04.3D Continuously improving CBM Effectiveness

How good is our CBM performance?

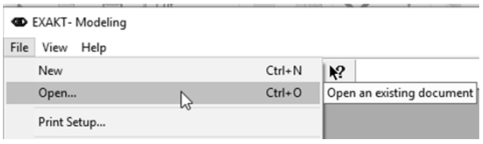
How can we measure CBM Performance?

A process of continuous improvement is essential in any maintenance department. Situations change. New failure modes and their effects are observed. Operational context evolves. Maintenance engineers must have a way to regularly verify and improve their decisión models.

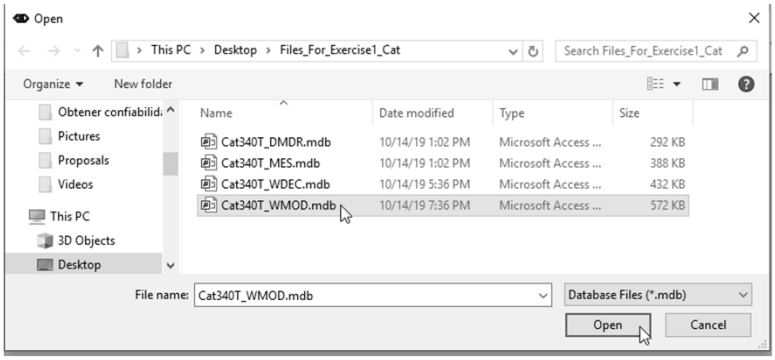
1

Revisiting Exercise 1

2



3

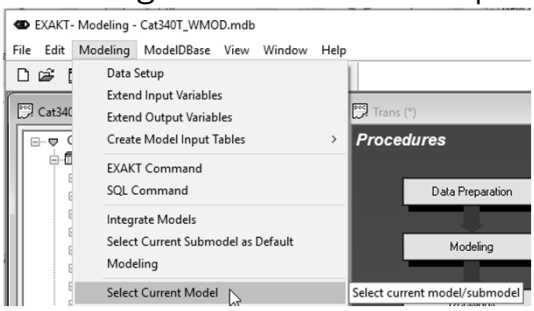


1. Reopen EXAKT for modeling
2. File, Open
3. Navigate to folder Files_For_Exercise1_Cat, Cat340T_WMOD.mdb, Open

2

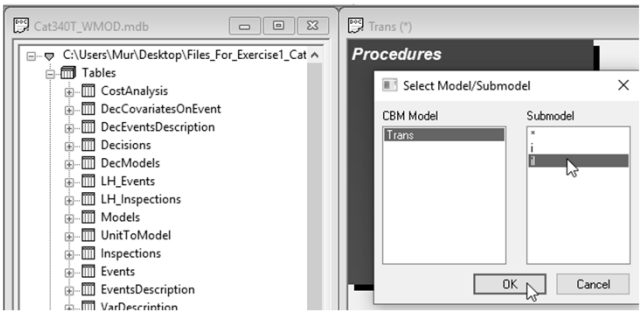
Selecting the model whose predictive performance is to be verified

1



1. Modeling, Select the model.
2. il, OK

2

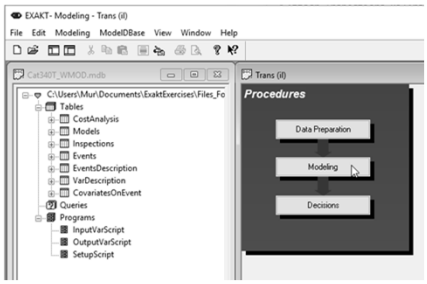


3

MW1

Cost comparison function

1

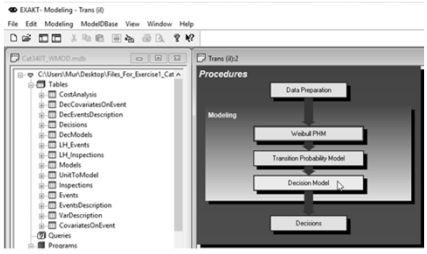


1. Hit Modeling
2. Hit Decision Model
3. Hit Cost Comparison
4. Examine "Exclude History" table

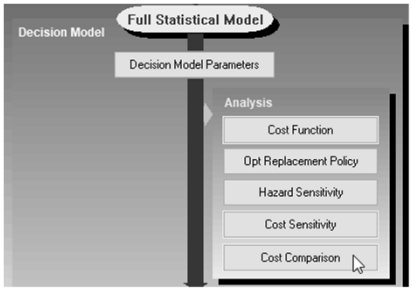
This table lists each history in the sample upon which the model is based. In the next step we will decide which, if any, histories should be excluded from the assessment.

