

Inter-island Transport in Fiji Powered by Renewable Energy

Abstract

Introduction

The Pacific Islands meet in average 80% of their energy needs from imported fossil fuel and quarter of their total import on diesel (Pacific Energy Summit, 2013). Less than 10% of their energy demand comes from renewable domestic sources. Transport to remote islands becomes hugely costly because of the imported fuel and that the islands populations are not large enough to sustain a commercial ferry services with big vessels with high running costs.

Fiji consists of 300 islands and 97 of those are inhabited (Mario, 2003) and have a population of about 844000. However developed commercial activity is concentrated to Viti Levu and Vanua Levu while the rural islands are depending on traditional work like farming and fishing (Fiji Bureau of Statistics, 2007). Now the outer islands are dependent on government shipping and a few subsidized commercial operators. In many cases the population will have to use small unsafe fibre boats with outboards and run regularly 60nm or more with passengers and cargo to comply with the most urgent needs.

Pacific voyagers have operated 7 solar/wind powered vessels since 2009. 2011 Pacific Voyagers built a small solar/wind powered cargo vessel capable of transporting a total load of 4t or 20pax estimated to satisfy the transport need of a typical 2-300 people village in a remote Pacific island. The design incorporates information shared from many different island groups, resulting in a design specific to Pacific inter-island transport. The prototype vessel Okeanos is 14,8m long, double hull solar/wind powered vessel with auxiliary electrical motors that assist maneuvering in harbor and lagoon areas. The solar is charged from 8 solar panels and/or from the motors set in a ReGen mode that generate power while sailing. Okeanos is unique in her zero emission/zero fossil fuel dependence approach.

During the period April-July 2013 Pacific Voyagers Okeanos was conducting a research project in Fiji. The aim was to collect baseline data from rural islands in Fiji to see and test how a wind and solar powered smaller sailing vessel could work as a transport solution to isolated islands and villages.

Method

Pacific Voyagers operated the prototype vessel Okeanos in Fiji between April and July 2013. Okeanos is unique in her non-fossil fuel dependence approach. She is solely propelled with Solar Power through 2 electric motors and wind, through an simple but efficient Bermuda rig. Okeanos is a 14,8m long double hull sailing vessel capable of taking a load of 4 tons in mix of passengers and cargo. The design is highly flexible to accommodate a variety of use from carrying passengers and cargo, to fishing. The double hull configurations shallow draft allows the vessel to land directly on a beach and reach shallow areas where normally boats can't sail. This is a significant advantage as Okeanos can sail straight to many villages who normally depend on secondary transport to a jetty with proficient depth for a inter island ferry to dock (appendix 1).

The vessel is not registered in Fiji's ships registry which is a requirement to operate a ship commercially in Fiji. Instead Okeanos obtain a temporary research license to comply with the Maritime Authority and the Transport Ministry. However the research permit prevented fully commercial operations, i.e charging to transport passengers and cargo. The Maritime Safety Authority Fiji (MSAF) certified Okeanos to take 8 passengers and a total of 4 tons load including passengers and cargo.

Okeanos arrived in Fiji in April. Four weeks were used for securing the necessary document to be able to use Okeanos for transporting goods and passengers in Fiji. Preparations for the trial started in February 2012 but the administrative traditions in the country demanded face to face discussions hence the actual preparations started not until in April. Data about transport cost was collected through research and interviews. Value of the transportation Okeanos performed was estimated on the current freight charges in the area.

During the trial period Okeanos was set up to run with a crew of four, one skipper and three deckhands. The skipper was on a full time contract and the deckhands on daily rate contracts.

The trials to transport cargo and passengers was concentrated to 3rd May to 4th June. Interviews were done opportunistically during the whole period until the 7th July.

