Predictive Analysis of Railway Asset Regeneration

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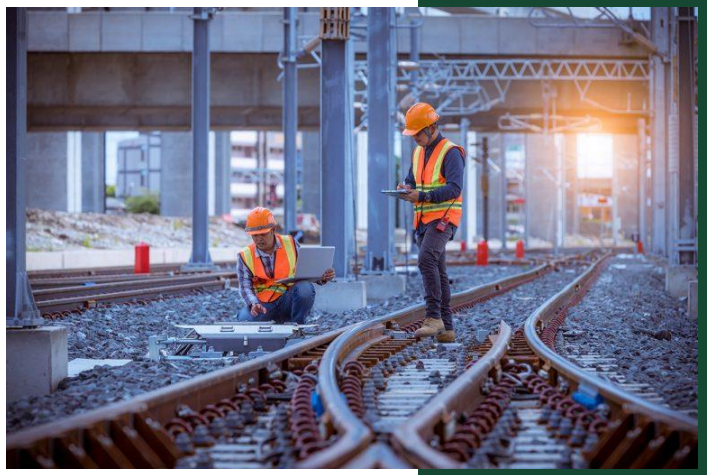
Predictive Analysis of Railway Asset Regeneration

- Track Infrastructure (rails, switches, Ballast,…)
- Signaling (signals, Automatic Train Control,…)
- Electrical system (substations, catenary,…)
- Bridges and Tunnels



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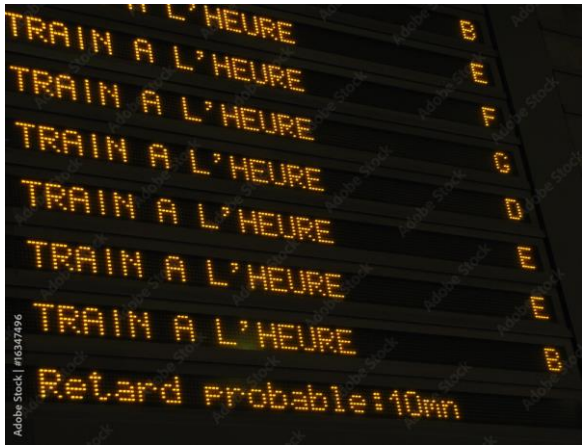

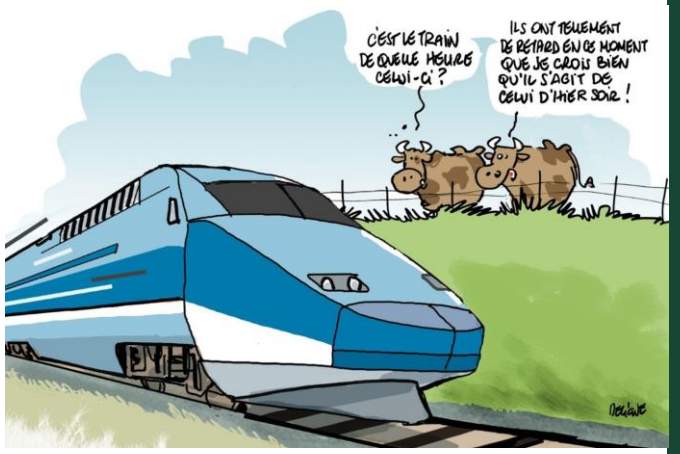

- Improve safety
- Reduced impact of accidents and delays
- Customer satisfaction

- Complex prioritization
- Multiple criteria to consider Budget and capacity
- constraints

Prioritizing the regeneration of critical assets

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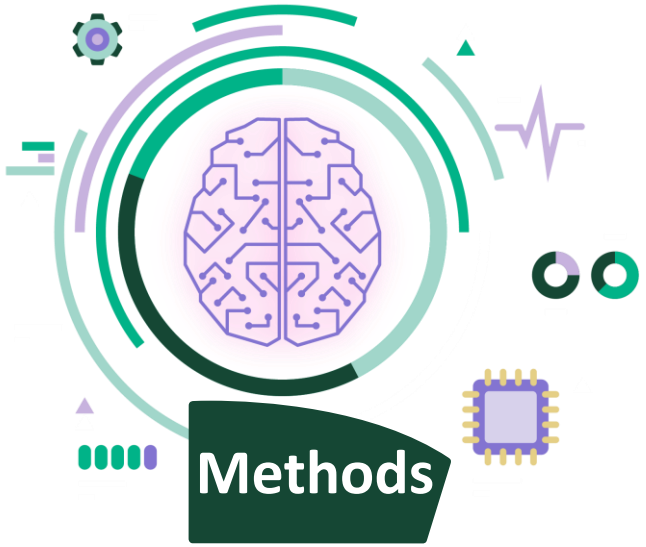
Predictive Analysis of Railway Asset Regeneration

