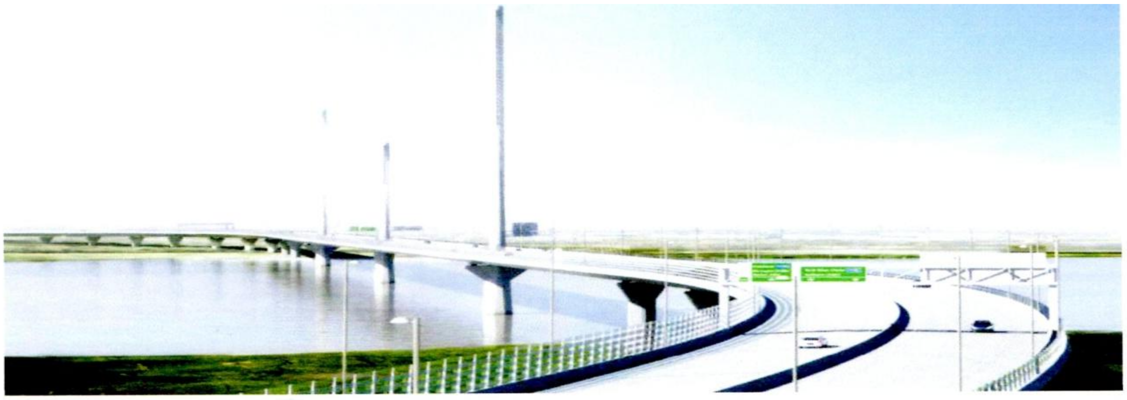
Incentive Collars for Mersey Gate Bridge[1]



The Mersey Gate Bridge promoted by the Halton Borough Council (HBC) is a public-“private” partnership (“PPP”) project partly financed by tolls. There will be a six-lane cable-stayed toll bridge over the River Mersey, supplementing the existing Silver Jubilee Bridge (SJB) (currently toll-free but congested), linking the separate HBC towns of Widnes and Runcorn. The total capital costs are estimated to be £600 million spread over four years, with a project lifetime of over 30 years. Annual operating and maintenance costs are possibly around 5% of the operating revenue.

Thousands of pages have been published on this project, including the Inspector’s Report from the Public Inquiry (2009) (Alan Gray), the MacDonald (2009) MGTM report on estimating traffic for both the MGB and SJB after 2017, the expected opening date for the MGB, an alternative appraisal by Castles and Parish, supported by the Campaign for Better Transport

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[1]© This case was prepared by Dean A. Paxson for purposes of class discussion and student coursework only, and not as an illustration of either good or bad business practices. The model is based on parts of “Real PPP Investment with Collar Options” presented at the Real Options Conference in Trondheim June 2016, by Roger Adkins and Dean Paxson, and uses as purely illustrative examples material from MG Inspector’s Report (2009), the MacDonald (2009) report, and Castles and Parish on MGB. Since this paper extracts from those documents, and typically simplifies and/or amends the figures, often based on strict assumptions, it should not be used as a representation of those documents or opinions, or as the basis for investment decisions. Alliance Manchester Business School, Booth St West, Manchester, M15 6PB, UK. dean.paxson@mbs.ac.uk

(2010), and a financial analysis by KPMG which has not been publically released by the HBC or the UK government. However, it is apparent that the arrangements with the concessionaire (Merseylink Ltd., owned by BBGI (Luxemburg), Macquarie Capital (Australia) (associated with Macquarie financial advisors to the project), and FCC Construccion (Spain) (one of the bridge construction firms) involve: (a) a capital support from the UK government of £XXX, (b) a 29 year fixed 3.842% rate bond guaranteed by the UK government of £257 million and (c) a minimum revenue guarantee also from the UK government. It is not clear that all of the details of the revenue guarantee have been completely disclosed. The National Audit Commission (2015) reviewed some of these arrangements. Of the “unguaranteed” finance, £55m is apparently from equity, £50m in Mezzanine debt, £102m in short-term loans to be repaid in 2017, and £143m in bank debt to be repaid in 2032.

