A road to Pondicherry for ALL seasons.

Team 14

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Disclaimer

We declare the following to be our own work, unless otherwise referenced, as defined by the University’s policy on plagiarism.

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I Sergey Hunt (10181422) declare that my contribution to this assignment is my own.
Executive Summary

The aim of this report is to investigate issues regarding transport which are faced by the people of Devikulam, Tamil Nadu. We need to develop a solution which is compatible with the culture and beliefs of the people of Tamil Nadu. This solution needs to be as environmentally friendly as possible and as economically beneficial as possible. We will go through several options in order to find the perfect solution.

Commuting to the nearest town, Pondicherry is a real mission. This trip is close to impossible during the monsoon season. Our aim is to investigate as many modes of transport as well as different paths the people of Devikulam could use. The current path used is completely submerged in the monsoon season and thus becomes unusable. The other alternative route adds another 46km and several more hours to the journey.

Devikulam’s ‘economy’ is primarily run by the process of farming. A large percentage of income is based on farming and agriculture. Devikulam is a tropical, dry and evergreen forest. The local weather patterns include frequent wind storms and monsoons that lead to erosion of the top soil. Devikulam is a culturally rich village. The main religion is Hindu although there are a few different religions and dialects in this town. Although there is a cast system in Devikulam, it does not create any conflict. Both ‘castes’ get along perfectly. The nearest highway to Devikulam is approximately 5km. This highway leads to Pondicherry. The total distance would be 25km. This route however is unusable during the monsoon season due to it being submerged. The route is created using simple, poor quality gravel and red clay. There is a 200m stretch on the route which subjected to extreme flooding during the monsoon season. The road to Pondicherry is poorly constructed and consists of no drainage throughout.

Our aim in the project is to create an alternate path(s) which would not only make the commute easier and faster but also safer.

To make this a successful project, we have were given criteria to follow:

- The solution must be of low cost
- The solution must be aligned with cultural responsibilities
- This project must create opportunities for the village and its people

- The solution must ensure that the existing natural environment is protected and preserved

- The solution must be maintainable by the local community.

- The solution must encourage traditional practices

- The solution must set an example for sustainable land management

This will be judged on what impact the intended solution will have on the village’s cultural beliefs and practices. Cultural alignment will have a high impact on the acceptance of any proposed solution and this rated high in importance.

By teaching the people of Devikulam labor techniques, we can obtain some help from them not only to create an alternate path but it also teaches them how to maintain the solution in the future. This will reduce costs greatly. One of the main factors we need to consider is environmental effects. This will have a very high rating as environmental impact needs to be as close to nil as possible. We need to create a solution which is not only easy to create, cheap, environmentally capable but also easy to maintain.

The options we have chosen, which could be a solution for these people, are

- Elevate + Fascines + ablution

- Bridge + Fascines + ablution

- Water channel + barge

- Train line + engine + cars

- Hovercraft

We have listed out the pros and cons for all the above options and using trade off analysis as a tool we can come up with an ultimate solution which will match the criteria listed above. Some solutions will be better for some reason and worse for others. We have to come up with a solution which will be as close to perfect for every factor.
Team Reflection

The people living within the Panchayat region of India, which includes Devikulam village, suffer from a variety of transportation issues. The difficulty these people face in commuting to their nearest capital city of Pondicherry during the two monsoon seasons of the region is of particular concern (Engineers Without Borders Australia, 2011). The communities within this Panchayat region would like access to an appropriate pathway that minimises travel times between their villages and the city of Pondicherry at all times of the year, as opposed to the present pathway which becomes unusable during the monsoon seasons and leaving them with an alternative route to Pondicherry that is an additional 46km in a round trip (Engineers without borders Australia, 2011)

The project sponsors, EWB and Pitchandikulam Forest, have also specified a set of criteria that must be met by any proposed solution, as follows (Engineers Without Borders Australia, 2011):

- The solution must be of low cost, both in its implementation and in ongoing maintenance,
- The solution must be aligned with the cultural responsibilities of the Devikulam village community,
- The solution must create opportunities for the Devikulam village community to improve their livelihoods,
- The solution must ensure that the existing natural environment of the region is both protected and preserved,
- The solution must be maintainable by the local community,
- The solution must encourage traditional practices, and
- The solution must set an example for sustainable land management.

Team 14 has an invested interest in developing novel and practical solutions to transportation issues. We share the view that, whilst contemporary society faces many challenges, the ability to commute safely and quickly is becoming a major bottleneck holding back growth in all regions with an expanding population. Team 14 holds the belief that it can produce an
exceptional solution to the “road to Pondicherry” issue presently faced by the Panchayat region that fulfills all specified criteria. We believe that we can devise an exceptional solution whilst at the same time stay within the specified requirements. Team 14 consists of 3 students studying Mechanical Engineering, and 2 students studying Civil Engineering, thus the solution will experience the benefits of both of what these two different areas of study can bring to the table.
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Introduction

This report looks at a pressing transport issue faced by the local community of Devikulam, located in the Tamil Nadu state of India, and proposes a solution that is compatible with the traditions and beliefs of the local community, has minimal environmental and social impact, provides economic benefit to the local community and is considered safe to an acceptable standard. This report aims to present the case that the proposed solution is the best option available to alleviate the commute issue to Pondicherry for the local community of Devikulam when all relevant factors are taken into consideration.

