IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Investment Decision Planning In Road Network Using Database

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Abstract: Highway infrastructure plays a crucial role for national and regional economic growth, by making accurate investment by evaluating the essential. This study compares 27 road stretches in Meghalaya using four frameworks—Cost–Benefit Analysis (CBA), System Dynamics Modelling (SDM), HDM-4, and the Hybrid Annuity Model (HAM)—based on NPV, IRR and payback period. Results show that CBA and HDM-4 provide consistent, standards-aligned assessments of economic viability, while HAM offers strong financial stability under the PPP structure with balanced risk and reliable annuity returns. Although SDM provides dynamic insights, it tends to overestimate IRR and is less reliable for final decisions. Overall, the analysis identifies HAM as the most feasible and sustainable investment option, offering balanced economic performance, financial security, and a practical payback period of about 4–8 years.

Index Terms – Highway Investment, Payback Period, Rate of Returns.

I. INTRODUCTION

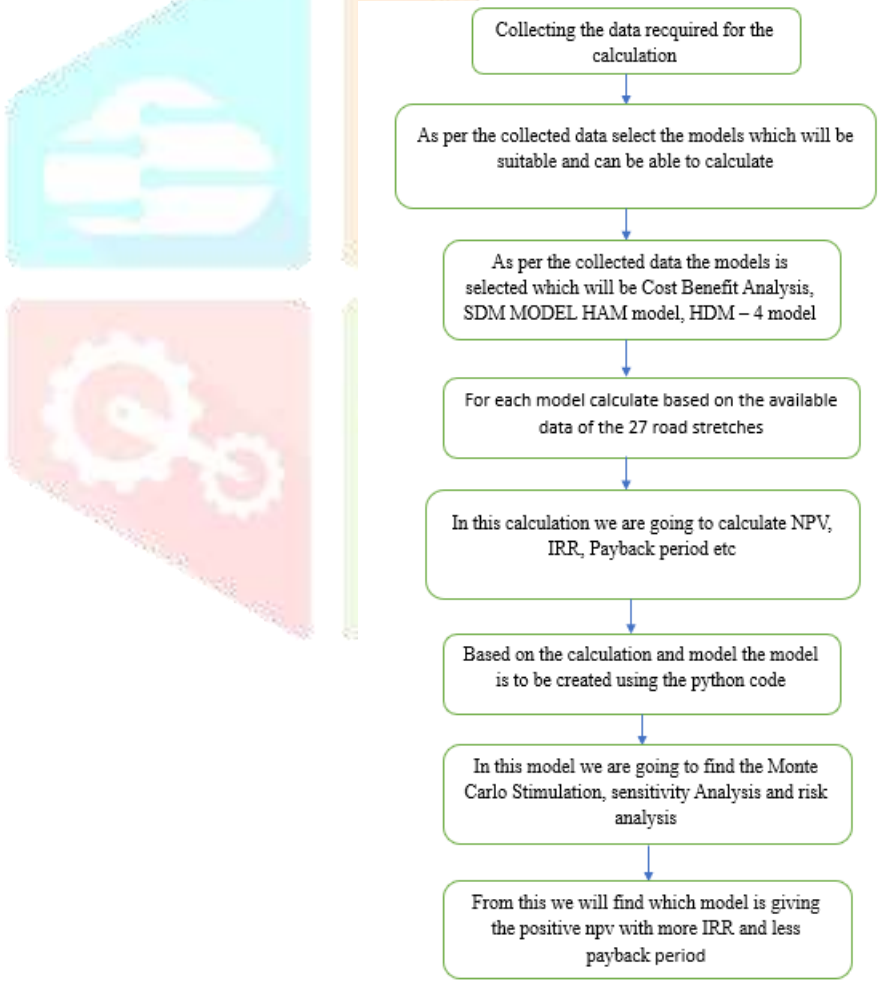
Highway infrastructure is the backbone of the transportation between the states and regional connectivity, by which it will reduce the travel time and vehicle operating costs while promoting economic and social development. Since highway construction requires large amount of investments involving both public and private sectors, through which by selecting the most suitable evaluation model is essential for long-term sustainability. In India, IRC and MoRTH recommend economic indicators such as NPV, IRR, and Payback Period, and modern PPP frameworks like the Hybrid Annuity Model (HAM) have strengthened risk-sharing and financial stability. Among analytical tools, Cost–Benefit Analysis (CBA), System Dynamics Modelling (SDM), and HDM-4 provide structured methods to assess economic and financial feasibility, with SDM offering dynamic feedback-based insights though it may overestimate IRR without cross-validation.