- Infrastructure data
- Results of aging laws and survival analysis
- Maintenance vs renewal costs
- Impacts on regularity
- Related data (availability, etc.)



Proposal of a set of regeneration scenarios

Inputs → **Methods** → **Outputs**

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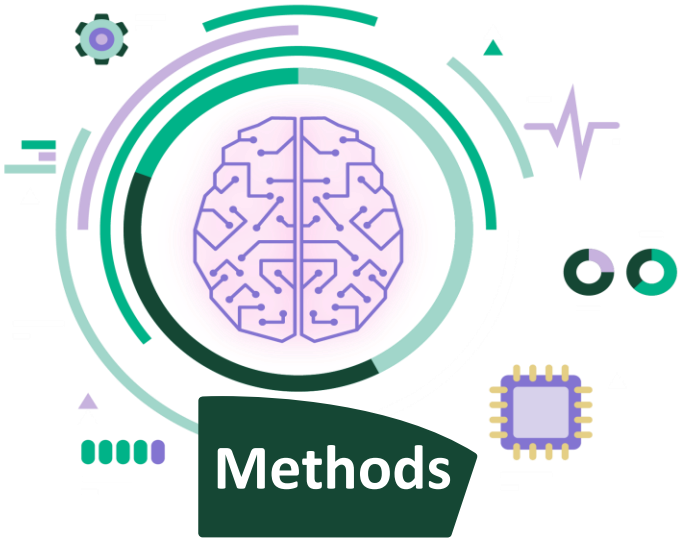
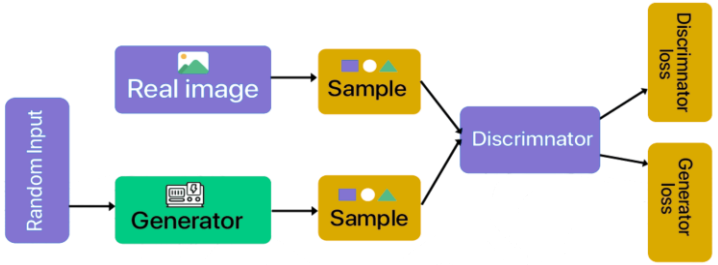


1. **Prioritise** what needs to be done using multi-criteria optimisation methods : CRITIC/TOPSIS



2. Generation **maintenance schedule** with AI Generative : GAN models

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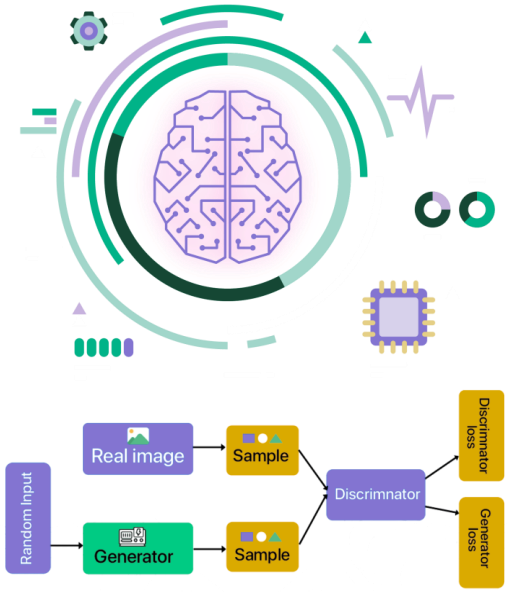