5. Close the Exclude History window for now.

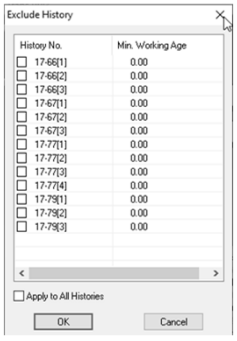
2



3



4



5

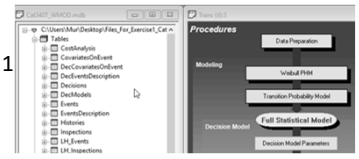
4

Slide 4

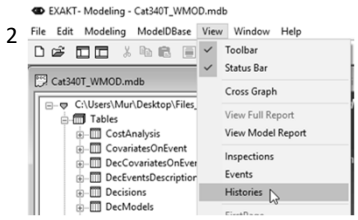
MW1 Murray Wiseman, 10/14/2019

Deciding on which, if any, histories to excclude

1



2



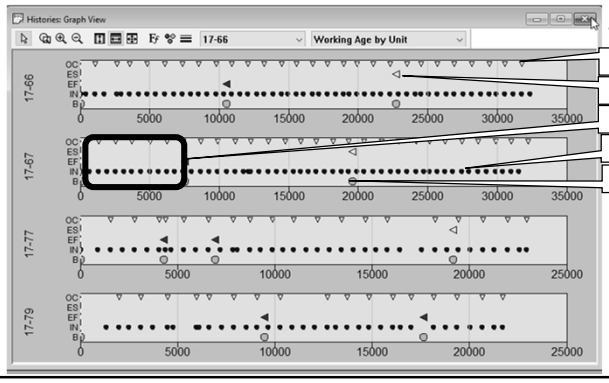
1. Activate left window pane
2. View, Histories
3. Examine the Histories Graph View

We should exclude histories that:

a) Have only just begun
b) Are missing a substantial number of inspections
c) Are part of another time window whose performance we wantto compare with. That is we want to determine if the model has maintained or improved its effectiveness.

4. In this example, no histories need be excluded. Close the Histories Graph View

3



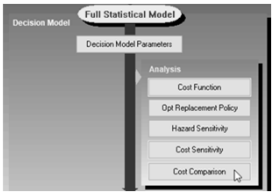
4

- Non-rejuvenating event
- Ending by Suspension
- Ending by Failure
- CBM Inspection
- Beginning