This study evaluates 27 road stretches across Meghalaya using four key approaches—CBA, SDM, HDM-4, and HAM—to identify the most effective and sustainable investment option. While CBA and HDM-4 deliver realistic and IRC-compliant feasibility assessments, SDM captures dynamic interactions among traffic growth, costs, and revenues, and HAM ensures balanced risk distribution and steady returns within the PPP structure. The other models like EPC, BOT, and BOT-Annuity are not included, as they are primarily addresses the contractual and implementation aspects rather than economic evaluators. Overall, within this the four selected models offers a comprehensive basis for comparing NPV, IRR, and Payback Period, which supports the reliable decision-making for highway in investment planning process.

II. LITERATURE REVIEW

The study by **B. Čutura, G. Mladenović, B. Mazić, and I. Lovrić** used this HDM-4 model which prioritize the maintenance for the deteriorated road sections in the Herzegovina–Neretva Canton, showing that even though the most low-traffic road stretches produce the negative NPVs and IRRs, systematic HDM-4–based planning can still efficiently improve the conditions under the limited budgets. In northern Italy, **Ilaria Henke, Armando Cartenì, and Luigi Di Francesco** developed a sustainable evaluation framework combining Cost–Benefit Analysis (CBA), Multi-Criteria Analysis (MCA), and stakeholder participation, demonstrating that while both CBA and MCA identified the same best highway alternative, CBA undervalued environmental and social benefits that MCA captured more effectively, underscoring the need for integrated decision tools in sensitive regions. Complementing these, **Rajaa Alasad and Stephen O. Ogunlana** proposed a System Dynamics (SD) modelling process emphasizing stakeholder-driven development of Causal Loop Diagrams to capture the complex, dynamic interactions influencing transport demand. Meanwhile, **Nissar A. Jamadar, Satish Deshmukh, and Suraj C. Tandale** developed a Hybrid Annuity Model (HAM) financial risk framework using NPV analysis and Monte Carlo simulation, revealing high sensitivity to construction cost risks and highlighting the importance of incorporating uncertainty analysis for PPP-based highway investments. Together, these studies illustrate how HDM-4, CBA–MCA integration, SD modelling, and HAM risk analysis collectively strengthen the economic, financial, social, and dynamic foundations of sustainable transportation decision-making.

III. METHODOLOGY



The process begins with collecting all necessary data for the 27 road stretches and selecting suitable evaluation models, including Cost–Benefit Analysis (CBA), System Dynamics (SDM), the Hybrid Annuity Model (HAM), and HDM-4. Using the available data, each model is applied to calculate key economic indicators such as NPV, IRR, and Payback Period. These calculations are then implemented through Python-based modelling to enable further analysis. The Python model is used to perform Monte Carlo simulation, sensitivity analysis, and risk assessment to understand uncertainties and their impact on project outcomes. Finally, the results from all models are compared to identify which approach provides the most favorable investment decision—specifically, the model that offers a positive NPV, higher IRR, and a shorter payback period.

IV. EXPERIMENTAL ANALYSIS

As per the above studies in this studies we have considered four analytical models like CBA, SDM, HAM, and HDM-4 are thoroughly examined to completely evaluate the economic and financial feasibility of highway infrastructure. Each model offers a distinct perspective on investment assessment, and this studies compares their applicability, sensitivity, and effectiveness in analyzing the project sustainability, financially viability, and the long-term economic impact.

Cost-Benefit Analysis (CBA): The CBA model assesses highway projects by comparing total costs with expected benefits over time, using factors such as traffic volume, vehicle operating costs, travel time savings, accident reduction, and maintenance costs. Through the discounted cash flow analysis the evaluation of the NPV, BCR, and IRR through which it provides a clear view of economic basis for the selection of project and also it helps to prioritize the investments that yield the highest net benefits.

System Dynamics Model (SDM): The SDM model analyze how technical, financial, and economically variables can be calculated in highway projects by adjusting factors such as traffic growth, toll revenue, O&M costs, and discount rates to analyze which variable will impact more on the NPV. Through the sensitivity and scenario analyses, it reveals how the behavior of the parameters will effect on the investments under varying economic and financial conditions, helping policymakers understand the effects and assess long-term project sustainability. And this calculation is done as per by taking reference from this (Nida Fariza Maulanisa et.al 2024) using this I have calculated but through the python code i have one the calculation like sensitivity analysis, risk analysis.