Interviews

During the period 20th April to 7th July Okeanos visited 24 villages in Gau, Kadavu, Yasawa's. Through 40 interviews baseline data was collected about current transport needs, the methods used and costs in the islands and villages:

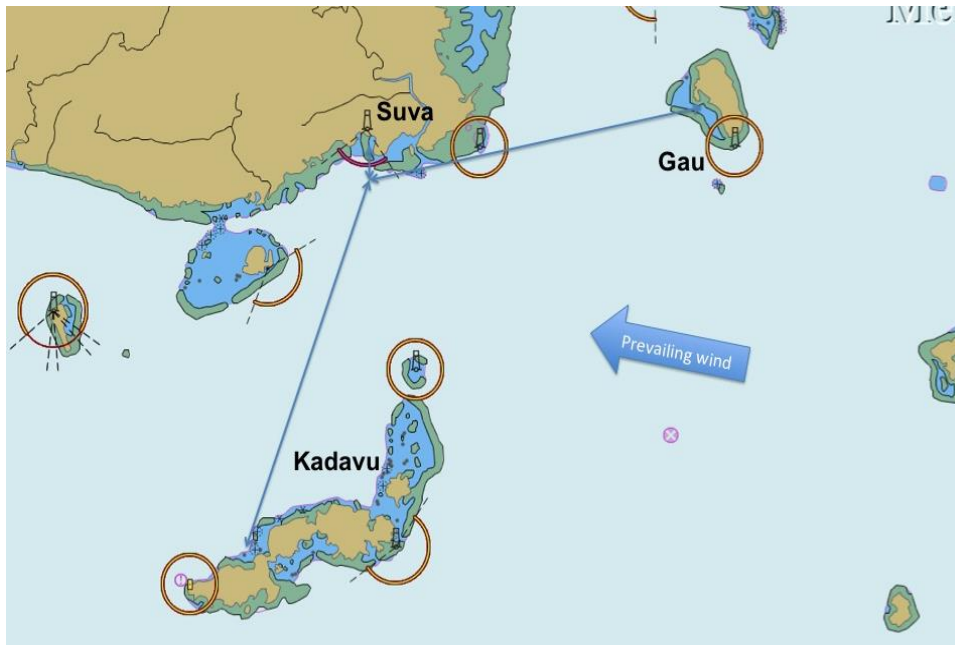
- *Current transport cost/frequency*
- *Type of transport (ferry/private)*
- *Passenger/Cargo*
- *Type of cargo*
- *Typical village needs*

Sail/Solar Transport Trials

The project was limited in time therefore it was chosen to concentrate the transport routes to Gau and Kadavu for the main reasons;

1. Main ports, Nawaikama in Gau and Vunisea in Kadavu are of similar distance from Suva, about 57 respectively 60nm.
2. The course over ground is almost perpendicular to each other, Gau is east of Suva and Kadavu south.
3. Contacts in the villages were established in April.
4. Gau is part of the uneconomical routes and Kadavu is economical.

Through the sailing trials data was collected about the vessels capacity and performance to establish the suitability of the design. It was also important to find out how the crew performed and could operate the vessel, how passengers found the experience to travel on a sailing vessel, what the administrative needs were and what kind of licenses and permits was needed to operate commercially.



Results

Between 3rd May and 4th June Okeanos did 16 sails between Suva, Gau and Kadavu. 14 of those were with cargo and passengers. Suva was used as the base and returning port. One return sail to Kadavu aimed to establish contact in a village and did not take cargo.

Each sail was aiming to minimize the total time spend until Okeanos returned to Suva.

