Decision Trees, EMV and Thee [1]

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In my previous two **PMWJ** Advisory articles, **Benefit/Cost analysis** was presented as a systematic technique to determine whether a ***particular approach*** was worth the ***monetary cost*** in terms of a **Benefit/Cost Ratio;** whereas **Cost:Effectiveness analysis** was for **comparing** the relative benefit of ***two or more options*** in terms of ***subjective*** **effectiveness**, where either or both the benefit and the cost were in non-monetary terms. **Decision Tree analysis** is another useful quantitative Planning Phase[2] technique in the **Benefit-Cost-Effectiveness** trilogy in project situations where ***several alternatives*** – *i.e. not just Plan A, but also Plans B[3], C, D, E or whatever* – are under consideration (and in contention) to achieve a particular objective, and:

1. ***Both benefits and costs are monetary***, and the
2. ***Benefit/Cost Ratio*** is in terms of ***Expected Monetary Value (EMV)***.[4]

Decision Tree Analysis attempts to take the major risk factors into consideration — both ***negative*** and ***positive*** — into consideration in all options, depicting them in a complex multi-stage decision process as a series of steps, then systematically quantifies and weighs alternate approaches to select the best option under pre-selected conditions of uncertainty before deciding on a particular course of action. Such step-by-step clarification is helpful — even when all the data for completing the analysis are not readily available. Project options are usually both numerous and complex and the best choice is not readily apparent, so ***systematic analysis is usually better than no analysis at all***. Even when -- superficially -- one choice appears to be better than others, taking the time to do some systematic analysis is also helpful, as frequently there are hidden issues; and apparent options are sometimes counter-intuitive. This is where active team participation and brain-storming really pays off.

As its name implies, Decision Tree Analysis identifies various project options in a ***graphic format*** as a tree – actually a 'fallen tree' – then is developed further in the following manner:

[1] How to cite this article: Smith, K. F. (2021). Decision Trees, EMV and Thee, *PM World Journal*, Vol. X, Issue X, October.

[2] The technique can also be used during Program Evaluation to update prior assumptions about probabilities after some experience has been gained, to reassess the likelihood of an actual project outcome, in order to determine the relative merits of an on-going program.

[3] On a humorous note: There is a **company** in **Bangkok --** as well as a **bar** in Metro Manila -- named "**Plan B**"!

[4] **The Decision Tree technique can also be used to estimate the size of a project management reserve schedule & cost buffer** based on an assessment of risk probabilities and impacts -- as outlined in my September 2020 PMWJ article: Smith, K. (2020). Risk Exposure, Murphy's Law & Management Reserve, *PM World Journal*, Vol. IX, Issue IX, September. https://pmworldlibrary.net/wp-content/uploads/2020/08/pmwj97-Sep2020-Smith-risk-exposure-murphys-law-and-management-reserve.pdf

1. A series of anticipated events and expected consequences for the "**normal**" situation ***(i.e. without the project)*** is first outlined as a process flow chart, with bars and milestones.
2. Several ***hypothetically feasible alternatives*** are then developed — represented as parallel branches.
3. Each branch is further sub-divided at key milestones, according to the criteria and weights specified by the team or decision-maker, in conjunction with technical specialists.
4. The **probabilities** of each event occurring and **relative outcomes** are then estimated together with their monetary value.
5. The alternate paths are then computed to determine the expected "payoffs" for each option.
6. From this process, the most appropriate alternative should then become more apparent.

Once the various tree options have been established, **Sensitivity Analysis** trials can also be conducted to examine how susceptible particular aspects might be to fluctuations — and hence the extent to which they are able to withstand drastic deviations from "normal" expectations. From such an analysis the more robust option(s) can be determined, recommended and/or selected for adoption.

In essence, ***if the major aspects of a situation can be quantified,*** a systematic process can be used to conduct repetitive ***"what if"*** simulation trials. The **biggest drawback** of course is that the ***probabilities of different future events and impacts are often difficult if not impossible to obtain*** — or even, sometimes, to get anyone to estimate. Hence — although the results can be refined somewhat through simulation trials and sensitivity analysis -- the **reliability** of the decision is ***often questioned*** &/or questionable. Thus, **because the choice is being made systematically, the manager may be falsely reassured** — but the choice may be for the wrong option. Nevertheless, since no-one can forecast the future accurately, we do the best we can!

The step-by-step procedure is detailed below.

12 Step Decision Tree Analysis Procedure

Decision Tree Analysis is essentially a twelve (12) step process, as follows:

1. Describe the 'Normal' BASELINE Situation (but Ignore the costs involved)

a. Make an initial starting point "node".

b. Make a "Branch" from the starting point node to represent the Baseline situation. [Ignore the Cost of the Baseline Situation]

2a. Identify and Construct Possible Alternatives as first Stage Branches

a. Identify any Alternatives being considered.

b. Make a separate branch from the starting point node to represent each of the alternatives being considered.

c. Note on the branch the **Additive Cost** of each alternative over the baseline situation.

3. **Identify the Results Expected from the Baseline and each Alternative**

   a. Describe the Expected Results of each branch (baseline and alternatives) and depict them as separate nodes on each of the branches.