CRITIC/TOPSIS

1. Establishment of an investment program to be evaluated

2. Identification of investment valuation criteria

3. Quantifying the performance of investments according to the selected criteria

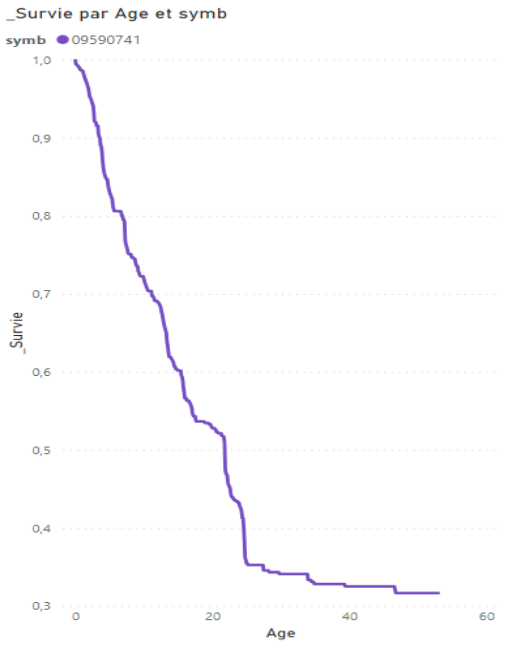
4. Aggregate the performance of investments according to the selected criteria

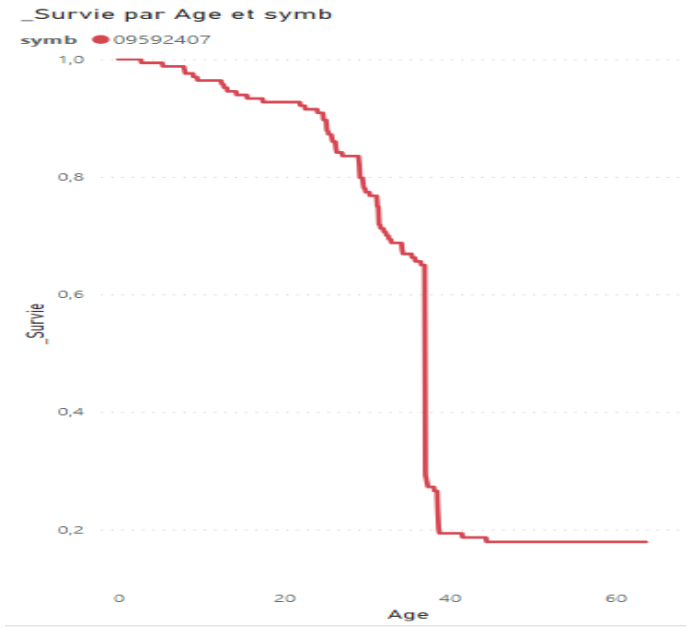
5. Prioritising investments according to decision-making needs

Predictive Analysis of Railway Asset Regeneration

1. Establishment of an investment program to be evaluated

Asset Survival analyses





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Predictive Analysis of Railway Asset Regeneration

1. Establishment of an investment program to be evaluated

Asset Survival analyses

Column1	description	age1	Durée de vie résiduelle
0	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V	9.0	54.76315789473684
1	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V 692517	0.3	63.463157894736845
2	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V 1999	7.7	56.06315789473684
3	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V	1.2	62.56315789473684
4	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V 1289	5.1	58.66315789473684
5	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V 1918	45.1	18.66315789473684
6	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V	6.7	57.06315789473684
7	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V	5.6	58.16315789473684
8	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V 1941	4.9	58.863157894736844
9	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V 1492	0.9	62.863157894736844
10	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V	7.8	55.963157894736845
11	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V	17.7	46.06315789473685
12	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V 831002	31.1	32.66315789473684
13	DISJONCTEUR A COUPURE DANS L'AIR ALSTOM DJ 1500V JR 2000A EN=1500V MN=..48V	28.7	35.06315789473685

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Predictive Analysis of Railway Asset Regeneration