Hybrid Annuity Model (HAM): The HAM model was evaluated as a PPP framework by allocating 40% of project cost as government support and 60% as private investment, recovered through semi-annual annuity payments. Using inputs such as construction cost, annuity amounts, and O&M expenses, the analysis demonstrates how HAM balances government and private-sector efficiencies while reducing investor financial risk and ensuring accountability in project performance.

Highway Development and Management Model (HDM-4): The HDM-4 model was used to evaluate highway alternatives over their life cycle by analyzing pavement performance, maintenance strategies, and traffic forecasts. And in this calculation i have not used the software of hdm-4 model I have done the calculation in excel (Pratiksha. R. Patil et.al 2020) It estimated key parameters such as VOC, RUC, and roughness to compute NPV, IRR, and BCR, enabling comparison of do-nothing, rehabilitation, and upgrading options. The results identified the most cost-effective strategy, showing that HDM-4 effectively links engineering performance with economic outcomes and is well suited for long-term investment planning in line with IRC-recommended practices.

V. RESULTS AND DISCUSSIONS

COST BENEFIT ANALYSIS MODEL

Sl No	Road Stretches	Type of Road	Type of Analysis	Excel Based NPV (in Lakh)	Recommended NPV (in Lakh)	Recommended IRR , %	Recommended Payback Period (years)
1	Road stretch : Sonkanong - Mawten	MDR	Economic	–61,911	–61,911	25.00	5
			Financial	42,229	42,229	13.8	7.2
3	Road Stretch : Selsella - Chibragre	MDR	Economic	-398,935	+198,935.0	25.0	5
			Financial	2,28,347	2,28,347	15.58	12
4	Road Stretch ; Shillong – Dawki	NH	Economic	-663,800	+663,800	25	4
			Financial	837,037	837,037	17.5	7

5	Riangdo – Athiabari	SH	Economic	-181,780.46	+181,780	20	6
			Financial	-6,276	3245	8.5	5
6	Warangre – Kimbaldam	SH	Economic	-118,921.45	118,921	12.0	9
			Financial	437,249	524,699	18.6	9
7	Rongram Phulbari (RP) Road	SH	Economic	-1,003,826	1,003,826	16	8
			Financial	-1,196,741	1,316,415.10	18.0	7
8	Barengap?ra, Dalu- Rongram	NH	Economic	-1,778.93	+94,456	7.5	4
			Financial	631,163	631,163	33.5	1.2
9	Tura - Danakgre, Anggalgre, Harigaon, Goramara – Garobadha	SH	Economic	-802,524.	+240,757.50	24	5
			Financial	-631,639	+245,000	24	5
10	Moorap-Jowai	SH	Economic	-85,882	+5,000	5.2	10.8
			Financial	350,466	350,466	15-16	12
11	Mawshaliah – Mawsynram	SH	Economic	-108,093	+123,093	13	8
			Financial	79,403	79,403	24.6	7.5
12	Nongspung-Nongstoin	NH	Economic	-5,355.91	-5,355.91	18.0	6
			Financial	78,895	78,895	15.58	12
13	SH1 near Siso Bibra - Dalbot Bollonggre, Rongsak, Songsak, Rongre Bazar, Nadingre - SC1 near Nengbret	NH	Economic	-23,825	+38,250	24	5
			Financial	1,221,360	1,823,000	25	5.5
14	Dawki – Katrang	NH/SH/MDR	Economic	-130,302.31	+130,302	25	5
			Financial	1,514,055	1,514,055	15.58	12
15	Nongstoin-Mawngap	NH	Economic	-41,773.35	+41,773.35	25	5
			Financial	2,290,964	2,290,964	17.1	8
16	Shallang/Riangdo - Nonbah Taxi Stand,NH 44E, Upper New-Nongstoin	NH	Economic	-133,078.11	+75,000	25	5
			Financial	79,359	79,359	18.9	7.48