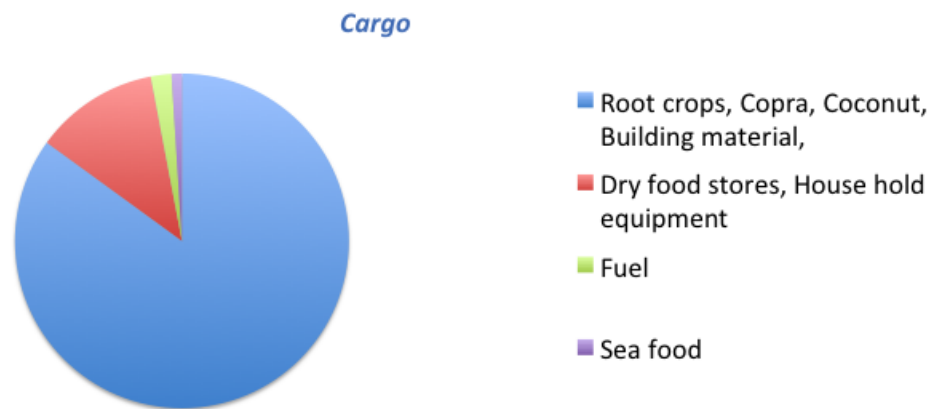
On the 14 sails Okeanos transported a total of 21797kg of cargo and 55 passengers, a mean of 1557kg and 4 passengers per sail. This is about half of Okeanos current allowed capacity in Fiji of 8 passengers and about 3tonns.

Of the transported goods, 85% consisted of root crops and copra/coconut being transported from the islands to Suva and building material, house hold equipment being transported to the island from Suva. 15% was food stores and fuel to the islands.

In 31 days (May) – 16 sails

Max load: 3660 kg / 3 pax

Tabel 1 *Average load/sail: 1557 kg / 4 pax / village*



In average each round sail took 3 days or 1,5days per way including loading and unloading cargo and passengers, rest for the crew and waiting for the right winds and weather. However there is a large difference in travel time between Gau and Kadavu. A return sail from Suva to Gau takes on average 3,4 days or 1,7 days one way. A return sail from Suva to Kadavu takes on average 2,3 days or 1,15 days one way. Okeanos spend about 33% more time and effort sailing between Suva and Gau compared to Suva and Kadavu.

The fastest sailing time to Kadavu and Solomdavu was 7hrs 45min with an average speed of 8,4kn. The average speed over 5 sails to Kadavu was 6,7kn and took 8h54min. To Gau the average time was 15h to Nawaikama.

Interviews

In all the islands and villages the main need for transport is to get income generating produce to a market and to bring food stores and building material back to the villages. The reminder is personal transport to education institutions, for trading, family functions and occasional village functions.

The costs for transporting the cargo on the ferry to and from Suva are similar in Kadavu and Gau and generalized over four categories:

- 30-40kg Bags-Which usually is produce, copra, building material, coconuts
- 15kg Boxes-Usually food stores, house hold equipment
- 10kg Buckets-usually sea food
- 44lb Drum-fuel

Tabel 2

Ferry Prices Kadavu/Lomaiviti			Ferry Prices Yasava		
Coconut	0,17	\$/kg	Coconut	0,5	\$/kg
Yem	0,17	\$/kg	Yem	0,5	\$/kg
Yaqona	0,17	\$/kg	Yaqona	0,5	\$/kg
Dalo	0,17	\$/kg	Dalo	0,5	\$/kg
Cassava	0,17	\$/kg	Cassava	0,5	\$/kg
Copra	0,17	\$/kg	Copra	0,5	\$/kg
Rice	0,17	\$/kg	Rice	0,5	\$/kg
Flour	0,17	\$/kg	Flour	0,5	\$/kg
Sugar	0,17	\$/kg	Sugar	0,5	\$/kg
Cement	0,17	\$/kg	Cement	0,5	\$/kg
Food stores	0,27	\$/kg	Food stores	0,67	\$/kg
Building material	0,27	\$/kg	Building material	0,67	\$/kg
Sasalu	0,3	\$/kg	Sasalu	0,5	\$/kg
Crabs	0,3	\$/kg	Crabs	0,5	\$/kg
Fish	0,3	\$/kg	Fish	0,5	\$/kg
Fuel	0,12	\$/ltr	Fuel	0,15	\$/ltr
Passenger Kadavu	55	\$/pax	Passanger	85	\$/pax
Passanger Gau	70	\$/pax	Yasawa-i-rara		

If the current commercial ferry charges are applied to the kind and amount of cargo and passengers Okeanos transported in May it could have generated \$7487FJD on the 14 cargo sails done in 22 sailing days or 340FJD per day (appendix 2).

