AN AXIOMATIC DESIGN BASED APPROACH ON ANALYSIS OF ALTERNATIVE ROUTE(S) TO THE CONGESTED MENDANA HIGHWAY OF SOLOMON ISLANDS

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ABSTRACT

The Solomon Islands road network consists of three major highways, Kukum, Tandai and Mendana. The Kukum highway has major and minor un-signalized junction, overhead pass, and a dual carriageway. Tandai Highway has light traffic, minor junction and a single carriage way. The Mendana Highway has major & minor un-signaled junction, roundabout, underpass, and dual carriageway. Of the three highways, Mendana undergoes the most traffic congestion at Honoria section because of the high demand of the road use to access the basic services whilst vehicle increases and uses on a fewer road availability competing with the pedestrian users. The paper discusses on how to find alternative route to ease the traffic congestion of existing highway by axiomatic design (AD) approach contributing to the over-all analysis of process to determine which alternative route is the best viable. Selection of alternative route is a complex process and the application of AD is found to simplify the overall analysis.

Keywords: Cost Benefit Analysis, Axiomatic Design, Benefit cost analysis, Traffic Congestion, Net Present Worth

1 INTRODUCTION

Traffic congestion is a condition on road networks that occurs as use increases, as demand approaches the capacity of a road or of the intersections along the road. Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity. Traffic congestion negative impacts are: wasting time of motorists and passengers or opportunity cost, non-productive activity for most people, reduces regional economic health, delays (which may result in late arrival for employment, meetings, and education) resulting in lost business, disciplinary action or other personal losses, inability to forecast travel time accurately leading to drivers allocating more time to travel (just in case) and less time on productive activities, wasted fuel increasing air pollution and carbon dioxide emissions owing to increased idling, acceleration and braking, wear and tear on vehicles as a result of idling in traffic and frequent acceleration and braking leading to more frequent repairs and replacements, and stressed and frustrated motorists that leads to road rage and reduced health of motorists and higher chances of collisions due to tight spacing and constant stopping-and-going.

Urban traffic congestion is a serious and growing problem in many large and small cities around the world. Solomon Islands is also among these countries around the world that suffers urban traffic congestion. Its capital city Honiara (2013), a springboard for tourism activities is located on the northwestern coast of the island of Guadalcanal (Guadalcanal Campaign in World War II) with population of 64,609 people as of 2009, but as of 2012 record the population reached 549,598 according to World Bank (2014) data. Referring to an increase in population of 8.51%, the demands of road services is not enough to support it causing much congestion of the highway leading to major government services, schools and Honiara International Airport (former known as Henderson Field). The traffic concentration according to Gupta (2002) is eighty percent at Honiara City and the remaining is spread throughout the two populous provinces. The roads in Honiara were built decades ago (during the world war II) with little maintenance and expansions. The article titled Why Honaria Has A "Failed Transport Service" (2014) unveils the issues of poor road management and infrastructure that causes traffic jam on the roads as drivers tend to take shorter routes to avoid getting stuck and not getting enough income at the end of the day. Moreover, because more buses are running on a fewer roads resulting in a competition for space on the roads and passengers directing drivers in short routes to get ahead of other buses.

Table 1**.** Analysis of Existing Transport Infrastructure **Feature**

			Major junction		Minor Junction			Carriage-way				Contribution to the City									
		Bottleneck	Signal	Unsignal	Signal	Unsignal	Over-pass	Single	Dual	roundabout	Under-pass	Commercial area	Historical area	Residential	Accident Prone	Most desired	Short distance to most services	Attraction	Access to airport	Access to major gov't service	Schools
1	Kukum Highway	x		x		x	x		x					x							
2	Tandai Highway			x		x		x						x							
3	Mendana Highway	x		x		x			x	x	X-closed	x	x	x	x	x	x	x	x	x	x
4	Metaniko	x														x			x	x	x
5	Roundabout	x								x		x	x		x	x	x	x	x	x	x

The table 1 above is established to get the scenario of the traffic condition of Honiara. Even the two way lane bridge (new bridge) at the Mataniko River cause a bottle neck before and after the bridge as it holds traffic that flows to and from the four way lanes. The merging lane is unsmooth and does not continue to the end of the lane at a speed that matches to the other lane in which racing to the other end infuriates other drivers, finding a short bus route. Short bus route is a new behavioral concept currently practiced by public bus owners causing inconvenience for Honiara population today. It is in this context that the study is conducted to ease the traffic congestion of Honiara City that leads the researchers to consider axiomatic design concept to simplify the best design approach in the analysis.