A primary uncertainty for the project is the traffic projected for each bridge, each year. Without allowing for any concessionary tolls for local and regular users, Castle and Parish projected revenue as follows (£ millions) based on a tariff for the Mersey Tunnel of £1.40/car:

	2015	2020	2025	2030	Traffic[2] 2015	2030
MGB	31479	34586	37692	40797	61	78
SJB	7897	8591	9285	9980	13	16

Without subsidies or guarantees, gross revenues might be 8.5% annualized in 2030 of the original investment cost. Mr. Alan Gray (the Inspector) reported in 2009 that he was satisfied about the commercial viability of this project.

PPP with Collar Model

For a firm in a monopolistic situation confronting a single source of uncertainty due to revenue[3] variability, and ignoring operating costs and taxes, the investment in an irretrievable project at

[2] Forecast traffic flows are 78,000 vehicles per weekday for MG and 16,000 for SJB in 2030, compared to 94,286 for SJB currently in 2015, which were toll free. Tolls are to be imposed on both bridges after 2017, with possible exemptions for HBC residents.

[3] The Adkins & Paxson (2016) model has been altered to involve net revenue (R) uncertainty, for toll roads with stochastic traffic (Q) and tolls (P), where R=P*Q.

cost K depends on the revenue evolution, which is specified by the geometric Brownian motion process:

$$\mathrm{dR} = \alpha R \mathrm{d}t + \sigma R \mathrm{d}W \tag{1}$$

where α denotes the expected revenue risk-neutral drift, σ the revenue volatility, and $\mathrm{d}W$ an increment of the standard Wiener process.

1.1 Real Collar Option

A collar option is designed to confine the revenue for an active project to a tailored range, by restricting its value to lie between a floor level R_L and a cap level R_H. Whenever the R trajectory falls below the floor, the received R is assigned the value R_L, and whenever it exceeds the cap, it is assigned the value R_H. By restricting the R to this range, the firm is benefiting from receiving an R that never falls below R_L and is obtaining protection against adverse revenue movements, whilst at the same time, it is being forced never to receive revenue exceeding R_H thus sacrificing the upside potential. Protection against downside losses are mitigated in part by sacrificing upside gains. Using contingent claims analysis, for an active project, the revenue accruing to the firm is given by $\pi_C\left(R\right) = \min\left\{\max\left\{R_L, R\right\} R_H\right\}$ and its value V_C is described by the risk-neutral valuation relationship:

$$\tfrac{1}{2}\sigma^2 R^2 \frac{\partial^2 V_C}{\partial R^2} + \left(r - \delta\right) R \frac{\partial V_C}{\partial r} - rV_C + \pi_C\left(R\right) = 0\,. \tag{2}$$

where $r > \alpha$ denotes the risk-free interest rate and $\delta = r - \alpha$ the rate of return shortfall, or net asset yield. The generic solution to the option part of (2) is:

$$V\left(R\right) = A_1 R^{\beta_1} + A_2 R^{\beta_2} \tag{3}$$

where A_1, A_2 are to be determined generic constants and β_1, β_2 are, respectively, the positive and negative roots of the fundamental equation, which are given by:

$$\beta_1, \beta_2 = \left(\tfrac{1}{2} - \frac{r-\delta}{\sigma^2}\right) \pm \sqrt{\left(\tfrac{1}{2} - \frac{r-\delta}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} \quad (4)$$

In (3), if $A_2 = 0$ then Vis a continuously increasing function of R and represents an American perpetual call option, Samuelson (1965), while if $A_1 = 0$ then it is a decreasing function and represents an American put option, Merton (1973).