The islands have few or no roads or even paths in some cases. The main intra island transport is by fibre boats or walking. There is a main port and the villages that are not located next to it have high additional transport cost.

The Okeanos crew of four found that the vessel itself easy to handle and quite capable of carrying cargo fast between the islands. Upwind performance were effected when sailing with a full load but significantly. They found that the short distances and turnover time was exhausting after a couple of return sails. The crew was not suppose to participate physically with loading and unloading cargo but had to supervise and inevitably they helped carrying cargo.

The loading of the canoes cargo holds was done manually and a full load could be handled by 6 people and be done is less than an hour. The main sail boom is meant

to double as a crane but the crew found that it was neither easy nor time efficient to use with the holds and cargo hatches current design.

Passengers found it initially awkward to be on Okeanos offshore compared to the big ferries because of her size. The movement of the vessel in higher winds created nausea with about 20% of the passengers (skippers estimation). However, the general impression of the vessel from all passengers was positive when they arrived to their destination and they would favor travel on Okeanos directly to their village rather than travel first on a big ferry then on a chartered fibre boat.

Okeanos went through one MSAF survey and received a limited safety certificate to carry 8 passengers. The limiting factor was the amount of seats provided for passengers. In relation Okeanos current Cook Island Safe Manning Certificate allows for 20 passengers. Okeanos were not able to get a Coastal Trading License but a verbal agreement with the Permanent Secretary for Ministry for Works, Transport and Public Utility secured Okeanos operations in Fiji waters however on the condition that it was non-commercial.

Gau.

Gau has 16 villages with populations varying between 50-200. In average Gau is visited by one ferry per month or less by either a government or company ship. The villages run the 57nm sail to Suva with smaller fibre boats for the most urgent food stores, to sell small amounts of produce and Yagona and for personal travel. The income generating cargo like root crops and copra is dependent of the ferry.

The Ro-Ro ferry dock is on the Nawaikama jetty. The villages around Gau have to bring their cargo to the Nawaikama jetty by chartering a fibre boat. In average a fibre boat cost 200FJD to hire one way, typically for a 3nm sail. The fibre boats Okeanos encountered carried 30 30kg bags in one load. From the most remote villages, like Vadravadra, it can take 3-5days to transport their crops or copra to Nawaikama and cost 2000FJD. Typically it cost more to transport the cargo to the jetty in Nawaikama than it cost to transport the cargo on the ferry to Suva. In our example about, 6,70FJD per 30kg bag or 0,22FJD per kg from a village about 3nm from the ferry port.

In Gau each village has need for transport about once a week to transport 2-3 tons goods and between 5-10 passengers. Once every 2-3 months each village is engaged in a village function that require between 50-70 people to travel.

The ferry charge 70FJD one way for passengers from Nawaikama to Suva. The villages away from Nawaikama that need to travel to Suva has to charter a fibre boat to get to the main port then catch the ferry from there. In the Gau example the village closest to the main port will pay 200FJD to charter a fibre that can carry about 10 people or 90-0kg to travel to the main port.

Kadavu

Kadavu has a regular ferry service one or two times a week from Suva to Vunisea and Kavala Bay. The ferry charges 55FJD between Suva and Vunisea for passengers. Kadavu's main income is from Yagona and other root crops. However, the villages away from the two main ferry ports faces the same problem as in Gau with expensive intra island transport. One of the northern most villages (closest to Suva), Dravuni, pay about 128FJD per person to travel to Vunisea then an additional 55FJD to Suva. Dravuni is favouring charter fibres boats and travel straight to Suva even if the cost is much more (500FJD and more). Kadavu also have a tourist flow to a number of resorts on the island. This has helped to keep a ferry service that is reasonable regular. The average village with a population of about 100 has a general need of transporting a estimated 3-4 tons or more per week and an excess of 10 people travelling to Suva per week.