2 METHOD: AXIOMATIC DESIGN AS A DESIGN TOOL

Congestion is a lot more complex than simply "too many vehicles trying to use the road at the same time," although that is certainly a major part of the problem. Congestion results from the interaction of many different factors — or sources of congestion. Congestion has several root causes that can be broken down into two main categories: 1) Too much traffic for the available physical capacity to handle, and 2) Traffic-influencing events. And congestion levels have risen in cities indicating that the transit routes are not able to keep pace with rising demand.

Identifying the complexity of which highway to be considered a new route as to ease traffic congestion is complex for Honiara City whose financial resources are limited. However, there is a simple design process popularized by Suh (1990) called axiomatic theory of design, which presents the independence and the information axioms, a theory that can explain or prescribe the design process. The axiomatic design (AD) approach provides a rational and systematic framework to help designers during the development of products, systems, and processes. AD is applied in many different fields that foresee design activities, such as this case study, modelled after Suh and shown in figure 1.

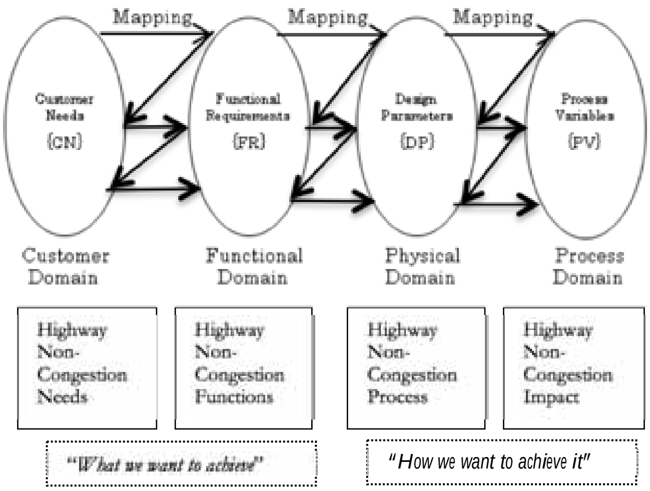

Figure 1. Axiomatic Design Study Model

Suh (1990) stressed that a good design should satisfy the independence and the information axioms. These axioms can identify a solution that fulfils the perceived needs through a mapping process between functional requirements (FRs) and design parameters (DP's). To resolve the design problem a FR-DP relations are mapped as follows: FRs-*DPs* (that describes the real condition of the system): congested-*bottleneck*, no traffic signal-*minor/major junction*, carriageway-*single/dual*, quick turnaround-*roundabout*, pedestrian-*overpass/underpass*, access to business-*commercial area*, access to historical area-*tourism*, occurrence of accident-*accident prone*, preferred/desired-*convenient*, less time travelled-*short distance to most services*, attraction-*beautiful site*, easy access to airport-*airport*, access to government agencies/school-*government services*, and access to residential-*residential blocks*.

The FRs-DPs are mapped for each highway as presented in section 2.1 of problem identification. The mapping leads to the preparation of an axiomatic design matrix for the study. According to Suh (2001), AD drives the designer through the different domains by mapping CA's, FR's, DPs and PVs, in which this process of mapping gets from a domain to the other. The CA's are first defined, then the minimum set of independent FRs are provided in line with the design goals, then DPs are mapped to satisfy the predefined FRs, and finally the PV or the plan for the product production is mapped. Each domain is decomposed into a hierarchy until the design is sufficiently detailed as shown in the figure 2.