The valuation of a with-collar active project is conceived over three mutually exclusive exhaustive regimes, I, II and III, specified on the R line, each with its own distinct valuation function. Regimes I, II and III are defined by $R \le R_L$, $R_L < R \le R_H$ and $R_H \le R$, respectively. Over Regime I, the firm is granted a more attractive fixed R_L compared with the variable price R, but also possesses a call-style option to switch to the more favorable Regime II as soon as R exceeds R_L. This switch option increases in value with R and has the generic form AR^{β_1}, where A denotes a to be determined generic coefficient. Over Regime III, the firm is not only obliged to accept the less attractive fixed revenue R_H instead of R but also has to sell a put-style option to switch to the less favorable Regime II as soon as R falls below R_H. This switch option decreases in value with R and has the generic form AR^{β_2}. Over Regime II, the firm receives the variable revenue R, possesses a put-style option to switch to the more favorable Regime I as soon as R falls to R_L, but sells a call-style option to switch to the less favorable Regime III as soon as R attains R_H. The various switch options are displayed in Table 1, where A denotes a generic coefficient.

Table 1: The Various Switch Options

From - To	**Option Type**	**Value**	**Sign of** A
I - II	Call	AR^{β_1}	+
II - I	Put	AR^{β_2}	+

II - III	Call	AR^{β_1}	-
III - II	Put	AR^{β_2}	-

If the subscript C denotes the with-collar arrangement, then after paying the investment cost, the valuation function for the firm managing the active project is formulated as:

$$V_C\left(R\right)=\begin{cases}\dfrac{R_L}{r}+A_{C11}R^{\beta_1} & \text{for R} < R_L\\ \dfrac{R}{\delta}+A_{C21}R^{\beta_1}+A_{C22}R^{\beta_2} & \text{for R}_L \le R < R_H\\ \dfrac{R_H}{r}+A_{C32}R^{\beta_2} & \text{for R}_H \le R.\end{cases} \tag{5}$$

In (5), a coefficient's first numerical subscript denotes the regime $\left\{1=I,2=II,3=III\right\}$, while the second denotes a call if 1 or a put if 2. The coefficients A_{C11}, A_{C22} are expected to be positive because the firm owns the options and a switch is beneficial. In contrast, the A_{C21}, A_{C32} are expected to be negative because the firm is selling the options and is being penalized by the switch. The real collar is composed of a pair of both call and put options. The first pair facilitates switching back and forth between Regimes I and II, which results in the firm being advantaged, while the second pair facilitates switching back and forth between Regimes II and III, which results in the firm being disadvantaged. The real collar design differs from the typical European collar, which only involves buying and selling two distinct options.

A switch in either direction between Regimes I and II occurs when $R=R_L$. It is optimal provided the value-matching relationship:

$$\frac{R_L}{r}+A_{C11}R^{\beta_1}=\frac{R}{\delta}+A_{C21}R^{\beta_1}+A_{C22}R^{\beta_2} \tag{6}$$

and its smooth-pasting condition expressed as:

$$\beta_1 A_{C11}R^{\beta_1}=\frac{R}{\delta}+\beta_1 A_{C21}R^{\beta_1}+\beta_2 A_{C22}R^{\beta_2} \tag{7}$$

both hold when evaluated at $R = R_L$. Similarly, a switch in either direction between Regimes II and III occurs when $R = R_H$. It is optimal provided the value-matching relationship:

$$\frac{R}{\delta} + A_{C21}R^{\beta_1} + A_{C22}R^{\beta_2} = \frac{R_H}{r} + A_{C32}R^{\beta_2} \tag{8}$$

and its smooth-pasting condition expressed as:

$$\frac{R}{\delta} + \beta_1 A_{C21}R^{\beta_1} + \beta_2 A_{C22}R^{\beta_2} = \beta_2 A_{C32}R^{\beta_2} \tag{9}$$

both hold when evaluated at $R = R_H$. This reveals that:

$$\begin{aligned} A_{C11} &= \left[\frac{R_H}{R_H^{\beta_1}} - \frac{R_L}{R_L^{\beta_1}}\right] \times \frac{\left(r\beta_2 - r - \delta\beta_2\right)}{\left(\beta_1 - \beta_2\right)r\delta} > 0,\ A_{C21} = \frac{R_H\left(r\beta_2 - r - \delta\beta_2\right)}{R_H^{\beta_1}\left(\beta_1 - \beta_2\right)r\delta} < 0, \\ A_{C22} &= \frac{-R_L\left(r\beta_1 - r - \delta\beta_1\right)}{R_L^{\beta_2}\left(\beta_1 - \beta_2\right)r\delta} > 0,\ A_{C32} = \left[\frac{R_H}{R_H^{\beta_2}} - \frac{R_L}{R_L^{\beta_2}}\right] \times \frac{\left(r\beta_1 - r - \delta\beta_1\right)}{\left(\beta_1 - \beta_2\right)r\delta} < 0. \end{aligned} \tag{10}$$