1 Problem definition

1.1 Problem scope

The people living within the locality of Devikulam village, located in the state of Tamil Nadu of India, suffer from a variety of transportation issues. The difficulty these people face in commuting to their nearest capital city of Pondicherry during the two monsoon seasons of the region is of particular concern (Engineers Without Borders Australia, 2011). To address this commute issue the local Devikulam community would like access to an appropriate pathway that provides for the shortest commute possible between their village and the city of Pondicherry at all times of the year including during the yearly monsoon seasons. Presently the shortest route to Pondicherry becomes unusable during the monsoon seasons due to a combination of; sections of the pathway being severely flooded, or sections of the pathway becoming excessively soft and waterlogged and hence not readily traversable. The shortest “all seasons” route that the Devikulam community presently possesses involves an additional 46km commute on a round trip as compared to the problematic route just discussed, a major problem for members of the community that must travel by either foot or bicycle (Engineers Without Borders Australia, 2011).
1.2 Technical Review

The remote farming community of Devikulam, henceforth referred to as Devikulam village or just Devikulam, is located in 70 acres of Pitchandikulam forest as depicted in Figure 1, with a diverse range of flora and fauna (Engineers Without Borders Australia, 2011).

Figure 1 - Map of Devikulam Village (Engineers Without Borders Australia, 2011)

The Devikulam environment consists of tropical dry evergreen forest - a type of forest that only exists in Southern India and Sri Lanka (Auroville Foundation, 2011). Devikulam is home to 735 vegetative species, of which 400 have potential medical uses (Auroville Foundation, 2011). The local weather patterns include frequent windstorms and monsoons that lead to erosion of top soil and the carving of channels into the local landscape (Auroville Foundation, 2011). The two monsoon seasons occur between June and September and between October and December and can dump anywhere between 350mm to 660mm of rain in those periods (Government of Tamil Nadu, 2011). The environment consists mostly of flat
red earth with relatively few hills. There are a couple of small ponds located within the village, which serve as either animal watering holes or for bathing, swimming and washing cattle (Auroville Foundation, 2011). The primary fauna living within the region are fox bats and parrots, both of whom cause great difficulties in attempts to grow fruits and vegetables due to their destruction eating habits (Auroville Foundation, 2011). Pitchandikulam Forrest was designated a protected region in 1993 due to the large number of plants with medicinal properties (Engineers Without Borders Australia, 2011). This protected status severely restricts the capability of sourcing or constructing materials from the native flora or from local mining.

Currently a variety of cultures exist throughout Devikulam with the dominant language being Tamil, though many speaking broken English (Auroville Foundation, 2011). The primary religion followed in Devikulam is Hindu, with three Hindu temples located within the vicinity of Devikulam; Ganesh Temple, Mariyamman Temple and Ayennar Temple (Auroville Foundation, 2011).

Traditions within the Devikulam community are largely a product of the social class, or caste, that community members are defined to belong to, with Devikulam containing two distinct social classes; the Scheduled Class (SC) and Most Backward Class (MBC) (Buzza Land Information Systems, 2011). Traditional dictates that members of the different castes do not intermingle, however in Devikulam the two castes have a good relationship and they do mingle at certain functions (Buzza Land Information Systems, 2011). Members of the two castes do however live in separate regions, with the SC occupying an area known as the Colony and MBC occupying Devikulam village proper (Buzza Land Information Systems, 2011).

The Devikulam community operates through an experimental economic policy that aims for self-sufficiency as a community and also aims to internally forego the exchange of monies for goods and services. Income amongst the village members is relatively very low and even non-existent for some amongst them, with the primary source of income being through farming (Engineers Without Borders Australia, 2011).

Devikulam is located approximately 5km from a major state highway, with the highway providing direct access to the nearby city of Pondicherry via an additional 20km journey (as depicted in Figure 2). The green path in Figure 2 depicts the town people’s preferred (aka
common) route to the major state highway. During the monsoon seasons this route becomes largely impassable and the community must resort to travelling to Pondicherry using an alternative route, shown in blue in Figure 2, which is significantly longer than the common route by around 26kms on a one way trip (Buzza Land Information Systems, 2011).

![Figure 2 - Routes to Pondicherry (Engineers without borders Australia, 2011)](image)

This common route is an unsealed gravel road of generally poor quality (Auroville Foundation, 2011) as can be seen in Figure 3 - a frame grab from a video capturing a portion of this road.

The heavy rainfall during the monsoon seasons can severely flood one particular section of the common route (of roughly 200m in length and to a maximum depth of 1.5m or so) and furthermore these heavy rains soften and waterlog vast tracts of the remainder of the road to
an extent that renders them impassable to much of the normal traffic – such as bicycles and motorcycles (Engineers Without Borders Australia, 2011). The entire region surrounding this road consists of very flat terrain and thus the road has next to no natural drainage, with the water eventually dispersing via seepage into the ground and evaporation (Auroville Foundation, 2011).

The Devikulam community has requested a proposal be developed that would solve the issues they face in commuting to Pondicherry during the monsoon seasons which meets various criteria in the areas of costs, sustainability, economic development, traditional practices, cultural practices and environmental issues.