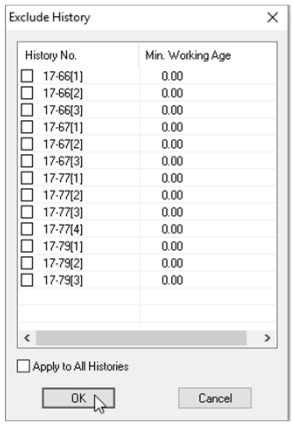
5

Accepting all data

1



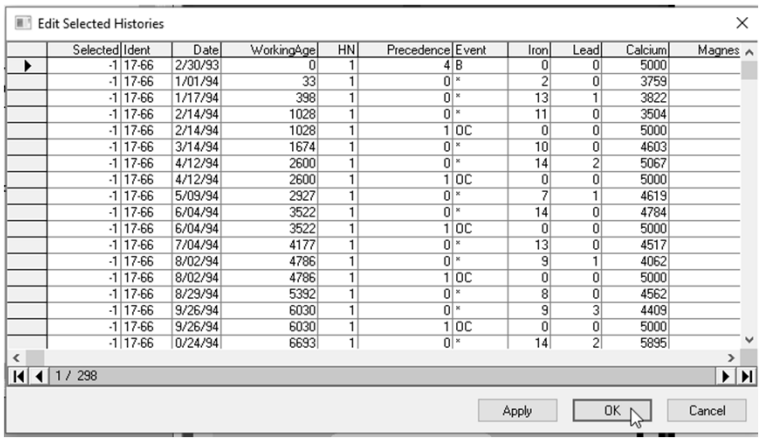
2



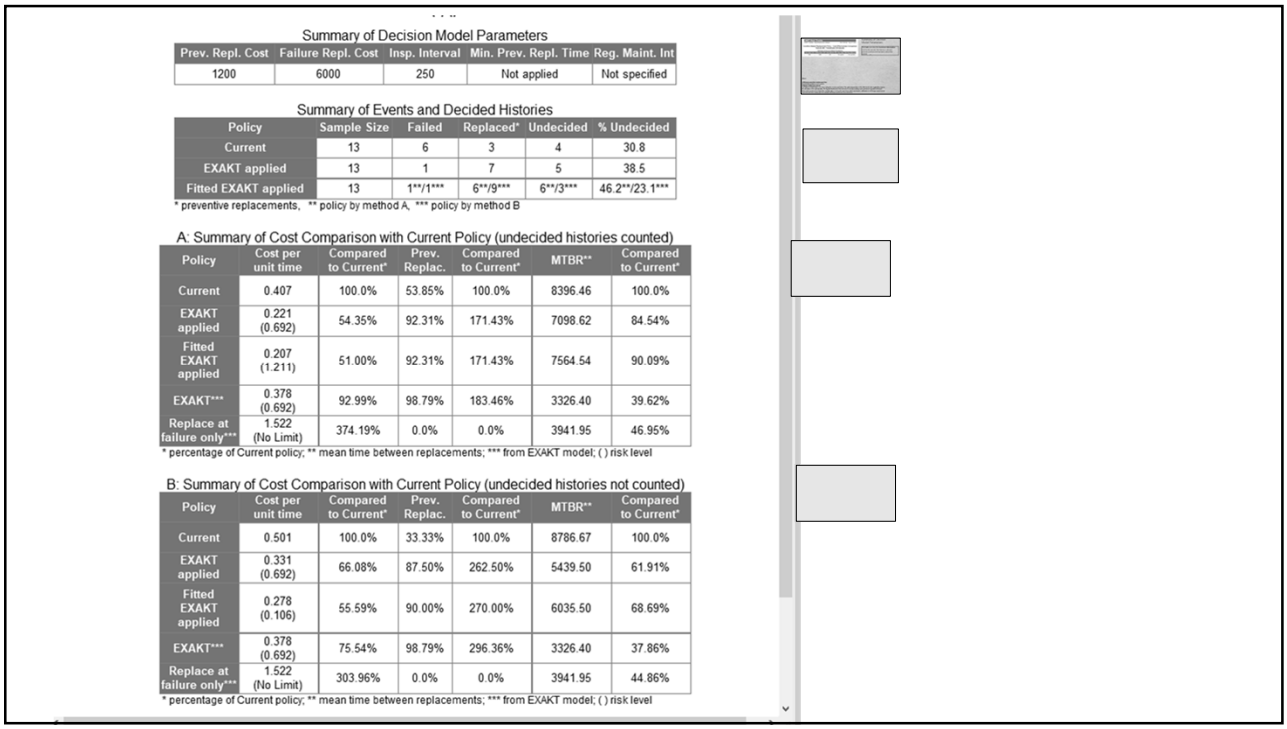
1. Hit Cost Comparison again
2. Hit OK in Exclude History window to accept all histories.
3. Examine the Edit Selected Histories table.

In this table we may exclude any CBM records that are obviously in error.