17	Road Stretch : +Dhorom – Umtyngar	SH	Economic	-55,955.03	+55,955.03	25	5
			Financial	1,430,410	1,430,410	18.65	7.8
18	Darugre - Dobu Rimding - Nengkhra	NH	Economic	-38,745.97	+38,745.97	25	5
			Financial	354,352	354,352	22.8	6.5
19	Nengkhra - Siju - Baghmara Circuit House	NH	Economic	52,912.74	52,912.74	18	6
			Financial	-1,770,460	+11,00,000	16	8
20	Barengapara - Nokchi - Purakhasia	SH	Economic	-34,575	+40,425	20	6
			Financial	1,466,161	1,466,161	16.8	10.5
21	Dawki- Ummulong	SH	Economic	-61,868.03	+61,000	25	5
			Financial	1,947,379	1,947,379	17.8	6.9
22	Lad Rymbai Dongwah – Ratachera	NH	Economic	-412,846.92	+500,000	20	5
			Financial	2,114,289	2,114,289	108.91	3
23	Nongjri,- Baghmara	NH-6	Economic	-1,732,266.83	72,485	113.2	4.3
			Financial	-2,636,213	+922,675	24	5
24	AMPT Road	NH	Economic	-244,080.44	+235,000	20	5
			Financial	679,317.05	679,317.05	60.22	6
25	Adokri - Shigrang, Memillan, Mitegittim, NengkraM, Simseng Atimbo, Mangsang Rangme Agal, Dalbot A – Shallang	SH	Economic	-139,292.66	+160,000	20	5
			Financial	311,721	311,721	50.70	5
26	GSB Road	NH	Economic	-244,314.54	+97,726.00	25	5
			Financial	139,025	139,025	25.22	8
27	Purakhasia – Garodoba	NH/MDR	Economic	-10,454.41	+35,000	20	5

			Financial	73,984	73,984	181.35	1.81

SYSTEM DYNAMIC MODEL (SDM)

Sl No	Road Stretches	Type of Road	Type of Analysis	Excel Based NPV (in Lakh)	Recommended NPV (in Lakh)	Recommended IRR , %	Recommended Payback Period (years)
1	Road stretch : Sonkanong - Mawten	MDR	Economic	12,030.70	43,831.75	22–23	6–7
			Financial	80,811.18	1,27,474	26–28	4
3	Road Stretch : Selsella - Chibragre	MDR	Economic	55,865.81	2,55,568	24–25	7.4
			Financial	4,80,302.31	7,63,317	23-25	6
4	Road Stretch ; Shillong – Dawki	NH	Economic	4,64,945.37	882,162.62	38.51	4.15
			Financial	13,91,042	2,021,853.31	65.89	2.57
5	Riangdo – Athiabari	SH	Economic	−35,945.21	26,248.28	17.87	7.84
			Financial	100,600.01	188,256.86	28.82	5.42
6	Warangre – Kimbaldam	SH	Economic	208,434.81	351,635.18	54.32	3.07
			Financial	512,024.80	717,826.26	85.40	2.12
7	Rongram Phulbari (RP) Road	SH	Economic	−779,967.59	+257,389.30	11.5	4.6
			Financial	-562,307.84	+2,26,543	65–68	2.5–2.8
8	Barengap?ra, Dalu-Rongram	NH	Economic	70,232.03	391,585.20	24.34	6.76
			Financial	800,027.01	1,264,223.92	36.03	4.43
9	Tura - Danakgre, Anggalgre, Harigaon, Goramara – Garobadha	SH	Economic	-391,377.02	+14,144	2–15	8-10
			Financial	-2,899.73	+430,973	23.65	7
10	Moorap-Jowai	NH	Economic	158,548.08	264,912.86	46.16	3.58
			Financial	385,150.01	264,912.86	13-15	8-9
11	Mawshaliah – Mawsynram	SH	Economic	24,104.40	81,400.95	33.56	3.96
			Financial	147,227.26	230,099.27	33.56	3.96
12	Nongspung- Nongstoin	NH	Economic	47,830.22	71,348.01	33.56	3.96
			Financial				
13	SH1 near Siso Bibra - Dalbot Bollonggre, Rongsak, Songsak, Rongre Bazar, Nadingre - SC1 near Nengbret	NH	Economic	491,252.35	717,118.90	33.56	3.96
			Financial	967,383.03	12,84,856.00	34	4
14	Dawki – Katrang	NH/SH/MDR	Economic	68,366.39	1,55,571.56	33.56	4
			Financial	967,383.03	3,75,370.54	34	5
15	Nongstoin- Mawngap	NH	Economic	111,643.11	175,934.94	84.94	2.10
			Financial	254,482.32	357,296.20	149.97	0.96
16	Shallang/Riangdo - Nonbah Taxi Stand,NH 44E, Upper New-Nongstoin	NH	Economic	20,176.94	84,436.21	25.15	6.40
			Financial	163,016.14	262,090.69	37.43	4.42