2. Identification of investment valuation criteria

3. Quantifying the performance of investments according to the selected criteria

Taux de panne	Fonction de risque	Ratio MC/Durée de vie résiduell	Colonne	Colonne
0.0358400146877137	0.036296406393720816	438.25084094185485		
0.025523052413041588	0.022292174822856104	378.17216785536573		
0.03529916443716327	0.03569556978495151	428.0886218550507		
0.028833342324742547	0.027826619179614227	383.61234962564146		
0.03382583901915247	0.034030979360546526	409.1153777139781		
0.040256025805347456	0.04106642627200617	1285.9560067681896		
0.03480753142927342	0.035144984766606595	420.58660763696736		
0.034164203816162496	0.03441733523888611	412.6323409646186		
0.03368072756828778	0.03386444961210281	407.725321888412		
0.027995000460715066	0.026616753878615604	381.78164768921636		
0.03534435460432968	0.03574595989296443	428.8535690774005		
0.03799413249126383	0.038648494068497866	521.0237659963436		
0.03946856900028701	0.04022945048715651	734.77280051563		
0.0392788350540374	0.04002707326600054	684.4791353947762		
0.02302047991496159	0.0	376.392901361948		
0.029079261651609036	0.028167336390521987	384.22649140546		
0.04100003526184226	0.04185322424139537	inf		

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Predictive Analysis of Railway Asset Regeneration

4. Aggregate the performance of investments according to the selected criteria

Criteria	Weights
age	0,163909372
Remaning Useful Life	0,33700476
Failure rate	0,076525828
Risk function	0,071311146
Corrective Maintenance/RUL	0,160418667

CRITIC method

Experts choices

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Predictive Analysis of Railway Asset Regeneration

4. Aggregate the performance of investments according to the selected criteria

Criteria	Weights
age	0,163909372
Remaning Useful Life	0,33700476
Failure rate	0,076525828
Risk function	0,071311146
Corrective Maintenance/RUL	0,160418667

CRITIC method

Normalization Data → Standard deviation → Correlation Matrix → Information quantity → Weights

$$C_j = \sigma_j \times \sum_{k=1}^{n} (1 - |r_{jk}|) \qquad w_j = \frac{C_j}{\sum_{j=1}^{n} C_j}$$

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Predictive Analysis of Railway Asset Regeneration

5. Prioritizing investments according to decision-making needs

TOPSIS : Technique for Order Preference by Similarity to Ideal Solution

	age	Remaning Useful Life	Failure rate	Risk function	Corrective Maintenance/RUL
	0,00053306	0,005770873	0,000687296	0,000631428	7,03319E-07
	0,00497293	0	0,001185379	0,001112667	0,008550012
	0,00497293	0	0,001185379	0,001112667	0,008550012
	0,00335352	0,001140883	0,001333503	0,00125618	3,55756E-07
	0,00335352	0,001140883	0,001333503	0,00125618	3,55756E-07
A+	0	0,007753572	0,002575799	0,002443821	0,008550012
A-	0,00585011	0	0,000228054	0	3,40991E-09

A+	***Minimum***	***Maximum***	***Maximum***	***Maximum***	***Maximum***
A-	***Maximum***	***Minimum***	***Minimum***	***Minimum***	***Minimum***

A- : Negative ideal solution

A+ : ideal solution

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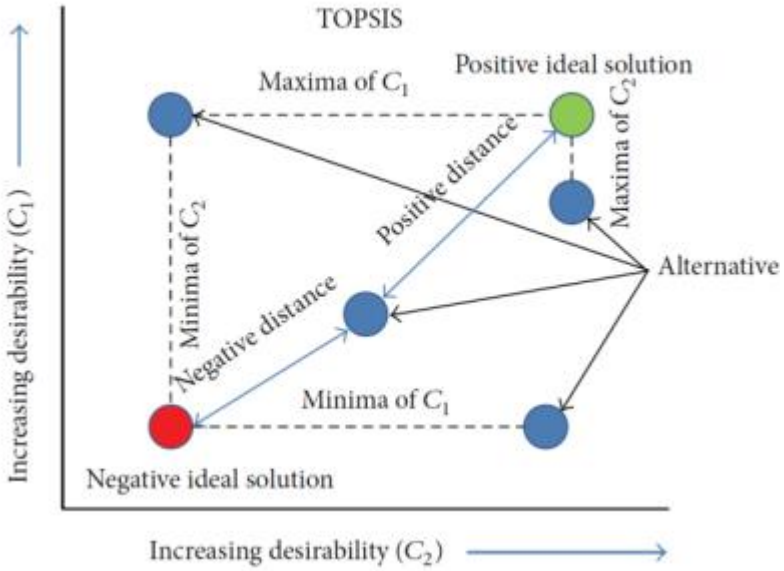
5. Prioritizing investments according to decision-making needs