The signs of the four option coefficients comply with expectations. Other findings can also be derived. The coefficient A_{C22} for the option to switch from Regimes II to I, which depends on only R_L and not on R_H, increases in size with R_L. This switch option becomes more valuable to the firm as the floor level increases. Similarly, the coefficient A_{C21} for the option to switch from Regimes II to III, which depends on only R_H and not on R_L, decreases in magnitude with R_H. This switch option becomes less valuable to the government as the cap level increases. The coefficients A_{C11} and A_{C32} for the switch option from Regimes I to II and from Regimes III to II, respectively, depend on both R_L and R_H.

1.2 Revenue Floor Model

We use the additional subscript f to indicate a model with only a floor. From (5) the active project valuation function becomes:

$$V_{Cf}\left(R\right)=\begin{cases}\dfrac{R_L}{r}+A_{Cf11}R^{\beta_1} & \text{for R} \leq R_L \\ \dfrac{R}{\delta}+A_{Cf22}R^{\beta_2} & \text{for R}_L \leq R,\end{cases} \tag{11}$$

with: $$A_{Cf11}=\frac{-R_L\left(r\beta_2-r-\delta\beta_2\right)}{R_L^{\beta_1}\left(\beta_1-\beta_2\right)r\delta}\geq 0,\ A_{Cf22}=\frac{-R_L\left(r\beta_1-r-\delta\beta_1\right)}{R_L^{\beta_2}\left(\beta_1-\beta_2\right)r\delta}\geq 0. \tag{12}$$

Numerical Illustrations

Suppose the current net revenue is 6 with a volatility of 25%, no operating costs, instantaneous construction cost is 100, and r=δ=4%. With only a floor guarantee using (11), the ROV=150+29.98=179.98. If the government guarantees in perpetuity a R=4, with a cap of 10, the ROV of operating such a perpetual activity is (5), while the present value is R/δ =150. With a collar, the ROV=150-41.61 call plus 29.98 put=138.37.These results are very sensitive in changes in most of the parameter values.

	A	B	C	D
1			**ACTIVE PPP WITH FLOOR OPTION**	
2	**INPUT**			EQ
3	R	6.00		
4	K	100.00		
5	σ	0.25		
6	r	0.04		
7	δ	0.04		
8	R_L	**4**		
9				
10	**OUTPUT**			
11	VCf	**179.9818**	**IF(B3<$B$8,$B$8/B6+B14*(B3^B12),B3/B7+B15*(B3^B13))**	11
12	β_1	1.7369	0.5-(B6-B7)/(B5^2)+SQRT(((B6-B7)/(B5^2)-0.5)^2 + 2*B6/(B5^2))	4
13	β_2	-0.7369	0.5-(B6-B7)/(B5^2)-SQRT(((B6-B7)/(B5^2)-0.5)^2 + 2*B6/(B5^2))	4
14	ACf11	3.63821	(-B8*(B6*B13-B6-B7*B13))/B16	12
15	ACf22	112.28	(-B8*(B6*B12-B6-B7*B12))/B17	12
16	[ ]	0.04398	(B8^B12)*(B12-B13)*B6*B7	12
17	( )	0.00143	(B8^B13)*(B12-B13)*B6*B7	12