17	Road Stretch : +Dhorom – Umtyngar	SH	Economic	734,629.36	1,059,905.61	383	0.28
			Financial	1,465,603.33	1,942,231.61	483.08	0.22
18	Darugre - Dobu Rimding - Nengkhra	NH	Economic	177,929.20	275,559.41	135.32	1.15
			Financial	378,357.55	517,738.73	180.06	0.74
19	Nengkhra - Siju - Baghmara Circuit House	NH	Economic	-1,256,130.62	+671,528.72	13.9	9
			Financial	-419,047.53	+145,750.79	17.59	8.47
20	Barengapara -Nokchi - Purakhasia	SH	Economic	322,488.15	3,22,488.15	16.9	1.3
			Financial	652,605.43	68,383.91	18.2	1.2
21	4Dawki-Ummulong	SH	Economic	1,101,805.42	1,101,805	22-23	0.28
			Financial	2,177,543.34	2,177,543.34	24	0.12
22	Lad Rymbai Dongwah – Ratachera	NH	Economic	1,034,111.79	1,647,829.53	75.07	2.29
			Financial	2,375,566.92	3,284,770.31	127.52	1.20
23	Nongjri,Nonghyllam - Maweit Rd - Nekora – Baghmara	NH-6	Economic	−1,428,947.69	+258,005.30	7.5-8	13
			Financial	-1,130,028.31	+258,005.30	7.48	13.74
24	AMPT Road	SH	Economic	314,623.98	553,991.98	45.39	3.47
			Financial	833,379.70	1,186,200.26	69.22	2.49
25	Adokri - Shigrang, Memillan, Mitegittim, NengkraM, Simseng Atimbo, Mangsang Rangme Agal, Dalbot A – Shallang	NH	Economic	139,978.64	258,707.25	37.67	4.27
			Financial	399,356.50	574,522.78	66.68	2.57
26	GSB Road	NH/ MDR	Economic	33,709.34	149,729.97	22.67	6.86
			Financial	293,087.19	461,429.14	36.77	4.27
27	Purakhasia – Garodoba	NH/ MDR	Economic	36,619.17	57,358.73	147.53	1.01
			Financial	80,006.01	80,006.01	9.8	1.6
28	Nengkhra - Sawilgre – Asanang	SH	Economic	1,086,519.18	1,559,048.19	244.99	0.47
			Financial	2,197,490.78	2,963,616.35	535.01	0.19

HYBRID ANNUITY MODEL (HAM)

Sl No	Road Stretches	Type of Road	Type of Analysis	Excel Based NPV (in Lakh)	Recommended NPV (in Lakh)	Recommended IRR , %	Recommended Payback Period (years)
1	Road stretch : Sonkanong - Mawten	MDR	Govt	78,903.42	11,092.85	23.7	7.8
			Private	80,811.18	1,27,474	26–28	≈ 4 years
3	Road Stretch : Selsella - Chibragre	MDR	Govt	476,928.85	476,928.85	17.10	8
			Private	9,489.97	30,198.74	22.6	8.5
4	Road Stretch ; Shillong – Dawki	NH	Govt	11,76,905.85	11,76,905.85	18.5 – 19.5	7-8
			Private	16,555.26	17,319.34	18	7
5	Riangdo – Athiabari	SH	Govt	122,628.06	122,591.73	18.6	6
			Private	3,700.43	3,904.00	17.85	8.5
6	Warangre – Kimbaldam	SH	Govt	450,566.49	450,566.49	18.6	7.4
			Private	2,029.70	2,160.42	16.8	10.2
7	Rongram Phulbari (RP) Road	SH	Govt	-779967.59	257,389.30	17	5
			Private	-562,307.84	257,389.30	65–68,	2.5–2.8
8	Barengap?ra, Dalu-Rongram	NH	Govt	70232.03	391,585.20	24.34	6.76
			Private	800,027.01	1,264,223.92	36.03	4.43
9	Tura - Danakgre, Anggalgre, Harigaon, Goramara – Garobadha	SH	Govt	-391377.02	14,144	12–15	8–10
			Private	-2,899.73	430,973	20.20	7.50
10	Moorap-Jowai	NH	Govt	3,38,103	40,288	10-11	8-9
			Private	1,149	1,241	16.5	9.8
11	Mawshaliah – Mawsynram	SH	Govt	1,43,219.70	20,021.48	18.92	11.2
			Private	1,738	1,856	16	8
12	Nongspung- Nongstoin	NH	Govt	68,909	8,019	12.45	6
			Private	-1,000.04	68,984	22	8-9
13	SH1 near Siso Bibra - Dalbot Bollonggre, Rongsak, Songsak, Rongre Bazar, Nadingre - SC1 near Nengbret	NH	Govt	1,038.58	119,429.04	28.8	6.8
			Private	−495	+396	18	13
14	Dawki – Katrang	NH/SH/MDR	Govt	1,360,139	156,563.25	22.4	7
			Private	2,346,	2,346,	18.72	6.8
15	Nongstoin- Mawngap	NH	Govt	19,46,877	217,601.02	14-16	9-11
			Private	−4	2,050.75	22-24	6.5
16	Shallang/Riangdo - Nonbah Taxi Stand,NH 44E, Upper New-Nongstoin	NH	Govt	161,142	34,402.70	21-23	7.5
			Private	2,404	9,183.41	24-26	5.5
17		SH	Govt	29,835.68	45,941.90	16.5	8.0