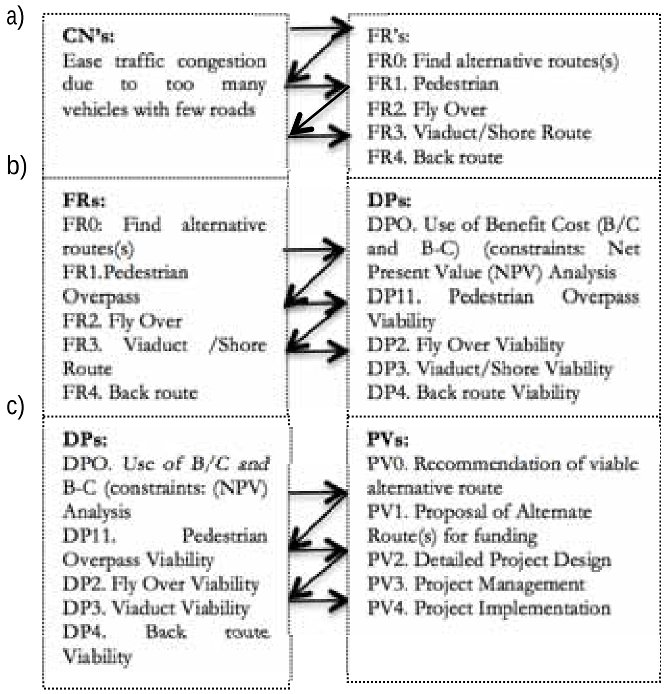

Figure 2. AD Decomposition Framework

Decomposition is a method to address the complexity of the design problem by dividing a problem into simpler sub-problems. In AD decomposition, the design decisions are made in an explicit way in order to solve the problem using the design axioms, eliminating bad ideas as early as possible to concentrate on promising ideas. The use of the independence axiom and the information axiom follows the concept of mapping and a design matrix is represented to display the relationships between FRs and DPs, as shown in figure 3. Mapping from FRs to DPs, are presented as cases to this study.

	DP1	DP2	DP3
FR1	X	O	O
FR2	X	X	O
FR3	X	O	X

Figure 3. FR-DP design matrix

2.1 PROBLEM IDENTIFICATION

Case 1. Kukum Highway

Kukum Highway	DP	bottleneck	minor junction	major junction	dual	roundabout	underpass	commercial area	tourism	Accident prone	convenient	short distance to most services	beautiful	airport	gov't services
FR	0														
congested	0	x													
no signal			x	x											
carriageway					x										
quick turnaround															
pedestrian															
access to business															
access to historical area															
occurrence of accident															
prefered /desired															
less time traveled															
attraction															
easy access to airport															
access to gov't services															
access to school															
access to residential															

Figure 4. FR-DP Mapping for Kukum Highway

Case 2. Tandai Highway

Tandai Highway	DP	bottleneck	minor junction	major junction	dual	roundabout	underpass	commercial area	tourism	Accident prone	convenient	short distance to most services	beautiful	airport	gov't services
FR	0														
congested	0														
no signal			x	x											
carriageway					x										
quick turnaround															
pedestrian															
access to business															
access to historical area															
occurrence of accident															
prefered /desired															
less time traveled															
attraction															
easy access to airport															
access to gov't services															
access to school															
access to residential															

Figure 5. FR-DP Mapping for Tandai Highway

Case 3: Mendana Highway

Figure 6. Traffic Jam at Mendana Highway

Mendana Highway FR	DP	bottleneck	minor junction	major junction	dual	roundabout	underpass	commercial area	tourism	Accident prone	convenient	short distance to most services	beuatiful	airport	gov't services
	0														
congested	0	x													
no signal			x	x											
carriageway					x										
quick turnaround						x									
pedestrian							x								
access to business								x							
access to historical area									x						
occurrence of accident										x					
prefered /desired											x				
less time traveled												x			
attraction													x		
easy access to airport														x	
access to gov't services															x
access to school															
access to residential															

Figure 7. FR-DP Mapping for Mendana Highway

The functional requirements (FR) in a FR-DP decomposition are listed along y axis and DP along x axis in figures 4, 5 and 7. Figure 6 shows a traffic jam at Mendana, and figure 7 shows that there is independence in this case. Also from observation of traffic congestion, Mendana is the most severely congested of the three highways because it traverses through the center of the City where the country's tourist office, Solomon Islands Visitors Bureau (located between the Yacht Club and the popular Solomon Kitamo Mendana Hotel), banks, major commercial establishments and government services such as government offices and schools. It also receives to and from the Roundabout transit as well as from Metaniko Bridge (figure 8).