**Figure 3** – Frame grab of a video showing a section of the common route to Pondicherry (Engineers Without Borders Australia, 2011)
1.3 Design requirements

1.3.1 Client Specified Requirements

The project sponsors, EWB and Pitchandikulam Forest, have specified a set of criteria that must be met by any proposed solution, as follows (Engineers Without Borders Australia, 2011):

- The solution must be of low cost, both in its implementation and in ongoing maintenance,
- The solution must be aligned with the cultural responsibilities of the Devikulam village community,
- The solution must create opportunities for the Devikulam village community to improve their livelihoods,
- The solution must ensure that the existing natural environment of the region is both protected and preserved,
- The solution must be maintainable by the local community,
- The solution must encourage traditional practices, and
- The solution must set an example for sustainable land management.

Many potential solutions exist to the commute issue facing Devikulam; as such our team has derived the following selection criteria, from the client requirements mentioned above, that will be employed within a trade-off analysis of all the potential solutions under consideration such that the most appropriate of these solutions can be determined and pursued in depth.

1.3.2 Selection Criteria for Option Trade-off Analysis

NRE Cost (Non-Recurring Engineering / Implementation Costs)

The implementation cost of the proposed solution is a very important constraint; any solution must be as low cost as possible due to the size of the village and its poor income (Engineers Without Borders Australia, 2011). Cost is distinctly measurable and thus easy to quantify. Cost will have a very high impact on viability of any given solution and thus is rated very high in importance.

Rating: 5
Implementation Time
The time taken to implement any solution is always a valid consideration. Time is distinctly measurable and thus easy to quantify. Implementation time has not been mentioned in discussions with the client and thus is rated low in importance.

Rating: 1

Cultural Alignment
This will be judged on what impact the intended solution will have on the village’s cultural beliefs and practices. This is a difficult criterion to quantify or measure, but for the purposes of this proposal will be a relative measure of the impact of a proposed solution on the relevant Hindu beliefs such as; endless cycles of creation, preservation and dissolution; karma (law of cause and effect); temple worship, rituals and sacraments; sacredness of all life – practice of non-injury; and tolerance and understanding (Himalayan Academy, 2011). Cultural alignment will have a high impact on the acceptance of any proposed solution and thus is rated high in importance.

Rating: 4

Local Opportunities
Devikulam is an extremely poor community and any avenue for improving the livelihood of the community should be pursued (Engineers Without Borders Australia, 2011). Employment opportunities that generate income can be readily quantified ($ = hourly rate x hours required) and thus compared. Local opportunities generated will have a high impact of the acceptance of any proposed solution and thus is rated high in importance.

Rating: 4

Environmental Impact
Devikulam exists within a protected environment and thus any impact of a proposed solution on the local environment must be taken into consideration. The actual environmental impact of any given solution can be difficult to quantify unless a detailed study is performed, so this will be a relative “educated guess” measure that employs the existing skills and knowledge of the team members on the topic. This will have a very high rating as environmental impact needs to be as close to nil as possible to ensure the acceptance of the proposed solution.

Rating: 5
Maintenance (Costs and Frequency)
This will be measured in terms of how often the solution will need to be maintained, the cost of each scheduled maintenance work, and the price. Also taking into consideration the required qualifications needed to carry out the work. This criterion is readily quantifiable and thus comparable. This will have a medium rating as it should be offset positively by the local opportunities criterion if the maintenance generates income opportunities for the local community.
Rating: 3

Traditional Alignment
This variable will be assessed on how the solution impacts on the locals traditional activities, as tradition is taken very seriously and is important (Engineers without borders Australia, 2011). This is a difficult to quantify criterion and again will be a relative figure as judged using the existing skills and knowledge of the team. Tradition appears to dictate that the members of the two castes live in disparate regions and to limit intermingling. Any solution must minimise clashes with the traditional beliefs of the community if it is to be accepted, therefore traditional alignment is rated medium in importance.
Rating: 3

Sustainability
The client requirements specify that any proposed solution must rate highly in terms of sustainable land management. Sustainable land management can be defined as managing land in such a way that ecological processes and biological diversity are not damaged (Commonwealth of Australia, 2009). This will be a relative measure based on what level of impact our team foresees a given solution having on ecological processes and biological diversity in and around Devikulam. Sustainability is very important to the client and thus a major factor in determining acceptance of a solution and therefore is rated high in importance.
Rating: 4

Seasonal Tolerance
Devikulam experiences a range of weather extremes, being most extreme in the rainfall department. This criterion measures how effectively a given solution copes with the typical extremes of weather experienced in Devikulam as a relative factor of the solutions nominal
performance in ideal conditions. The more effectively a solution copes with the expected weather extremes the more likely it is to succeed, thus this criterion is rated high in importance.

**Rating: 4**

**Traffic Tolerance**
Devikulam residents use several modes of transport to commute between their village and the city of Pondicherry, ranging from walking to using tractors (Buzza Land Information Systems, 2011). The more effectively a solution copes with the variety of transport and the volume of traffic the more successful it is likely to be, thus this criterion is rate high in importance.