	Road Stretch : +Dhorom – Umtyngar		Private	14,124	14,777	18.8	8.5
18	Darugre - Dobu Rimding - Nengkhra	NH	Govt	323,540.04	323,540.04	13	4.2
			Private	378,357.55	517,738.73	180.06	0.74
19	Nengkhra - Siju - Baghmara Circuit House	NH	Govt	−1,256,130.62	671,528.72	13.9	9
			Private	−419,047.53	145,750.79	17.59	8.47
20	Barengapara -Nokchi - Purakhasia	SH	Govt	5,73,114.44	6,87,737.33	16.80	3
			Private	−1,058.92	82,755	22	6
21	Dawki-Ummulong	SH	Govt	1,833,600.26	1,833,600.26	21.4	3.5
			Private	527.50	527.50	16	9
22	Lad Rymbai Dongwah – Ratachera	NH	Govt	2,065,707.98	2,065,707.98	18.6	4.2
			Private	9,882.48	9,882.48	16	9
23	Nongjri,Nonghyllam - Maweit Rd - Nekora – Baghmara	NH-6	Govt	–618,674.25	+210,500.00	18.7	10.5
			Private	44,988.18	62,988.18	19.5	8
24	AMPT Road	SH	Govt	743,138.48	743,138.48	17.6	3.5
			Private	5,368.54	5,368.54	18.6	9
25	Adokri - Shigrang, Memillan, Mitegittim, NengkraM, Simseng Atimbo, Mangsang Rangme Agal, Dalbot A – Shallang	NH	Govt	78,903.42	11,092.85	23.7	7.8
			Private	506.64	3,563.60	22.95	5.2
26	GSB Road	NH	Govt	29,835.68	45,941.90	16.5	8
			Private	5,369	14,777	18.8	8.5
27	Purakhasia – Garodoba	NH/MDR	Govt	68,463	68,463	17.8	4.2
			Private	−864	+120.00	10.5-11	14-15
28	Nengkhra - Sawilgre – Asanang	NH/MDR	Govt	-1,817,332.36	+6.5	25	5
			Private	-1,237,567.86	+592,197.20	39.94	5

HIGHWAY AND DEVELOPMENT MODEL (HDM – 4)