4. Hit OK to accept all records and to generate the model assessment.



6



Summary of Decision Model Parameters

Prev. Repl. Cost	Failure Repl. Cost	Insp. Interval	Min. Prev. Repl. Time	Reg. Maint. Int
1200	6000	250	Not applied	Not specified

Summary of Events and Decided Histories

Policy	Sample Size	Failed	Replaced*	Undecided	% Undecided
Current	13	6	3	4	30.8
EXAKT applied	13	1	7	5	38.5
Fitted EXAKT applied	13	1**/1***	6**/9***	6**/3***	46.2**/23.1***

* preventive replacements, ** policy by method A, *** policy by method B

A: Summary of Cost Comparison with Current Policy (undecided histories counted)

Policy	Cost per unit time	Compared to Current*	Prev. Replac.	Compared to Current*	MTBR**	Compared to Current*
Current	0.407	100.0%	53.85%	100.0%	8396.46	100.0%
EXAKT applied	0.221 (0.692)	54.35%	92.31%	171.43%	7098.62	84.54%
Fitted EXAKT applied	0.207 (1.211)	51.00%	92.31%	171.43%	7564.54	90.09%
EXAKT***	0.378 (0.692)	92.99%	98.79%	183.46%	3326.40	39.62%
Replace at failure only***	1.522 (No Limit)	374.19%	0.0%	0.0%	3941.95	46.95%

* percentage of Current policy; ** mean time between replacements; *** from EXAKT model; ( ) risk level

B: Summary of Cost Comparison with Current Policy (undecided histories not counted)

Policy	Cost per unit time	Compared to Current*	Prev. Replac.	Compared to Current*	MTBR**	Compared to Current*
Current	0.501	100.0%	33.33%	100.0%	8786.67	100.0%
EXAKT applied	0.331 (0.692)	66.08%	87.50%	262.50%	5439.50	61.91%
Fitted EXAKT applied	0.278 (0.106)	55.59%	90.00%	270.00%	6035.50	68.69%
EXAKT***	0.378 (0.692)	75.54%	98.79%	296.36%	3326.40	37.86%
Replace at failure only***	1.522 (No Limit)	303.96%	0.0%	0.0%	3941.95	44.86%

* percentage of Current policy; ** mean time between replacements; *** from EXAKT model; ( ) risk level

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340T Haul Trucks

EXAKT, Condition - Based Maintenance Software 09:41 AM Sat., Aug. 27, 2016

Condition-Based Replacement Policy - Cost Effectiveness Comparison

Trans (il) (350 T Transmission Oil Analysis)

Summary of Decision Model Parameters

Prev. Repl. Cost	Failure Repl. Cost	Insp. Interval	Min. Prev. Repl. Time	Reg. Maint. Int
1200	6000	250	Not applied	Not specified

Summary of Decision Model Parameters

The table provides the **business information** used in the model. The last two columns provide additional information about the model.

Where:

1.Minimum preventive maintenance time
To avoid false positives due to wear-in.

2.Regular maintenance interval
Is an option in EXAKT that is used when setting the decision parameters. This optional parameter of the CBM Model will, if applicable, improve the calculation of the optimal policy. The Regular Maintenance Interval refers to non-rejuvenating events performed regularly in time and those actions are known to impact the covariate values. Such events may include minor adjustments, calibrations or oil changes carried out at some interval of the working age. For example, oil changes performed every 600 hours.

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Summary of Events and Decided Histories

Policy	Sample Size	Failed	Replaced*	Undecided	% Undecided
Current	13	6	3	4	30.8
EXAKT applied	13	1	6	6	46.2
Fitted EXAKT applied	13	1**/1***	5**/8***	7**/4***	53.8**/30.8***

* preventive replacements, ** policy by method A, *** policy by method B

But at what **cost**?

Would this policy have resulted in significantly reduced **availability**, for example?

Summary of Events and "Decided" Histories

Compares the current CBM performance with the model's "retroactive" performance.

This looks promising for the proposed new model. But we aren't through. The proposed model may be impractical or much too costly. Therefore further analysis is required, before going ahead and implementing the new model.

1.Where: **"Current":**
What actually occurred? Of the 13 actual histories in the sample 6 failed, 3 were replaced, and 4 are "undecided" – that is, at this time we do not know whether they will eventually fail or be preventively replaced. (At present they are still operating).