**Rating: 4**

**Defecation Tolerance**
Due to the modes of transport including very slow forms, such as walking and bicycle riding, there exists a defecation problem along the common route wherein commuters stop to openly defecate on the sides of the road leading to hygiene and comfort issues (Auroville Foundation, 2011). This criterion looks at how effectively a solution deals with the issue of open defecation, ranging from completely resolved to not dealing with the issue whatsoever. The more effectively a solution deals with the issue of open defecation the more likely it is to be accepted by the community, but it would not be considered a deal breaker, thus this criterion is rated medium-low in importance.

**Rating: 2**
2 Design Options

Determining the most appropriate solution to a problem can be a hit and miss affair, and one that can easily gravitate towards a non-optimal solution if subjectivity enters the decision making process. A process termed the “engineering method” provides an excellent approach to producing the most appropriate solution possible for a given problem with specific performance criteria, and is the approach taken in this proposal (Dowling, Carew, & Hadgraft, 2010).

After researching the basic issues discussed earlier in this report the team collaborated and brainstormed for conceptual solutions and then filtered out those solutions that did not appear to be fundamentally feasible or viable. This process resulted in five alternative solutions as detailed below.

2.1 Elevate + Fascines + Ablution

This solution is a multi-faceted approach to the problem. The 200m section of the road that floods (up to a depth of 1.5m) would be raised a nominal height above that maximum expected flood level using a structure composed of quarry cut 1000x350x350mm limestone blocks that provides plenty of cross drainage and has a solid layer of blocks at the top of the structure. The final top layer of solid blocks would then be covered with a thin layer of crushed lime powder and compacted to become a solid and hard surface, with an appropriate camber out towards the sides to encourage water to runoff to the sides. To reduce safety issues presented by both a 1.5m drop in non-monsoon seasons, and flood waters during monsoon seasons, a barrier composed of a structure of old car tyres would be incorporated along both outer edges of the elevated section.

The remainder of the common route road would be improved by employing a “fascines”, a concept in which a rough bundle of brushwood can be used to make a path across uneven or wet terrain (Wikipedia, 2011).

Finally we would build one or more simple ablution facilities at key location(s) along the common route in the hope that the defecation issue is sufficiently resolved.

We feel that this solution would make good use of locally sourced materials such as limestone and crushed lime, benefit the environment in finding a use for a good number of old car or truck tyres, and provide for local opportunities for the community not only in the
initial construction of the elevated road section, but in both its maintenance, and the initial and recurring construction of the fascines and their maintenance and also maintenance of the ablution facilities.

### 2.2 Bridge + Fascines + Ablution

This would involve building a bridge across the road section susceptible to flooding, and in addition apply the same “fascine” process to the remainder of the common route and the same ablution solution as discussed in section 2.1 above. We believe that this solution although being relatively well suited, will be somewhat costly as ideally the required bridge structure will need to be approximately 200m in length.

The implementation of this solution, and the infrequent maintenance required will need to be performed by professionals, thus not really opening up many work opportunities for Devikulam locals. However, despite the possible ‘flaws’ of this solution, we decided to include it due to its functionality, it requires much less material than other proposed solutions (a flat bed with supports above the lower area, as a pose to completely filling this lower region), and also will cope with large volumes of water as beneath the bridge water is able to flow from one side to the other.

### 2.3 Water Channel + Barge

This would see the construction of a permanent water channel along the section that floods along with the deployment of a boat (or barge) for moving commuters across the water channel. This solution was deemed as a possible contender due to its authenticity, it steers away from ‘improving’ the current road network to remodeling the transport system all together. It was thought that the lower level areas could be used in conjunction with digging (approximately 1.5m in depth) of the remaining road network in order to obtain a river like channel in which multiple boats could operate on simultaneously.

Due to its rather involved and complex implementation procedure we expect a very high cost. Also maintenance costs would be very high, and only could be carried out by a professional. We believe that this solution was an interesting one, and that the community would really appreciate this system of transport as this would be somewhat exciting and a new phenomenon to experience.
2.4 **Train Line + Engine + Cars**

This would see the construction of a train line between Devikulam and Pondicherry, with the deployment of an engine to transporting commuters. We expected a very high cost from this proposed solution due to the fact that the lower areas would still need to be leveled, and on top of the surface a train rail would also need to be laid. Also a train itself would need to be sourced and likely externally imported.

Although this solution would obviously be of very high cost, we decided to keep it due to the fact that it would eliminate the need for some of the community members to have to walk and cycle on the current network, and hence reduce the time required to travel between Devikulam and Pondicherry.

Maintenance costs would be very high and require a trained professional to carry out the required work. As a result, local job opportunities would not really be created, except for the construction and maintenance of the rail line network, however a comfortable, time convenient transportation alternative we believe would impress the community.

2.5 **Hovercraft**

This would see the deployment of a hovercraft vehicle as a community “bus” which would regularly transport commuters between Devikulam and Pondicherry. Although at first glance this solution appears to be somewhat absurd, it would eliminate the requirement of road side toilets, as well as the requirement to modify the current road surface/layout.

The hovercraft bus would glide over the current road network with ease through all of the possible surfaces that the seasonal weather could throw. However, this solution would be very costly in terms of obtaining such a vehicle, on top of that parts would be hard to come across and professionals would be required to carry out any maintenance, however at the same time the hovercraft bus is the only part of this solution that would require maintenance.