Case 3.1: Metaniko Bridge

Figure 8. Metaniko Bridge 2-Lane exiting to Single Lane

Metaniko Bridge is a steel girder bridge with concrete decking in asphalt layered, sub-structure is concrete abutment and concrete piers. Length is approximately 80 m, width of 10 meters, and double lane. It lies along the Mendana Highway, adding the effect of congestion due to un-match exit lane to and from the bridge.

Metaniko Bridge FR	DP	bottleneck	minor junction	major junction	dual	roundabout	underpass	commercial area	tourism	Accident prone	convenient	short distance to most services	beautiful	airport	gov't services
	0														
congested	0	x													
no signal															
carriageway															
quick turnaround															
pedestrian															
access to business															
access to historical area															
occurrence of accident															
prefered /desired															
less time traveled															
attraction															
easy access to airport														x	
access to gov't services															x
access to school															
access to residential															

Figure 9. FR-DP Mapping for Metaniko Bridge

Figures 9 and 11 show strong problems of congestion. This is so because Metaniko Bridge as well as the roundabout (figure 10) runs along the Mendana Highway.

Case 3.2: Roundabout

Figure 10. Honiara Roundabout

roundabout FR	DP	bottleneck	minor junction	major junction	dual	roundabout	underpass	commercial area	tourism	Accident prone	convenient	short distance to most services	beautiful	airport	gov't services
	0														
congested	0	x													
no signal															
carriageway															
quick turnaround						x									
pedestrian															
access to business								x							
access to historical area									x						
occurrence of accident										x					
prefered /desired											x				
less time traveled												x			
attraction													x		
easy access to airport														x	
access to gov't services															x
access to school															
access to residential															

Figure 11. FR-DP Mapping for Roundabout

The roundabout has a diameter of 40 meters and has two arms, two double lane highways and three feeder networks.

Figure 12. Mendana Highway
(image source: Google map)

From figure 12, the three critical locations shown by circles are causing the congestions: 1) uncontrolled pedestrian crossing at the central market (figure 13), 2) the roundabout at the city council headquarters accommodates all two highways and three access roads, and 3) a single approaching lane to the 2-lane Metaniko Bridge (includes the new bridge) that funnels traffic into a bottleneck when approaching a 4 lane drive leading to the business area and the international airport. However, the cause of all these problems is the lack of road reserve for further expansion. Actually, there is none as of the conduct of this study. Commercial buildings and other structures occupied reserve spaces.

Figure 13. Uncontrolled pedestrian at central market

Table 2. Analysis **of Customer Needs for various** Stakeholders

Stakeholders	Customer Needs	Level
Motorists	Less vehicle operating cost, increased mobility, less frustration	Low
Passengers	Less time to commute to work/school/normal or business activities	Low
Pedestrians	Less pollution, safety on walkways used by frustrated drivers*	Low
Government/ Business	Workers arriving on time, optimum and/or increase productivity	Medium

******Normal situation in Honiara where out of frustration, motorist exploit pedestrian walkways hoping to escape congestion, compromising the safety of pedestrians using the walkways.*

2.2 THE BENEFIT COST ANALYSIS

According to Hamilton (2014, 2014b) axiomatic design (AD) provides a rational and scientific way to develop and assess design alternatives, and preemptively addresses and resolves design issues that traditionally are discovered so late that only suboptimal compromises are possible. AD allows systematic examination of multiple solutions to ease the congestion at Mendana Highway, which has two alternatives: to find new road network and cost, a problem that corresponds to 'what we want to achieve" in order to ease the traffic congestion by creating a new road network that that corresponds to 'how we can achieve it' by finding which economical route(s) is viable, as shown in figure 13.