Tabel 3 **Intra Island Transport Cost**

Cost from village to ferry port (FJD)	Cargo cost/fibre boat (max about 900kg)	Cargo cost per kg bags	Cost per passenger
Qarani	200	0,22	60
Navukailagi	200	0,22	70
Lovu	200	0,22	80
Vadravadra	250	0,28	100
Lamiti	200	0,22	?
Naikorokoro	200	0,22	?
Tavuki	500	0,56	60
Dravuni	400	0,44	128
Solodamu	100	0,11	20

Yasawa's

Yasawa's string of islands has an extensive tourist industry with many resorts. They have a daily fast ferry service that visits the resorts. The service is however very expensive and is not suitable for cargo. A barge run a service between Lautoka and Yasawa's about once a week but only to the southern islands. The north Yasawa have very infrequent ferry service with as little as once month or less occasionally. In general Yasawa's is facing similar transport issues as most of the Fiji islands with little ferry service to transport produce to markets to be able to sell. Yasawa's is however less dependent on produce as an income since many islands have tourist resorts which generate a local income to the villages. Almost exclusively the islands internal transport is done with fibre boats with an outboard engine.

The transport need is primarily to get produce and seafood to Lautoka to sell on the market and to get building material and dry food stores back to the islands. The remaining need is for personal transport. The transport costs are significantly higher in the Yasawa's compared to Lomaiviti and Kadavu.

Discussion

There is a great need of reliable sea transport throughout Fiji's islands. The most common reason found in this study and similar in all the villages is that the economic growth and possibilities are severely inhibited due to the lack and/or uncertainty of transport. Even in the islands with a regular service, the villages away from the ferry port have high intra islands transport cost or even lack of transport measures to get cargo to their island's main port. The lack of transport means lack of opportunities for the populations of the islands and they are forced to either live without money and only of the land and ocean or leave their home islands and move to the commercial centers in Viti Levu or Vanua Levu.

The Fiji government has identified 10 shipping routes that are essential to the outer districts of Fiji but that have proved un-economical for commercial operators. Usually these areas are remote and have a low population density, which means that the amount of cargo and passengers that needs to be transported is small and hence will make it hard for a bigger ship to cover its costs.

The Fiji Government has allocated 1,5M FJD/year for the Shipping Franchise Scheme to subsidy commercial shipping on these routes. Despite these efforts many areas have as little as 4-5months between a ferry visit and the commercial operators complain that the subsidy is not enough to cover their running costs.

Between April-June the Ministry of Works, Transport and Public Utilities subsidized the operators with an average of 28FJD/nm and transported 132 tons cargo and 473 passengers per month on un-economical routes (Naisara, 2013). In relation Okeanos transported 22 tons of cargo and 55 passengers in one month at half allowed capacity and could potentially have carried 44 tons and 110 passengers. In the example with Kadavu Okeanos direct costs where about 13FJD/nm which means that the subsidy alone could keep two Okeanos sailing on routes that the ferries couldn't service.

The ferry between Suva and Kadavu takes about 7h. Okeanos made that sail in 7h45min in favorable conditions. Over the trial month the average travel time between Suva and Kadavu was 9h. Okeanos twin hull design allows for a relative high average speed under varied wind conditions as this shows. The feed back from the passengers was that they found this time very acceptable. In addition Okeanos delivered the goods straight to the designated village, Solodamu, eliminating any intra islands transport, which save a considerable amount of time and cost.