2.6 **Option Selection**

The alternative solutions discussed above all have various advantages and disadvantages. The choice of the most appropriate solution to pursue is based on how these alternatives weigh up in respect to the selection criteria that were derived in section 1.3 above. The team weighed up each alternative solution against each of the discussed selection criteria to determine the
value to be assigned in each case. The resulting data is displayed in Table 1 - Option Trade-off Analysis Results below. As can be seen by the resulting ranking factors, the most appropriate solution to the commute issue, based on the client requirements and our estimates for the various criterion values, is shown to be the option discussed in section 2.1 – Elevate + Fascine + Ablution.

Using the option trade-off analysis results as our decision making tool, the team has determined that the recommended option to present to the client is the “Elevate + Fascine + Ablution” solution. This solution will be pursued in depth in the following sections of the report.
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Table 1- Option Trade-off Analysis Results
3 Design Description

As shown in Table 2 (Option Trade-off Analysis Results), the optimal solution from those we conceptualized, and based on our initial estimates of costs, time involved and the relative merits of each option vs. the selection criteria, has been determined to be;

1. the elevation of the flooded road section(s) with cross drainage, along with,
2. the construction and deployment of Fascines along the remaining boggy/muddy road sections, and additionally,
3. the construction of several ablution facilities along the unsealed road.

It describes both what the solution is and how it works

3.1 Summary of the Design

As stated earlier in the documentation, the problem in which the Village people of Devikulam in terms of transportation to the realms of their nearest major City of Pondicherry is the inability to take the short (approximately) 5.2km Road network to the main highway in the monsoon seasons due to flooding. With the aid of research our team discovered that the problematic region is a lower area in the current 5.2km stretch of road which continues for roughly 200m, and at stages reaches 1.5m in depth (Loden, 2011). Another factor which is somewhat unhygienic is the inexistence of road side toiletry facilities which see’s locals defecating along the roads side (Engineers Without Borders Australia, 2011).

The solution which our trade off analysis revealed to have the most suitable properties for this problem was the elevation of flooded road sections with cross drainage, along with grading the remainder of the Fascines along several other areas which tend to ‘bog up’ during monsoon season, and also include several toilet facilities along the route to cease their ablution problem.

3.2 Detailed Description

The implementation of this solution would result in an elevated limestone block-built structure, constructed of 6716 amount of 1000x350x350mm limestone blocks, plus extra 84 for safety or repairs. The Structure would be 250m in length, and exist across the 200m lower problematic region. It would be 6 courses high, and multiple 300x350 water pass by gaps would be present in the limestone structure. The final layer will contain another layer of lime
powder (approximately 300mm) on top of the final layer which will be compacted with the aid of water in order to achieve a smooth-concrete like finish. Safety of the Village people is also obviously very important, thus why the use of safety rails on each side of the bridge will be included.

The safety rails would be made out of tires which would be purchased from Kadappakkam a town within 50km radius of the village at a cost of $1.5US. The tire size is 315/80R22.5 (1.07m) which are truck tires. The tires would be bolted into the limestone and in between each other providing a solid and safe safety rail. It was calculated that 932 tires are required to create the safety rails. This is because in some areas the height from the edge of the structure to the surface below will be up to 2400mm. A Cad drawing of this section is shown in Figure 4 below (Alibaba, 2011).

![Figure 4 - The Safety Rail](image)

The remaining sections of the pathway will be built up using the Fascines technique, which is a buildup of dead plant/stick matter in order to overcome a damp bogginess, once elevated enough to overcome the dampness, a final layer of crushed lime powder will be applied to these areas and then compacting will begin.

Finally, approximately half way (2.6km) between Devikulam and the main highway we will provide a toiletry system much like figure 4 below. It will be made primarily out of tin sheeting with a small steel frame.
3.2.1 Functional Block Diagram

Essentially, our proposed solution will consist of 3 main systems in conjunction with one another which include:

- A limestone block elevation structure with safety railing (along the problematic 260m stretch)
- A build-up of Fascines in areas which experience minor bogy/dampness throughout monsoon season.
- A simple drop dunny 2.6km on the current path to the main highway from Devikulam.

The above systems are detailed as follows:

Figure 5 - Drop dunny toilet system (Fonearena, 2010)

Figure 6 - Limestone building block
Figure 6 is a depiction of the dimensions of the nominated limestone block that will be used in our final design solution. The blocks dimensions are 1000x350x350 (in mm). The approximate mass for each of these limestone blocks is roughly 240kg. (Blockstone, 2011)

![Figure 6 - Depiction of side elevation of flooded section of road](image)

Figure 7 – Depiction of side elevation of flooded section of road

Figure 7 depicts the problematic area in which the people of Devikulam currently experiences difficulties with during the monsoon season, the lowest area of this point is 1.5m deep, and the dip within the roads surface exists for 250m. (Loden, 2011)

![Figure 7 - Depiction of side elevation of flooded section of road](image)

Figure 8 - Creating flat foundation for limestone block structure

In order to perform the intended solution, the large limestone blocks will need a compact level surface, thus leveling of the 1.5m deep section for 200m at this depth, and then on each side, a square edge incline of 700mm (height of two limestone block), and then a 1000mm leveled area, then a 1050mm square edge incline (height of three limestone block), then 250mm remains above the overflow level or water level, which acts like a buffer.