	A	B	C	D
1			**ACTIVE PPP WITH COLLAR**	
2	**INPUT**			EQ
3	R	6.00		
4	K	100.00		
5	σ	0.25		
6	r	0.04		
7	δ	0.04		
8	R_L	**4**		
9	R_H	**10**		
10	**OUTPUT**			
11	VC	**138.3688**		5
12	VC PV	**150.0000**	**IF(B3<$B$8,$B$8/B6,IF(B3>$B$9,$B$9/B6,B3/B7))**	5
13	R/δ	150.0000	B3/B7	
14	β_1	1.7369	0.5-(B6-B7)/(B5^2)+SQRT(((B6-B7)/(B5^2)-0.5)^2 + 2*B6/(B5^2))	4
15	$\beta 2$	-0.7369	0.5-(B6-B7)/(B5^2)-SQRT(((B6-B7)/(B5^2)-0.5)^2 + 2*B6/(B5^2))	4
16	AC11*R^β1	**40.1361**	**B21*(B3^B14)**	5
17	AC21*R^β1	**-41.6129**	**B22*(B3^B14)**	5
18	AC22*^β2	**29.9818**	**B23*(B3^B15)**	5
19	AC32*R^β2	**-117.2670**	**B24*(B3^B15)**	5
20	VC	138.3688	B12+B17+B18	
21	AC11	1.7862	($B$9/($B$9^B14)-$B$8/($B$8^B14))*(B25/B27)	10
22	AC21	-1.8520	($B$9/($B$9^B14))*(B25/B27)	10
23	AC22	112.2797	(-$B$8/($B$8^B15))*(B26/B27)	10
24	AC32	-439.16	($B$9/($B$9^B15)-$B$8/($B$8^B15))*(B26/B27)	10
25	[ ]	-0.0400	(B6*B15-B6-B7*B15)	10
26	( )	-0.0400	(B6*B14-B6-B7*B14)	10
27	{ }	0.0040	(B14-B15)*B6*B7	10
28				
29	ODE	0.0000	0.5*(B5^2)*(B3^2)*B31+(B6-B7)*B3*B30-B6*B11+MIN(MAX($B$8,B3),$B$9)	2
30	VC Δ	9.2711		
31	VC Γ	-0.4136		
32	VC	IF(B3<$B$8,$B$8/B6+B21*(B3^B14),IF(B3>$B$9,$B$9/B6+B24*(B3^B15),B3/B7+B22*(B3^B14)+B23*(B3^B15)))		
33	VC Δ	IF(B3<$B$8,B14*B21*(B3^(B14-1)),IF(B3>$B$9,B15*B24*(B3^(B15-1)),1/B7+B14*B22*(B3^(B14-1))+B15*B23*(B3^(B		
34	VC Γ	IF(B3<$B$8,B14*(B14-1)*B21*(B3^(B14-2)),IF(B3>$B$9,B15*(B15-1)*B24*(B3^(B15-2)),B14*(B14-1)*B22*(B3^(B14-2))+B15*(B15-1)*B23*(B3^(B		

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By evaluating numerically an actual toll road concession involving both a guarantee and penalty, Rose (1998) shows that the government guarantee contributes significant value to the project because returns are conserved at a minimum level. This is replicated using an alternative formulation by Alonso-Conde et al. (2007), who show that this guarantee not only acts as an incentive but also has the potential of generously transferring significant value to the investor. Brandão and Saraiva (2008) evaluate the real option value of a minimum traffic guarantee combined with a limit on government exposure, using a Monte Carlo simulation. Shan et al. (2010) value sharing of revenue risks in transportation, which involve European collars of a revenue guarantee and upside compensation to the government. Carbonara et al. (2014) evaluate the real option value of revenue guarantee for a toll road project, also using a Monte Carlo simulation.

Besides these numerical investigations, there are two key analytical studies. Takashima et al. (2010) design a PPP deal involving government debt participation that incorporates a floor on the future maximum loss level where the investor has the right to sell back the project whenever adverse conditions emerge. Using an analytical model, they show the effect of such deals on the investment timing decision. Also, Armada et al. (2012) make an analytical comparison of various subsidy policies and a demand guarantee scheme to reveal their differentiated qualities.

Not all of these authors investigate the incentives for the concessionaire, for instance to control construction costs, or operate just short of the level that triggers the upside option, or reduce the project volatility by hedging or issuing risk sharing debt instruments. According to Shaoul et al. (2012), UK transportation PPPs are expensive and have failed to deliver value for public money. Various National Audit Commission (2014, 2015) reports have not provided contrary evidence, or periodic valuations of the UK government options in the various PPP arrangements.

