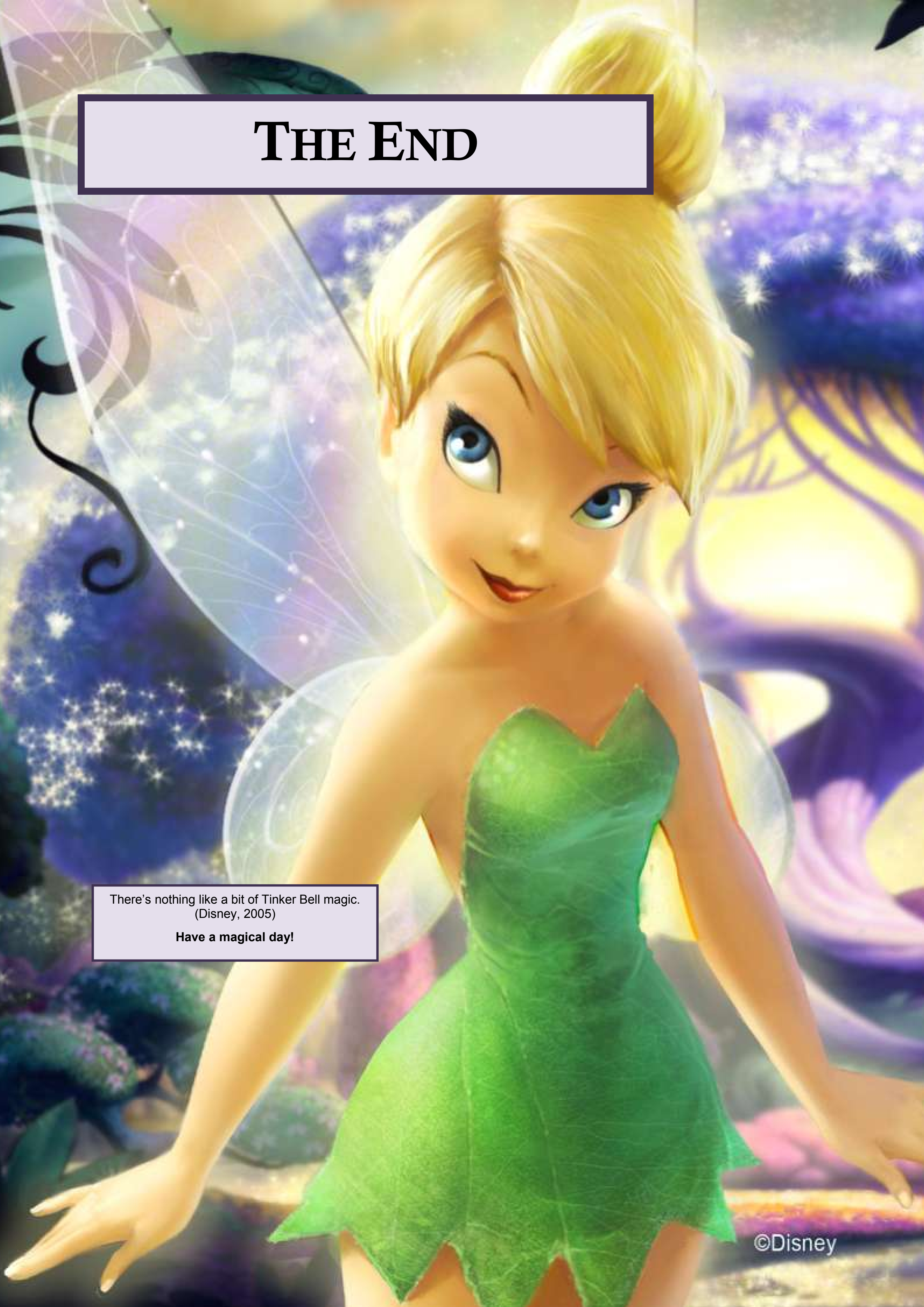

There's nothing like a bit of Tinker Bell magic. (Disney, 2005)

Have a magical day!