![Figure 8 - Creating flat foundation for limestone block structure](image)
This foundation work is required in order to ensure that the final layer of the limestone blocks will be level and that the initial layer (in contact with the ground) is stable and has zero movement. This is depicted in Figure 8.

![Figure 9 - Side view of repeatable part of limestone structure](image)

Figure 9 provides an idea of the intended layout of the limestone blocks, it is a side view, as noted, the initial layer is perpendicular to the length of road, and all of the blocks are very close together (just touching). No expansion gap was left on the grounded layer as the foundation will be dead flat and level, thus the tight fitment of blocks is used to reduce movement.

The second layer is once again laid perpendicular to the roads length, and every two blocks there is a gap of 300mmx350mm in order for water pass by. This is the optimum gap that still doesn’t affect the structures stability however providing water pass by with no cutting of the blocks required.

The third layer is then laid parallel to the length of the road the same way as the first layer. The fourth layer which is once again perpendicular to the length of road are the same as the second layer, which are gaps of 300mm of letting the water to pass through. The firth layer is same as the first and third layer, which is laid parallel to the length of the road.
The last layer which is the layer that will contain the 300mm layer of limestone gravel, which allocates drains on the road (the road as a slope). The blocks in this layer are packed tightly in order to prevent movement when the vehicles pass on them. In order to fill any remaining gaps and improve the roads surface, a 300mm layer of lime powder (from the same supplier as the blocks) can be spread across and compacted.

In total, the height of the structure will be 2400mm plus a layer of lime powder. The initial depth of the flooding region was 1500, thus leaving an elevation of 900mm above the level surface, thus at the start and beginning of the structure, once again lime powder can be used to smooth out the square edged step.

![Figure 10 - Top view of limestone block structure](image)

Figure 10 is a depiction of the top view as with the width of the limestone design to be 4m, the green lines on the figure demonstrate the safety rails, as where they would be located on the top layer. The figure also shows how the limestone block would be laid out on the top layer under the layer of crushed limestone or gravel (the dotted lines).

The drain away was design by elevating the middle of the road with limestone or grave up to about 300mm and decrease to the edges of the structure (as the arrows are pointing). This design works by the angle of the road, the safety rails or the tires have a gap on the bottom or in between each tire where the water can run of.

The road or the drain away set up can be maintained by the local people as by compacting the crushed limestone or the gravel, fill in gaps or wash a ways, replace any tires that get damage on the safety rail, concluding that the top view shows the setup of the top layer.
Figure 11 depicts the final look of the project once in place, each blue shaded region on the drawing depicts a water pass by area, the structure will protrude 900mm above the current road surface as a safety factor (Although they were experiencing up to 1500mm of flooding upon this stretch, the intended structure stands 2400mm for assurance), the red line indicates that there would be more blocks of the same design in the region.

Thus the resulting structure allows water to pass through the structure in the second layer, which will be at a height of 350mm from the ground level. In this level there will be 200 amount of 300x350mm water pass by channels (if looking from side view-refer to fig 4), also the same thing would happen on layer four, but it would contain 202 water channels of 300x350mm of size.

Fascines build up structure-
This part of the system is relatively simple, and can be done by local village people. It is simply a buildup of dead plant matter in specific areas on the current road path which become damp and boggy in monsoon season. The Process for doing this will be to continually place dead plant life and sticks/bamboo into these damp regions until a firm ground is present, upon the addition of this matter, a final layer of lime powder will be added in addition with compacting and water in order to achieve a smooth-compact result.
As a result, these damp areas will cease to exist, however, these Fascine regions should be built up with lime powder and be compacted with water quarterly by local village people in order to obtain optimum results.

Toilet-

In order to reduce the hygiene problems due to roadside defecation, the implementation of a simple tin-boxed drop dunny design will be used half way between Devikulam and the main highway (~2.6km from Devikulam) in order to assist walkers and cyclists. These can be brought as a kit from company Fonearena for $300US; the toilet contains ten seats or room when people could do their business and also the toilet is moveable so it could be placed on any spot of the track of the road.

This toilet design will be relatively easy to maintain, just simple daily cleaning which can be performed by the village locals. The Septic matter itself will not have to be emptied due to its design. The waste is directly dropped into a deep hole underneath, the hole will have plastic walls, and however the bottom of the hole is dirt, thus allowing the matter to be absorbed over time (refer to figure 5).

3.2.2 Manufacturing Procedure

In order to perform the intended solution, the large limestone blocks will need a compact level surface, thus leveling of the 1.5m deep section for 200m at this depth, and then on each side, a square edge incline of 700mm (height of two limestone block), and then a 1000mm leveled area, then a 1050mm square edge incline, then it’s over the flooding area and it goes out to the side flat at around 48.25m (900mm will remain to the level ground). This can be performed at a low cost with many local villagers with shovels, of course it will take time, however will result in the requirement for local work and thus fulfilling one more of the intended design requirements.

This foundation work is required in order to ensure that the final layer of the limestone blocks will be level and that the initial layer (in contact with the ground) is stable and has zero movement.