- Calculate **Euclidian distance** to ideal and not ideal solution
- Identify a solution that comes as **close** as possible to the to the ideal solution and as **far away** as possible from the negative ideal Impacts régularité

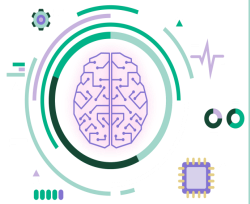
$$A^- / (A^- + A^+)$$

- **Rank** solutions from best to worst according to distances from the ideal and the anti-ideal

S+	S-	Similarity	ranking
7,7961E-05	0,0001068	0,57804339	1
7,9717E-05	0,00010553	0,56967762	2
7,8923E-05	0,00010445	0,56960648	3
7,9326E-05	0,00010356	0,56625237	4
7,8924E-05	0,0001026	0,56520764	5
7,9589E-05	0,00010236	0,56256888	6
7,9589E-05	0,00010236	0,56256888	6
7,9589E-05	0,00010236	0,56256888	6
7,9589E-05	0,00010236	0,56256888	6
7,9462E-05	0,00010218	0,56253701	10
7,9962E-05	0,00010268	0,56218248	11
7,9488E-05	0,00010194	0,56188579	12
7,9296E-05	0,00010158	0,56158752	13
7,902E-05	0,00010103	0,56112404	14
7,8572E-05	0,00010033	0,56079741	15
7,8975E-05	0,00010083	0,56077518	16
7,9004E-05	0,0001006	0,56011346	17
7,9525E-05	0,00010057	0,55842457	18
7,9439E-05	0,00010038	0,5582368	19

Predictive Analysis of Railway Asset Regeneration

ID	description	Similarity	ranking
3635	DISJONCTEUR A COUPUR	0,57804339	1
2348	DISJONCTEUR A COUPUR	0,56967762	2
2334	DISJONCTEUR A COUPUR	0,56960648	3
624	DISJONCTEUR A COUPUR	0,56625237	4
752	DISJONCTEUR A COUPUR	0,56520764	5
53	DISJONCTEUR A COUPUR	0,56256888	6
66	DISJONCTEUR A COUPUR	0,56256888	6
92	DISJONCTEUR A COUPUR	0,56256888	6
193	DISJONCTEUR A COUPUR	0,56256888	6
145	DISJONCTEUR A COUPUR	0,56253701	10
143	DISJONCTEUR A COUPUR	0,56218248	11
3594	DISJONCTEUR A COUPUR	0,56188579	12
3576	DISJONCTEUR A COUPUR	0,56158752	13
158	DISJONCTEUR A COUPUR	0,56112404	14
645	DISJONCTEUR A COUPUR	0,56079741	15
67	DISJONCTEUR A COUPUR	0,56077518	16
3596	DISJONCTEUR A COUPUR	0,56011346	17
2998	DISJONCTEUR A COUPUR	0,55842457	18



Proposal of a set of regeneration scenarios

- Insightful Planning for Interventions
- Optimal Timing for Equipment Replacement

Predictive Analysis of Railway Asset Regeneration

- Add constraints (budgets , capacity)

$$\max R(x) = \sum_{i=1}^{n} U_i * x_i \quad \text{,Constraint} \quad \sum_{i=1}^{n} c_i * x_i \leq C$$

- To explore Intelligence Artificielle Generative methods

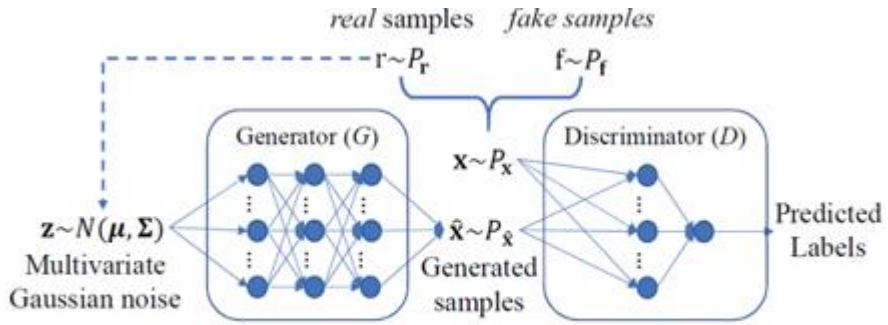


Fig. 3. The general scheme of model training in the proposed GMOEA.

Thanks

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