2.EXAKT applied: When the EXAKT policy is applied retroactively to the data set,

1. 1 history would have ended having failed,
2. 6 would have been preventively replaced, and
3. 6 would have been undecided

3.We may conclude that the number of failures would have been significantly reduced, but this is not enough to justify the CBM policy. We need to determine (in next steps) the real cost of the improved failure rate.
4.Fitted EXAKT applied: The curve of the EXAKT decision chart is fitted to the actual data; so as to minimize "average" realized cost.

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Examine Cost Summary Table A

A: Summary of Cost Comparison with Current Policy (undecided histories counted)

Policy	Cost per unit time	Compared to Current*	Prev. Replac.	Compared to Current*	MTBR**	Compared to Current*
Current	0.407	100.0%	53.85%	100.0%	8396.46	100.0%
EXAKT applied	0.221 (0.692)	54.35%	9		7098.62	84.54%
Fitted EXAKT applied	0.207 (1.211)	51.00%	9		7564.54	90.09%
EXAKT***	0.378 (0.692)	92.99%	98.79%	183.46%	3326.40	39.62%
Replace at failure only***	1.522 (No Limit)	374.19%	0.0%	0.0%	3941.95	46.95%

* percentage of Current policy; ** mean time between replacements; *** from EXAKT model; ( ) risk level

About 7% improvement

We will check two extreme edges of the envelope bounding our uncertainty. We are uncertain of the data in our sample with regard to the undecided histories.

Therefore we will perform the CBM effectiveness calculation under two assumptions.

Table A assumes that the undecided lifetimes ended by preventive replacement (suspension) at the end of the sample window.

EXAKT applied:
The cost of the policy obtained from applying the optimal model retroactively to the sample.
Fitted EXAKT applied: The curve of the EXAKT decision chart is fitted to the actual data; so as to minimize "average" realized cost. (That is using a model build on this data sample.)
EXAKT: The theoretical "expected" cost effectiveness of the EXAKT model.
Replace at failure: The policy of not using any proactive (neither scheduled nor on-condition) maintenance

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Examine Cost Summary Table B

B: Summary of Cost Comparison with Current Policy (undecided histories not counted)

Policy	Cost per unit time	Compared to Current*	Prev. Replac.	Compared to Current*	MTBR**	Compared to Current*
Current	0.501	100.0%	33.33%	100.0%	8786.67	100.0%
EXAKT applied	0.331 (0.692)	66.08%			5439.50	61.91%
Fitted EXAKT applied	0.278 (0.106)	55.59%			6035.50	68.69%
EXAKT***	0.378 (0.692)	75.54%	98.79%	296.36%	3326.40	37.86%
Replace at failure only***	1.522 (No Limit)	303.96%	0.0%	0.0%	3941.95	44.86%

* percentage of Current policy; ** mean time between replacements; *** from EXAKT model; ( ) risk level

About 24% improvement

Now we recalculate with the assumption that the undecided histories have no bearing on CBM effectiveness. In this calculation all lifetimes ending in temporary suspension are omitted from the sample.

Table B provides the other extreme assumption. While Table A assumed that histories that are at present incomplete will have been (successfully) preventively replaced by the proposed decision model, Table B simply ignores the incomplete histories. One may consider the assumptions of A and B as defining the envelope of possibilities of future performance of the model. If both provide satisfactory results (in the columns "Compared to Current"), we may confidently estimate the value of the proposed CBM policy and apply the model going forward.

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Conclusions

1. The preceding analysis provides a way to judge the potential **benefits** of a proposed CBM policy.
2. It provides an **objective** way to track and compare CBM performance in different calendar periods.
3. It uses a range of assumptions to probe the robustness / credibility of the proposed CBM decision model.
4. Tables A and B suggest improvement of 25 to 50%, indicating that we can **expect** an average improvement (over the current policy) of 33%.
5. It is a statistically robust method for demonstrating the **value**, (profitability) resulting from a given CBM policy.
6. The "living" RCM methodology enables such decision support by ensuring the **quality** of EAM history data.

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