After the foundation has been made, the ground level of the limestone blocks may be laid, again, this can be performed manually by locals. Taking into account that each block weighs
approximately 240kg, it would be safer and more time efficient to use hydraulic manual lifting devices which can be operated by local villagers. The device contains a lifting arm which is connected to a hydraulic pump-jack, on the arm there is chain which connects to a scissor device use to clamp the limestone blocks. Each level of blocks should be laid by first laying the centre rows, and then the lifting devices can be placed on the centre rows to have a flat-robust foundation in order to lay the outer rows. In this ground level the blocks are to be laid perpendicular to the length of road as tight together as possible.

Level 2 is to be laid perpendicular to the roads length, and every two blocks there is a gap of 300mx350mm in order for water pass by. This is the optimum gap that still doesn’t affect the structures stability however providing water pass by with no cutting of the blocks required.

Level 4 is to be laid in the same manner as above level 2; there is also a 300mx350mm gap which lets the water to pass through or to flow, but it would take high level of water to probably flow through this layer.

Level 6 to be laid in parallel to the length of road, this layer will be the one in which the traffic will be on. The blocks in this layer are packed tightly in order to prevent movement when the vehicles pass on them.

Upon the final level of limestone blocks will be a layer of lime powder. This should be done by first have crushed limestone or gravel, and compact it into all visible gaps on the final layer of the structure until no more will fit in the gaps. Once complete, the whole top level may have approximately 300mm in thickness of limestone or grave added on top. Whilst doing this it should be compacted with water. At the end this layer of crushed limestone or gravel creates a road, that would be on an angle, as to create draining on the structure or the road, figure 5 explains the unleveled lust layer.

The final layer of crushed limestone or gravel creates a road, that would be on an angle, as to create draining on the structure or the road, figure 5 explains the unleveled lust layer.

The compacting of the crushed limestone or gravel can be done with a heavy roller being rolled back and forth simultaneously with the application of water until it is uniform in density.

The above tasks may once again be performed by local villagers.
The limestone structure is then finished.

The implementation of the Fascines technique involves a buildup of dead plant/stick matter in order to overcome a damp bogginess, once elevated enough to overcome the dampness, a final layer of crushed limestone or gravel will be applied to these areas and then compacting will begin. The compacting technique is the same for the above.
4 Implementation Plan

4.1 Cost Analysis

4.1.1 List of Costing

This list describes all the thing that are required to create this design

- Limestone blocks
- Used truck tires
- Portable toilet
- Block lifting crane (manual hydraulic pump-jack)
- Block clamping device
- Chain
- Bolts/Nuts

4.1.2 The Cost of Things

This list shows the cost of the thing that are required to create this design

- Limestone blocks at 240kg each at the cost of $13US per ton
  The design needs to have 6,800 limestone blocks
  The total cost for the limestone blocks is $21,216US

- The used truck tires are at a cost of $1.5US
  The design or the safety rails require 932 of them
  The total cost of the used truck tires is $1,389US

- Portable toilet is $300US each
  The design requires only one
  The total would be $300US

- The block lifting crane is $700US each
  The design requires only one
  The total cost is $700US

- The block clamping device is $100US each
  The design requires only one
  The total cost is $100US

- The chain that will hold the block will cost an extra $50US with the block lifting crane
  The total cost of the crane and the chain is then $750US

- Bolts/Nuts are required to bolt down and clam the tires, the cost of 100 of them is $0.1US
  The design requires approximately 20,000
The total cost is $20US

### 4.1.3 The Total Cost

The total cost of all the gear required to complete the design is

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### 5 Impacts and Benefits

#### 5.1 Environmental

The introduction of such a large quantity of foreign material will have a considerable effect to any environment. So when raising the roads over the rivers and streams using limestone blocks there will be multiple changes that will occur, some beneficial and others with negative effects. When limestone is placed in water for any period of time traces of calcium carbonate will be found. Calcium carbonate helps to increase wildlife as it reduces acidity of the environment as well as reducing traces of toxic metals which include lead, cadmium, zinc and nickel (Lemon, 2011). The addition of this calcium is also beneficial to the agriculture as the nutritious gain stimulates growth in plants. A negative effect of the addition of the limestone block is the reduction in flow of water through the streams and rivers. This slowed rate of flow through the blocks will affect the how the water flows and may cause changes in the size and shapes of the streams which in turn could cause future problems for different sections of roads. To reduce chance of this having effect on our design we have chosen the greatest gaps between the block that will still allow maximum possible water flow and desired strength of the road surface.

#### 5.2 Economic

Creating a shorter more efficient path will have great economic gains for the community. By reducing transport time the cost is also reduced and the transportation of locally farmed product will be fresher when delivered to markets and therefore be more desirable and in higher demand, bringing more money into the Devikulam community. Better roads and transport will also be less hard wearing on motorcycles and other forms of transport, therefore saving on repair costs. An economic downfall of the modification in the road is they
will need to be maintained. The limestone will get cut up and may need to be groomed and redressed from time to time allowing it to stay safe and efficient. This work can create new jobs in the community which may also help boost the economic state of Devikulam.

5.3 Social

Creating a shortened path from Devikulam to Pondicherry that is accessible all year round will have immense social benefits for the community. Allowing this journey to be reduced by 26km each way during monsoon season will mean Pondicherry is not so out of reach from Devikulam and the social benefits of being in touch with Pondicherry will be achieved. As Pondicherry is a much larger community, it allows the community Devikulam to be in access of a lot more resources and allow a beneficial gain to anyone in the community who require access to these outside goods and services.
6 Ethical and Safety Considerations

In order for our Elevated limestone bridge like structure to be deemed safe in both the implementation of the structure and whilst being used by the local Devikulam Village people, we have proposed the following suggestions.