Sl No	Road Stretches	Type of Road	Type of Analysis	Excel Based NPV (in Lakh)	Recommended NPV (in Lakh)	Recommended IRR , %	Recommended Payback Period (years)
1	Road stretch : Sonkanong - Mawten	MDR	Govt	-56,565.89	18,671.97	12	9
			Private	76,820.40	76,820.40	13.5	8
3	Road Stretch : Selsella - Chibragre	MDR	Govt	-367,810.10	+478,153.13	38	4
			Private	455,399.20	548,931.61	38	4
4	Road Stretch ; Shillong – Dawki	NH	Govt	-580740.08	41,192.12	18-20	7
			Private	12,15,457	1,428,134.80	37.3	5
5	Riangdo – Athiabari	SH	Govt	-175,290.70	+288,409.30	22.5	6
			Private	94,539.02	786,632.55	38	4
6	Warangre – Kimbaldam	SH	Govt	-84,336.57	+1,18,000	38	4
			Private	504,486.75	504,486.75	64.73	3
7	Rongram Phulbari (RP) Road	SH	Govt	−1,046,855.79	+541,150.21	15.8	7
			Private	-624,697.17	+489,302.83	28-30	5
8	Barengap?ra, Dalu-Rongram	NH	Govt	-659,719.20	+32,880.00	17-14	9-10
			Private	755,743.46	755,743.46	28.96	6
9	Tura - Danakgre, Anggalgre, Harigaon, Goramara – Garobadha	SH	Govt	-806,281.67	+48,000	9-10	9
			Private	-52,816.49	+85,000	15.58	12
10	Moorap-Jowai	NH	Govt	-59,838.40	+25,161.60	9.5-10	13
			Private	379,663.90	379,663.90	67.7	3
11	Mawshaliah – Mawsynram	SH	Govt	-98,430.52	+101,569.48	8.5-9	13
			Private	140,370.54	140,370.54	31.69	6
12	Nongspung- Nongstoin	NH	Govt	293.47	293.47	17.38	5
			Private	81,207.21	81,207.21	285.03	1
13	SH1 near Siso Bibra - Dalbot Bollonggre, Rongsak, Songsak, Rongre Bazar, Nadingre - SC1 near Nengbret	NH	Govt	60,766.97	60,766.97	36.61	3-4
			Private	1,234,499.84	1,234,499.84	820.30	1
14	Dawki – Katrang	NH/SH/MDR	Govt	-21,545.33	+5,500.00	15.5	10-11
			Private	1,588,057.52	1,588,057.52	169.62	1

15	Nongstoin- Mawngap	NH	Govt	116,752.06	116,752.06	37.68	4
			Private	2,314,615.34	2,314,615.34	856.56	1
16	Shallang/Riangdo - Nonbah Taxi Stand,NH 44E, Upper New-Nongstoin	NH	Govt	-122,450.75	+25,000.00	8-10	14
			Private	154,590.84	154,590.84	30.15	6
17	Road Stretch : +Dhorom – Umtyngar	SH	Govt	44,195.35	44,195.35	24.17	7
			Private	1,461,944.70	1,461,944.70	384.91	1
18	Darugre - Dobu Rimding - Nengkhra	NH	Govt	-12,942.32	4,270.97	12.16	15
			Private	375,795.41	375,795.41	138.11	2
19	Nengkhra - Siju - Baghmara Circuit House	NH	Govt	-2,175,258.63	1,51,475	14	4
			Private	-551,706.95	254369	18	8
20	Barengapara -Nokchi - Purakhasia	SH	Govt	10,020.66	10,020.66	19.68	2.82
			Private	650,294.56	650,294.56	275.5	1
21	4Dawki-Ummulong	SH	Govt	-32,009.39	12,483.66	9.33	15-16
			Private	444,889.12	444,889.12	101.31	2
22	Lad Rymbai Dongwah – Ratachera	NH	Govt	-252,048.65	52,810.47	10.20	10
			Private	2,349,750	2,349,750	65.59	2
23	Nongjri,Nonghyllam - Maweit Rd - Nekora – Baghmara	NH-6	Govt	-1,817,332.36	+6.5	25	5
			Private	−1,237,567.86	+592,197.20	39.94	5
24	AMPT Road	SH	Govt	-188,073.82	+21,926.18	25	5
			Private	818,070.88	818,070.88	54.18	3
25	Adokri - Shigrang, Memillan, Mitegittim, NengkraM, Simseng Atimbo, Mangsang Rangme Agal, Dalbot A – Shallang	NH	Govt	-112,514.28	+77,485.72	25	5
			Private	390,558.07	424,611.85	70.27	3
26	GSB Road	NH	Govt	-225,293.98	+64,706.02	25	5
			Private	277,778.37	277,778.37	25	7
27	Purakhasia – Garodoba	NH/MDR	Govt	-4,943.81	+12,500	22	5
			Private	79,206.48	79,206.48	89.93	2
28			Govt	35,409.26	35,409.26	19.80	5