Excel MGB Template

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	MGB TEMPLATE																																		
2	**INPUT**	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
3	Year	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
4	K	-150	-150	-150	-150	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6
5	NR (PQ-C)					31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
6	Q					23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
7	σ	0.20																																	
8	r	0.04																																	
9	δ	0.04																																	
10	OpCost	0.05																																	
11	Inflation Rate	0																																	
12	Initial Q per weekday	76.67																																	
13	Days	250																																	
14	Adjust weekend	1.2																																	
15	Initial Toll	2																																	
16	Shadow Toll	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Q Growth	0																																	
18	Non-Exempt	0.7																																	
19	**OUTPUT**																																		
20	GPV	$529																																	
21	PV (K)	($544)																																	
22	NPV	($16)																																	
23	IRR	2.69%	Solver: B23=5%, Change B16																																
24	R Per Annum	21.16																																	
25	NR (PQ-C)	F6*($B$15+$B$16)*((1+$B$11)^F3)*(1-$B$10)*$B$18																																	
26	Q	MIN($B$12*$B$13*$B$14*((1+$B$16)^F3)/1000,180)																																	
27																																			
28	INSTRUCTIONS FOR USE																																		
29	K	B4:E4	Investment cost spread over four years. F4:AI4 NR from operations.																																
30	NR	F5:AI5	see B25, approximates NCF from operations, allows for changes in parameter values, especially % exempt from tolls. Default assumes no Q growth, 30% exempt.																																
31	Q	F6:AI6	see B26, approximates annual traffic, allows for changes in initial and Q growth, adjustment for weekend traffic, maximum traffic twice the SJB maximum.																																
32	GPV	NPV(B8,B5:AI5)			NPV of operational cash flows, discounted at r.																														
33	PV (K)	NPV(B8,B4:E4)			NPV of investment cost, discounted at r.																														
34	NPV	B20+B21			NPV of all cash flows, discounted at r.																														
35	IRR	IRR(B4:AE4)			IRR of all cash flows. When IRR low use Solver: B23=5%, Change B16,to determine the shadow tolls *Q*B18 paid to concessionaire for Min IRR=5%.																														
36	R Per Annum	B20*B9			Annual equivalent perpetual R that would result in GPV discounted at δ.																														

This spreadsheet illustrates a method for determining the IRR of a project like the MGB allowing for the investment cost to be spread over the first four years, and the project net cash flows projected over the next 30 years. The inputs are assumed to be the approximate weekday traffic for both bridges forecast by Castle and Parish (2010) with adjustments for weekend traffic, an initial toll of 2 pounds, no traffic growth and 30% of the traffic exempt from tolls. The result is a 2.7% internal rate of return for the concessionaire. Using the same base case assumptions what is the “shadow toll” supplied by the government to the concessionaire that results in an IRR=5%. The base case assumes no traffic growth or increase in tolls (at the rate of inflation) over the life of the project, or any reimbursement of the investment cost by the government.

MGB Case Questions:

1. What is the gross (and also net) present value (GPV) in 2012 of the apparent MGB project, stating your reasonable assumptions, including a 1.6% growth in traffic and inflation adjustment for tolls, with a termination 30 years from 2017, with both a net asset yield and discount rate of 4%?
2. Assuming toll exemptions are either 0% or 30% of expected traffic, and traffic has an annualized volatility of 10%, what is the real option value (government liability) of a possible MGB arrangement of a guaranteed revenue of $R=GPV*\delta$ million starting in 2017 compared to a collar (floor of IRR=5% and ceiling of IRR=15%)?
3. How sensitive are your answers to (1) and (2) to increase/decrease in the rate of traffic growth to +3% or -3%, and also to increases/decreases in the traffic volatility to 20% or 0.
4. What are the costs and benefits of a PPP Collar, or alternatively a Floor only, arrangement for the concessionaire (rewards and incentives) and for the government, and advantages/disadvantages of the perpetual real option method compared to net present values?