The big difference in sailing time to Gau compared to Kadavu is depending on the prevailing wind situation. Of course local conditions over a limited time like for the trial will play a big role and the average sailing time is only a rough estimate. It is however indicative and not surprising to find a big difference in the sailing time from Suva to Gau and Kadavu. Gau is in a unfavorable direction of sail from Suva and and it is likely that Okeanos would need subsidy to service that route.

The prevailing winds are an important factor in choosing routes for a wind powered vessel and in general a route in a North-South direction will work much more favorable, like Suva-Kadavu route shows. If a route were planned from Gau in a more favorable wind direction, like to Koro the sail will be much faster. If the routes could be coordinated with the regular ferry service to Koro and be arranged so Okeanos can transfer its cargo and passengers directly to the ferry, the service could be very efficient and reliable. Of course there will then be a secondary cost for passengers and cargo then but at least there would be a regular way of transport from Gau.

Technically Okeanos I and worked flawless during the trials. The Solar Electric system was used extensively to give additional power in low wind conditions and always to go through reefs and dock or beach. The system is well up to the commercial task this type of transport will require as also the previous 4 years of extensive marine use and development ensures.

Some features of the vessel needs improving like bigger cargo holds and larger hatches to make loading and unloading easier and so the boom can assist to lift cargo. Other changes to accommodate more passengers might be necessary to satisfy MSAF regulation.

The overall impression from the passengers who travelled with Okeanos and from the people who shipped cargo was positive. Okeanos can be improved but the sail/solar concept was very well received and the fact that Okeanos isn't dependent on fossil fuel was a major factor to this.

Okeanos is designed to be easy handled by a small crew. Inevitably a sailing boat will need enough hands onboard to manage sails in changing weather conditions but still be cost effective when running commercially. The demands of the crew is therefore higher than on a motor ship in that they need to constantly monitor the weather as well as the rig. During the trial the technical demands didn't create problems for the crew. The pressure came rather from fatigue because of the short legs and high turnover rate when docked. During the pilot project Okeanos skipper was constantly on duty for every sail. The crew rotated the 3 deckhand positions between 5 people. Not surprisingly there need to be a 2-crew system to run Okeanos non stop.

Can Okeanos be successful and commercial on the routes chose for the trial or similar routes?

Appendix 2 shows a couple of simulations for different scenarios based on data from the trials and estimated figures. The first to tables shows the examples of Gau and Kadavu extrapolated to 10 month annual operation. The last is a mixed system experiment where normal cargo operations are blended with a tourist scheme that might be suitable in the islands. The numbers are not absolute but gives a fair idea of what effects the commercial possibilities.

The Cargo only option

Here it is assumed that Okeanos is mostly used to carry cargo and local passengers to the chosen destinations. The limiting factor is the total carrying load (around 4000 kg). Here it is simulated that Okeanos is carrying basic goods in bulk, box, bags or barrels and the existing transport prices have been used. Local passengers will pay their fare (one way) and the level of fare will make a significant difference on profitability. The scenario analysis will bracket variations of sailing months (thus sailing days) and passenger fares to evaluate dominating factors.

As below table shows the operations could be feasible under reasonable and optimistic scenarios

	Base case	Pessimist	Optimist
Sailable months	8	6	10
Fare per passenger	80	60	120
After tax net income	29,979	(12,805)	147,923

The sailing time will affect the profitability significantly as will the rates for cargo and passengers and of course operation time. This highlights the need to plan the routing to take advantage of the local conditions. It also indicates that on shorter routes Okeanos can be profitable with the existing rates but her freight capacity would probably not be sufficient on longer routes and might require subsidy. Considering that Okeanos will eliminate a lot of secondary transport and cost by transporting directly to the villages it is reasonable to assume that Okeanos could charge more on passengers and freight.