B/C Selection	DP - Design Process	pedestrian lane w traffic light	concrete road	asphalt road	aggregate surfacing	accessibility to major areas	short route	commercial area	tourism	availability of land	budget/cost	clear view
FR-Provide Non-Congested Traffic	0											
allocate pedestrian	0	x									x	
sealed potholes			x	x							x	
find new network			x	x	x	x	x	x			x	
secure road sign								x			x	
eliminate obstruction											x	x
alloacate special lane										x	x	
Provide overpass at Central market											x	
improve roundabout											x	
Improve Metaniko Bridge											x	
Improve Kukum Highway											x	
Improve Tandai Highway											x	
Improve Mendana Highway											x	

Figure 14. FR-DP B/C Selection

The need to find solution for the design problem, the design parameter (DP) is devised to fulfill the functional requirement (FR) within the specified customer needs (CNs). It quantifies the exploration needed to satisfy the FR. Also, its result is the basis for the implementation of the project that is, if the project is a case of new road construction or new road infrastructure. Finding its viability is important, and appropriate institutions can support in the realization of the problem posed by the CNs. In this case, the authors explore Benefit-Cost Analysis (Benefit Cost Ratio and Benefit Cost Difference), with Net Present Worth (PW), as constraint inasmuch as road projects do not provide an immediate return of investment (ROI). Therefore, decision makers are reluctant to decide on pursuing the project and investors to finance new road projects. Benefit-cost analysis (BCA) is simply a rational decision-making, formal technique to keep our thinking clear, systematic and rational because our natural grasp of costs and benefits is sometimes inadequate when the alternatives are complex or the data is uncertain. Even though most trans-portation policies are local, their influence often spreads out beyond the area of implementation, such as seeking support from international entities like the Asian Development Bank (ADB) or the World Bank.

Responding to road changes, traffic will shift from the impacted part of the network to other areas, and the intensity of the shift will depend on a Cost-Benefit Analysis. Thus, quantification of the likely changes in transportation benefits and costs associated to the expansion capacity is crucial for policy planners in order to determine the net benefits from capacity expansion projects. Such information can be used in the process to select the projects that are most likely to generate the highest return to society. This design parameter is used to determine which one of the alternative route(s) is viable.

Although there are many methods to find the solution to the problem, economic indicators are strong factors in the earlier AD analysis. Also, in economic evaluation of projects, there are several commonly used economic indicators that can be placed in a final comparable format. The Benefit-Cost ratio (B/C) and (B-C) are among of those most commonly used performance measure. The B/C ratio can be calculated using the following formula,

$$B/C = \frac{\textit{Benefits} - \textit{disbenefits}\ (B)}{\textit{Cost}\ (C)} \tag{1}$$

$$B/C = \frac{\textit{Annual benefits from improvement}}{\textit{Annual cost of improvement}} \tag{2}$$

Criteria:

If the B/C Ratio is ≤ 1, reject alternative
B/C Ratio is ≥ 1, then accept alternative

And Benefit Cost Difference is calculated in the criterion as

B - C Criterion : (3)

where : B (net benefits) = overall advantage, less the disadvantage to the user

C (cost) = overall disbursement, less any savings to the investor

For the alternative to be acceptable:

The Benefit-Cost difference (B-C) between the net benefits and the net costs must be positive, that is the benefits must exceed the costs.

Boardman (2006) listed nine steps used in valuation process that comprise a generic cost–benefit analysis as follows: 1) list alternative projects/programs; 2) list stakeholders; 3) Select measurement(s) and measure all cost/benefit elements; 4) Predict outcome of cost and benefits over relevant time period; 5) Convert all costs and benefits into a common currency; 6) Apply discount rate; 7) Calculate net current value of project options; 8) Perform sensitivity analysis; and 9) Adopt the recommended choice.

2.2.1 Net Present Worth (PW)

There is a constraint in the selection of alternative route(s) that resulted from BCA because the opportunity cost today is different to that in the next future, and net present worth (NPW or PW) analysis (also called discounted cash flow techniques, DCFs) will compliment the best analysis of viability and high return of the investment.