6.1 Production of structure

Evidently each 1000x350x350 Limestone block has a mass of approximately 185kg (Just Rocks Limestone SA, 2011), thus posing danger to the locals who will be erecting the structure. In order to overcome this potential threat, as a pose to manually lifting these enormous limestone blocks, the use of a manual hydraulic pump-jack design crane will be used to do the lifting. Several of these cranes will be used simultaneously during the construction of the structure (refer to figure 12).

![Block lifting crane](Gantry-crane.org, 2010)

Attached to the eye of the lifting arm chain will be another mechanism (called a limestone lifter which acts as a clamp as the tension in the chain is increased (depicted in figure 13).
In addition to this lifting system, two workers will be required to guide the block into position as the third mans the hydraulic pump, and will be required to release the blocks slowly into position in synchronization with the workers guiding it.

6.2 During use

As our proposed structure stands at points up to 1.75m above ground level thus being a danger for traffic if it was to fall of the edge, we have included the implementation of a safety edge which is constructed from vehicle tires (315/80R22.5), the design is depicted below (figure 14).

As depicted above, the safety rail is simply two courses of tires standing upright (vertically) upon the edges of the final structure. They will be fastened to the structure via the use of rio bar pegs.

This safety rail will stop traffic falling from the sides, as well as providing a soft impact collision due to the flexibility of the rubber tires.
The surface of the road being a compact lime powder, thus the coefficient friction will be very similar to that of concrete and as a result should see all forms of traffic stay in contact with the structure well. Also, to ensure the friction between traffics tires/shoes is not overcome, the maximum speed along the structure will be limited to 50km/h. However this is a realistic limit as most of the forms of traffic (walkers, bulls, cyclists, tractors) are not able to travel at speeds greater than this safety-factored speed (Buzza Land Information Systems, 2011).

If the above safety restrictions are abided by, both during the manufacturing of the structure, and throughout its operation time, then the workers, nor the traffic should have no safety issue with the structure as a result.

7 Conclusion

Producing a shorter more efficient path will have great economic gains for the community. By reducing the size of the path from Devikulam, not only are we cutting commute time but also the cost. This means, people can get to and from Pondicherry quicker, transporting the farmed products fresher and saving more money. This will mean, they can get more work done in a day and can earn and save more money. This would be a real boost to the minor economy of Devikulam.

This shortened path will not only be convenient for business purposes but also for cultural and social purposes. During large festivals such as “Diwali” and “Holi” the people of Devikulam are not constricted to their village, it means they can travel to Pondicherry, using the shortened path, and join in the celebrations with the larger town and its people.

By attempting to create an alternate path, we are always meddling with environment. This could be positively or negatively. For instance, by using limestone blocks to increase the level of the road/path, we are having a positive as well as a negative effect. Over time calcium carbonate forms on the limestone, the calcium carbonate is good for the environment as it reduces acidity and helps sustain wildlife. It has a negative impact as the large blocks reduce water flow and thus may be a problem in the future. To tackle this issue, we have decided to put larger gaps and thus let the water flow be unaffected.
A major problem at the start was the management of costs. Specifically these were Labor costs. This included the transportation of laborers over the period, housing for the laborers and other minor costs. To reduce these costs we have decided to train the men and women of Devikulam about the techniques of construction. This will not only save production costs currently but will also reduce future maintenance costs.

As shown in Table 2 (Option Trade-off Analysis Results), the optimal solution from those we conceptualized, and based on our initial estimates of costs, time involved and the relative merits of each option vs. the selection criteria, has been determined to be;

4. the elevation of the flooded road section(s) with cross drainage, along with,
5. the construction and deployment of Fascines along the remaining boggy/muddy road sections, and additionally,
6. the construction of several ablution facilities along the unsealed road.

It describes both what the solution is and how it works

The original path used by the people of Devikulam was approximately 25km in length and then during the monsoon the alternate path was 45 km. Both paths are highly impractical and an alternate method of travel was needed for the people. 5 different solutions were listed. The options we have chosen, which could be a solution for these people, are

- Elevate + Fascine + ablution
- Bridge + Fascine + ablution
- Water channel + barge
- Train line + engine + cars
- Hovercraft

The hovercraft is a rather impractical solution as it would cost quite a lot not only to purchase but to drive and maintain. The train line solution is more practical but might just be a solution of the future. The water channel, bridge and elevate are three good solutions which could be implemented in the current situation which more ease than the other two.
The aim of this report is to investigate the problem and to create a viable solution which is limited to criteria which follows several factors. The problem in this case is that a method of transport which is safe, practical and quick is not available for the people of Devikulam. We have come up with 5 solutions which are limited to factors:

- The solution must be of low cost
- The solution must be aligned with cultural responsibilities
- This project must create opportunities for the village and its people
- The solution must ensure that the existing natural environment is protected and preserved
- The solution must be maintainable by the local community.
- The solution must encourage traditional practices
- The solution must set an example for sustainable land management

Together, we have worked to create a solution which will provide a better lifestyle for the people of Devikulam. It will help them develop at a greater pace and create new opportunities for them.
8 References