The Cargo + Cruising passengers option

It becomes an interesting scenario from a business perspective if a tourist scheme was mixed with carrying cargo. If assume that Okeanos is used to offer a "working cruise" to tourists who would combine a 5-stars type of camping + sailing experience with a working holiday idea, with a "feel good" feeling of helping in the provisioning of small island communities. The chosen community would provide a camping site and some "touristic" activities (lovo, meke, church service, trekking, snorkelling, etc). For example a cruise would take place over 5 days, one way from Suva or similar to the island, delivery of cargo in different locations, camping and visiting of the final destination village and return to Suva. Compared to the previous model, cargo revenues would be reduced since only one return transport would occur during the cruise by loading from Suva to destination and, eventually return load from the village. Again the scenario analysis will bracket variations of sailing months (thus sailing days) and passenger fares.

This type of operations would be quite reasonably profitable and possibly profitable enough to justify the construction of subsequent boats financed by the profits on the operation.

	Current Values:	pessimist	optimist
Daily fare for passengers	200.00	100.00	300.00
Sailable months	8	6	10
After tax profits	75,661	(38,363)	237,685

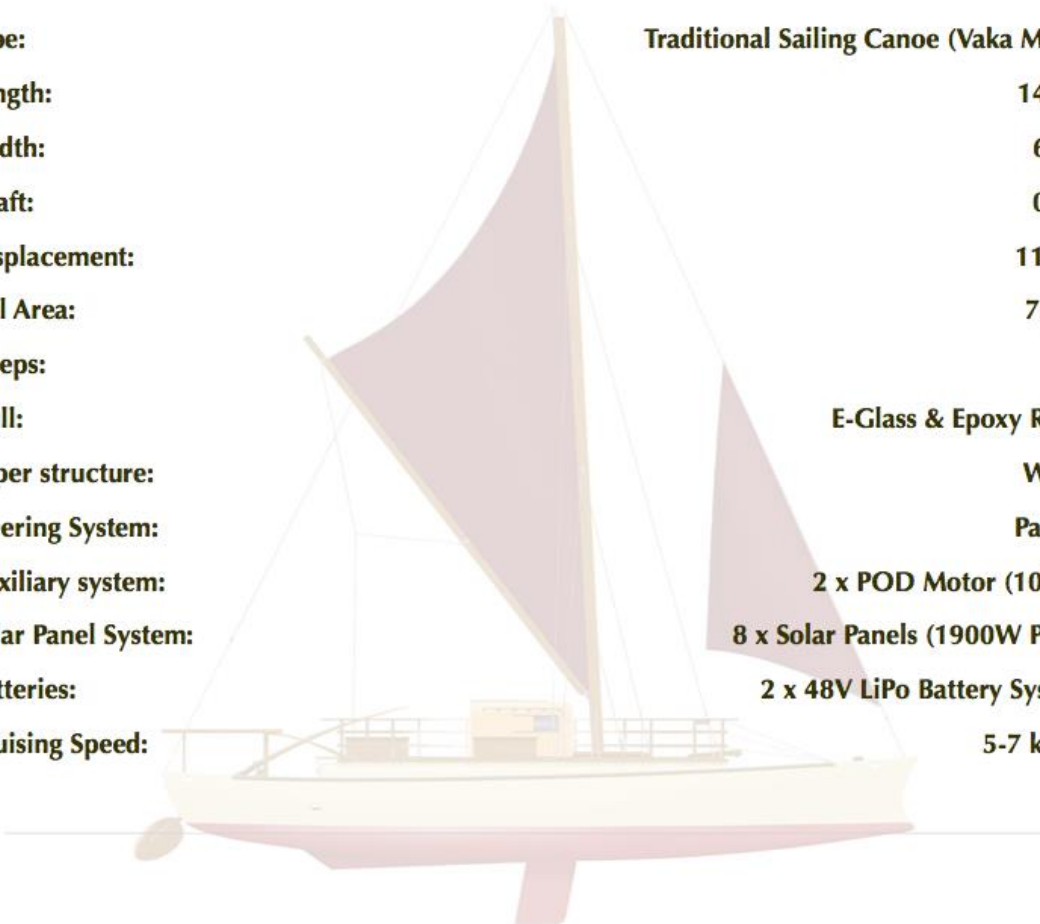
Of course all the hypothesis used in the simulations are 'best effort based'. Some numbers are best estimates and cannot be taken at face value. The idea is to use the model as a template that could be refined as more valid data are confirmed. The results are not static, they should evolve and be modified by whoever may want to experiment. The Excel workbooks are available from the authors.