The net present worth (PW) is the difference between the present worth of all cash inflows and outflows of a project; it is a discount rate that is used to convert future costs and benefits to present values. Since all cash flows are discounted to the present, the PW method is also known as the discounted cash flow technique. This method not only allows the selection of a single project based on the PW value but also a selection of the most economical project from a list of more than one alternative projects. To find the PW of a project, an interest rate is needed to discount future cash flows. The most appropriate value to use for this interest rate is the rate of return that one can obtain from investing the money somewhere. Alternatively, it can also be the rate that you will be charged if you had to borrow the money. The selection of this rate is a policy decision. Given the cost of the project, and given that the benefits are estimated, the net present value or worth, PW, of the project can be calculated by the equation below.

$$PW(i) = \frac{A_0}{(1+i)^0} + \frac{A_1}{(1+i)^1} + \frac{A_1}{(1+i)^2} + \cdots \frac{A_N}{(1+i)^N} \tag{4}$$

$$= \sum_{n=0}^{N} \frac{A_1}{(1+i)^N} \tag{4.1}$$

$$= \sum_{n=0}^{N} A_0 \left(\frac{P}{F}, i, n\right) \tag{4.2}$$

where PW = is the net present worth
i = interest rate
N = number of years
A_0 = initial Annuity
A_1 = first year Annuity
A_2 = second year Annuity
A_3 = third year Annuity
A_N = N^{th} year Annuity
P = Present
F = Future
n = initial year

PW Criterion:

The present worth of all cash inflows associated with an investment project is compared with the present worth of all cash outflows associated with the project.

PW(i) Decision Rule:

If PW(i) > 0, accept the alternative
PW(i) = 0, remain indifferent (5)
PW(i) < 0, reject the alternative

The PW decision rule stresses that it is not advisable to undertake projects whose NPV is less than zero, unless one is willing to 'lose money' which the authors believe to be undesirable as a means to achieve a non-financial objective.

To fully account the PW, a sensitivity analysis to account for risk is included. Risk is measurable because it refers to situations with known probabilities such as environmental damage cost and air pollution. Riabacke (2006) noted that managers defined risk as where the outcome is unknown to the decision-maker, which outcome will occur and the corresponding uncertainty that may lead to erroneous choices. Risk facing in public sector projects, such as roads, may not be independent, and the technique that can be used to accommodate risk and minimize risk in project design may be to use sensitivity analysis (SA). The values included in a cost-benefit analysis are the average estimates. Sensitivity analysis is a simple procedure for providing the decision-maker with information about the effect of errors in those estimates, as for example the cost implicated by environmental damage and cost of air pollution.

In terms of the impact on carbon dioxide emission, for example from congestion of vehicles and population increase, using environmental damage equation 6 to quantify the damage, where damage is a function (f) of three industrial and urban growth W (indicator of the degree to which culture promotes wasteful consumption of natural resources, P (population), I (index that can cause environmental damage), and D is the Environmental damage illustrated below:

$$D = f(P \times I \times W) \qquad (6)$$

Solomon Islands CO_2 emissions (World Bank, 2014) is 0.38 (2009) metric ton per capita, which in 1981 reached 0.57 metric ton per capita, with a ranked number 147 from available records out of 197 countries. The CO_2 emissions of the World bank accounts for the stemming from the burning of fossil fuels and the manufacture of cement, include CO_2 produced during consumption of solid, liquid and gas flaring, but the current CO_2 emission produced by congestion is not accounted for. The value of cleaner air is another aspect which the public consider as valuable. According to World Bank (2014) health expenditure per capita of Solomon Islands is 133.99 US $ (2011) and ranked 125 out of 186 countries. Also, the record does not account the expenditure for 2012-2014.

An air pollution cost can be calculated by the equation (EPA, 2002)

$$C_{air} = Q\,(0.01094 + 0.2155\,F) \qquad (7)$$

where:

$$F = 0.0723 - 0.00312Vf + 5403 \times 10^{-5}\,V^2 \qquad (7.1)$$

F = fuel consumption at cruising speed (gl/mile)
V = average speed (mph)
Q = volume (veh/hr)

The fuel consumed is related to the average speed (or travel time) and to quantify the energy use, the following equation is considered:

$$F = k_1 + k_2T \qquad (8)$$

$$F = k_1 + \frac{k2}{v} \qquad (8.1)$$

where,

F = Fuel consumed per vehicle per unit distance (l/km), T = Travel time per unit distance, including stops and speed changes (minutes/km), v = Av. speed measured over a distance including stops and speed changes ($10 \leq v \leq 56$ km/h), k_1 = parameter associated with fuel consumed to overcome rolling resistance, approximately proportional to vehicle weight (l/veh-km),

k_2 = Parameter approximately proportional to fuel consumption while idling (l/h).