	Nengkhra - Sawilgre – Asanang	NH/MDR	Private	2,190,177.19	2,190,177.19	272.24	1

VI. CONCLUSIONS

- Cost Benefit Analysis (CBA) – Shows realistic and balanced results with most road stretches (e.g., Shillong–Dawki, Dawki–Ummulong, Lad Rymbai–Ratachera) having positive Economic NPV and EIRR ≥ 20%, meeting IRC:SP:30 standards. It provides the most dependable and practical assessment for government decision-making.
- System Dynamic Model (SDM) – Produces extremely high IRR values (>100%) and very short payback periods (<2 years) for some stretches (e.g., Nengkhra–Sawilgre–Asanang, Dhorom–Umtyngar), indicating overestimation due to feedback loops. SDM is useful for trend simulation, but not reliable for final investment decisions without cross-validation.
- Highway Development and Management Model (HDM-4) – Demonstrates strong economic feasibility in major corridors like Selsella–Chibragre, Warangre–Kimbaldam, Nongstoin–Mawngap. However, the very high Financial IRRs (up to 800%) highlight optimistic revenue projections. Still, HDM-4 remains the standard reference tool for technical–economic evaluation as per MoRTH.
- Hybrid Annuity Model (HAM) – Balances economic soundness and private participation. Projects such as Barengapara–Dalu–Rongram, Shillong–Dawki, Dawki–Katrang show both high EIRR (>18%) and strong financial viability. HAM is best suited for PPP projects, ensuring shared risk and stable annuity-based returns.
- Across all models, Economic NPV and EIRR remain positive for most road stretches, confirming that investments are socially beneficial and meet MoRTH economic feasibility norms (EIRR ≥ 12%).
- However, models like SDM and HDM-4 require sensitivity analysis to correct overestimated IRRs and unrealistic payback periods, ensuring practical financial planning.
- Overall Recommendation:
  - For policy and approval → CBA and HDM-4 are most reliable.
  - For PPP implementation → HAM provides the best cost–risk balance.
  - SDM should be used only for scenario forecasting, not final feasibility ranking.

VII. RECOMMENDATIONS

- Hybrid Annuity Model (HAM) emerges as the most suitable model for PPP-based highway investments, ensuring balanced risk-sharing and steady financial returns across diverse corridors.
- The model's 40:60 risk-sharing structure between the government (40%) and private concessionaire (60%) makes it more sustainable than fully private BOT or traditional EPC frameworks.
- Key stretches such as Barengapara–Dalu–Rongram (NH), Dawki–Katrang (NH/SH/MDR), Shillong–Dawki (NH), and Riangdo–Athiabari (SH) recorded positive Economic NPV and Financial IRR between 16–24%, satisfying MoRTH's PPP financial norms.
- Annuity-based payments ensure predictable and risk-free cash inflows to private investors, minimizing uncertainties arising from traffic or toll revenue fluctuations.
- When compared to CBA and HDM–4 results, HAM projects show stronger financial feasibility while retaining acceptable economic performance across most corridors.
- Though SDM projects reported high IRRs, many were inflated by feedback effects, making HAM a more realistic and dependable choice for implementation.
- Overall, HAM offers a balanced approach—combining economic soundness, moderate payback (≈4–8 years), and investor confidence—and is thus recommended for PPP-based highway development, especially for corridors like Barengapara–Dalu–Rongram, Dawki–Katrang, and Shillong–Dawki.

VIII. REFERENCES

Nida Fariza Maulanisa, Endang Chumaidiyah*, Iphov Kumala Sriwana (2024) A system dynamics modeling approach for improving engineering, procurement, and construction project performance: A case study
Journal of Infrastructure, Policy and Development 2024, 8(11), 8730.
https://doi.org/10.24294/jipd.v8i11.8730.

Murali Jagannathan 1 2 and Jeetu Soneji (2019) Hybrid Annuity Model In Highway Projects: A Review Of Current Challenges And Possible Solutions
NICMAR-Journal of Construction Management, Vol. XXXIV, No. 4

Yonghua Liu, Hao Deng, Hanqi Gao,* and Wei Ni (2024) Research on investment evaluation of highway projects based on system dynamics model
Volume 9, Issue 8, 20326–20349.
https://www.aimspress.com/journal/Math

Ruta Rudzianskaite-Kvaraciejiene, Rasa Apanaviciene, Algirdas Butauskas (2010) Evaluation of Road Investment Project Effectiveness
ISSN 1392 – 2785 Inzinerine Ekonomika-Engineering Economics, 2010, 21(4), 368-376
https://www.researchgate.net/publication/266572050

Pratiksha. R. Pati, Prof. Dhananjay. S. Patil (2020) Economic Feasibility Analysis of Highway Project using Highway Development and Management (HDM-4) Model
International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 9 Issue 07, July-2020
http://www.ijert.org