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Type:	Traditional Sailing Canoe (Vaka Motu)
Length:	14.8m
Width:	6.2m
Draft:	0.7m
Displacement:	11 Ton
Sail Area:	75m²
Sleeps:	12
Hull:	E-Glass & Epoxy Resin
Super structure:	Wood
Steering System:	Paddle
Auxiliary system:	2 x POD Motor (10kW)
Solar Panel System:	8 x Solar Panels (1900W Peak)
Batteries:	2 x 48V LiPo Battery System
Cruising Speed:	5-7 knots



Appendix 2 (Example Gau 10 months operation full load)

Expenses		
total salaries	55 200,00	
Additional equipment	40 000	
On a capital value of	700 000	
Depreciation rate for boat	12%	
Depreciation rate for other goodies	20%	
Depreciation (boat and equipment)	dep	92 000
Discount rate	disc	6%
Equipment life expectancy	life	10
Tax rate	tax	20%
Potential Gross income		
Cargo	33 024,00	
Passengers	192 000,00	
Total	225 024,00	
Expenses		
Salaries	55 200	
Insurance	25 000	
Permits	12 000	
Coastal trading licence	10 000	
Maintenance and repairs	40 000	
Sinking fund for replacement	5 435	
Fees to villages	10 000	
Guarantee costing	20 000	
Maintenance and repairs	40 000	
Advertising	30 000	
Net	77 389	
Taxes	-	
Direct Cost	77 389	

Fare per passenger		200,00		pdiem		FID	
Number of days per cruise	5	dpt	days/trip	Number of days per cruise	5	dpt	days/trip
Number of cruise a month	3	dpm	trips/month	Number of cruise a month	3	dpm	trips/month
Number of passengers	8	pass	PAX	Number of passengers	8	pass	PAX
Months of operation	8	months	months	Months of operation	8	months	months
Sailing days per year	120	days/sail	days/year	Sailing days per year	120	days/sail	days/year
Cargo generated income		33 024,00		cargo			
Passenger	Salaries	Daily rate	For Sailing days and Land service	Passenger	Salaries	Daily rate	For Sailing days and Land service
Luggage				Luggage			
Total				Total			
Remain	captain	80,00	14 400,00	Remain	captain	80,00	14 400,00
	crew 1	50,00	7 200,00		crew 1	50,00	7 200,00
	crew 2	50,00	7 200,00		crew 2	50,00	7 200,00
	crew 3	50,00	7 200,00		crew 3	50,00	7 200,00
For Koa	Administrative	50,00	12 000,00	For Koa	Administrative	50,00	12 000,00
Bag (R)	Loading staff	30,00	3 600,00	Bag (R)	Loading staff	30,00	3 600,00
Rice	Loading staff	30,00	3 600,00	Rice	Loading staff	30,00	3 600,00
Sugar				Sugar			
Yagona				Yagona			
Coconu				Coconu			
Copra				Copra			
Cassava				Cassava			
Boxes	per day/guest	60	supday	Boxes	per day/guest	60	supday
Building	per day/crew	30	supcrew	Building	per day/crew	30	supcrew
Househ	Total supply	72 000		Househ	Total supply	72 000	
Mats				Mats			
Bucket				Bucket			
Seacuc				Seacuc			
Sea foo				Sea foo			
Fuel				Fuel			
Total pe				Total pe			
Total pe				Total pe			
Fare pe				Fare pe			
Total in				Total in			
Total pe				Total pe			
Cargo g				Cargo g			

Cargo generated income

225 024,00