Fuel consumption is high for lower speeds and minimum for intermediate speeds. Moreover, fuel consumption increases as the number of stops of the vehicle increases.

3 ALTERNATIVE ROUTES

The alternatives in the case of Mendana Highway congestion are chosen in consultation with the Government of Solomon Islands, as the government owns the land so there is no problem with the acquisition as well as surveying the population of the country using formal and informal interviews. Among those considered alternative route(s) are: Mendana Highway rehabilitation/expansion by a flyover, pedestrian overpass, back-route and viaduct at shore-route.

Network assumptions for calculation of cost and benefits are presented in table 2.

Table 2. Network Assumptions

Network Assumptions	**Measurement** quality	Base Case/Alternative
Volume	Number of vehicles/unit time	5,763.00
	Number of pedestrians or cyclists/unit time	5,325.00
Speed, Delay	Time, distance, speed (time/unit distance)	<10 min., @60km/h
Growth rate	Growth rate in %	0.35
Inventory Generation	Vehicle type class	Bicycle, motorcycle, saloon car, 4WD, bus, truck
	Type of users	Elder, child, disabled, adult
Congestion	Time per vehicle	0.069-0.041 h
Duration	Days per year	260
Traffic usage Time	Use, mean duration, turnover rate	16
Travel time run	Travel time run	2 h
Safety	Fatal collision rate, injury collision rate, property damage only rate	0.23, 20, 40
Environmental Factors	Noise: dB (A, B, C) scales, L10, L50, Leq	4 dB
	Air pollution: concentration per unit volume (ppm), air temperature, wind speed	3 ppm, 28°C (84 °F); 0.45 m/s

The benefit and cost is analyzed under the criterion of the constraint PW, as well as the Benefit Cost (B/C, & B-C). The result is tossed to the FRs for mapping if it satisfies and tossed back to PVs to support the solution of the problem. The summary of Benefit Cost analysis for a 20-year period is presented in tables 3 and 4. The currency of the Solomon Islands was converted to USD at the rate of 1 USD = 7.25 SBD (Solomon Bokolo Dollar), as of July 29, 2013.

Table 3. Benefit & Cost of Alternative Route(s)

Alternate Route**(s)**	**Length (km)**	**Benefit** (Million **USD**)	**Cost** (Million **USD**)
Back route Road	12.0	53.76	89.6
Shore Route Road	1.50	27.06	23.8
Shore-Viaduct	1.50	82.79	69.85
Flyover	0.75	56.22	55.12
Pedestrian overpass	0.25	13.75	11.85

Table 4. Benefit Cost Analysis

Alternate **Route**	**PW** (USD in Million)				**B/C**	**B-C**
	7%		**3%**			
		SA		**SA**		
Shore Route	1.70	8.17	13.47	18.15	1.14	3.26
Back route	-59.19	-15.76	-50.40	-6.71	0.60	-35.84
Shore-Viaduct	-41.34	-9.59	72.2	-0.34	1.18	12.94
Flyover	-29.33	1.52	-20.80	12.67	1.02	1.10
Pedestrian overpass	3.29	13.78	13.29	23.97	1.16	1.90

The PW greater than zero is the most suitable criterion, the B/C ratio greater than 1 being the best alternative if B-C is positive. From the result of the Benefit Cost Analysis, two alternative route(s) comes up that best fit to the criterion rules: the shore route, and pedestrian overpass. In this case, the same procedure was applied to map the one that best solve the base case. After all the required possibilities are considered, one will map again to PV for system production.

4 CONCLUSION

The Axiomatic Design concept combined with Benefit-Cost Analysis is pretty suitable for the analysis of which alternative route is the best option. On the one hand, Benefit-Cost Analysis is useful for studying the viability of the alternative solutions. On the other hand, Axiomatic Design helps in the iterative process of narrowing down the existing alternatives.

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