4. **Identify an initial Risk Situation to the Baseline**

   a. Describe the Risk to the baseline and depict it as an additional branch after the Expected Results node.

   b. Replicate the Risk as an additional branch for each alternative after each of their Expected Results nodes.

5. **Estimate the Probability of the Risk Situation Occurring**

   a. Estimate the probability of the risk occurring.

   b. Add a node to the baseline and each alternative event branches and write the probability as a percentage.

   c. Add another branch and node to the baseline and each alternative event from the Expected Results nodes and write the probability of the Risk NOT Occurring as a percentage.

   d. Verify that the probabilities for all risk branches emanating from any node sum to 100%. *[i.e. If the probability for a risk Occurring is 65%, then the probability of it Not Occurring will be 35% = 100% – 65%.]*

6. **Replicate these probabilities to all alternative branches**

   If appropriate, Identify and Construct Successive Stage Risk Events

   a. Identify other Risks that could affect the outcome of the Baseline and initial alternatives.

   b. Add these Risks as second-stage branches to each of the probability nodes.

   c. Add another branch and node to the baseline and each alternative event from the previous probability nodes and write the probability of the Risk NOT Occurring as a percentage.

   d. Repeat the process for successive Risks

7. Estimate the Expected Outcome for each Branch

a. Estimate the Monetary Value of each outcome which would result from each branch – i.e. with and without the risk occurring.

8. Calculate the Anticipated Payoff (i.e. the Net Benefit) for each Possible Outcome

a. Multiply the value at each Expected Outcome node by the probability that the risk event will occur.

[For example, a $20 Expected Outcome with a 50% probability of occurrence results in a weighted Anticipated Payoff of $10]

b. Record this result as a weighted monetary value on a node at the right.

[If there are multiple risk events, repeat the process by multiplying this weighted value by the probability a secondary risk will occur.]

c. **This is the TOTAL BENEFIT.**

d. Subtract the ADDITIVE COST of the Alternative.

e. **The Result is the NET BENEFIT.** Record this value at the end of the path in a box at the far right of the chart.

9. Calculate the Expected Monetary Value (EMV) for the Baseline and Each Alternative

a. **WORK BACKWARDS** — i.e. from right to left — and Multiply the NET BENEFIT of Each Outcome by its Probability, to get an ***Expected Monetary Value (EMV)*** to that point.

b. Total the Expected Monetary Values for each node.

c. Continue this process until you get back to the initial alternative branch nodes.

10. Calculate the Benefit:Cost Ratio for an Alternative compared to the Baseline

a. Compute the Benefit:Cost Ratio for an alternative using the following formula:

$$\text{Benefit:Cost Ratio of Plan “A”} = \frac{(\text{Expected Value of Plan “A”} - \text{Expected Value of Baseline})}{\text{Cost of Plan “A”}}$$

*[**Note: Benefits are “additive”** — i.e. the increment over the baseline.]*

11. Repeat for All Alternatives

12. Select the "Best" Option

Review the data in the boxes and on the paths to select the "Best" option, given the most appropriate criteria for the situation:

1. **The Highest Payoff;**
2. **The Lowest Cost,** ***or***
3. **The Highest Benefit:Cost Ratio.**

DECISION TREE ANALYSIS CAN BE APPLIED IN A WIDE VARIETY OF SCENARIOS. The following three -- ***hypothetical*** **-- examples illustrate the basic elements of the decision-tree process and its analysis.**

1. ALTERNATIVES FOR A LIVESTOCK FATTENING PROJECT

BASELINE PROGRAM OBJECTIVES: 1. One Year Livestock Fattening of 100 Calves
2. Year-old cattle will be sold for $300 each

ANTICIPATED PAYOFF

PROGRAM OPTIONS	Expected Result after 1st 3 months	Risk Situation Probability in remaining time	Expected Outcome After 1 year	Total Cost* 000's	Total Benefit 000's	Net Benefit 000's
BASELINE	60 Survive	Disease 30%	10 Survive	$0	$3	$3
		No Disease 70%	60 Survive	$0	$18	$18

NOTE: Baseline Cost is treated as '0'** ***for simplicity in computing, and to highlight comparisons **it is not factored into the comparative analysis -- only subsequent additive costs**

EXPECTED MONETARY VALUE (EMV) = $13.5 ***[See below how calculated]***

CALCULATED as follows: ***WORK BACKWARDS and***

MULTIPLY NET BENEFIT x PROBABILITY & ADD **[for 100%]**

EXPECTED MONETARY VALUE of Baseline Situation =

(Net Benefit for Disease x 30%) + (Net benefit for No Disease x 70%)
($3 x .3) + ($18 x .7)
= **$0.9** + **$12.6** = **$13.5**

PLAN "A"

PROGRAM OPTIONS	Expected Result after lst 3 months	Risk Situation & Probability in remaining time	Expected Outcome After 1 year	Total Cost* 000's	Total Benefit 000's	Net Benefit 000's
				ANTICIPATED PAYOFF		
PLAN "A" VACCINATION	75 Survive	Disease 30%	55 Survive	$1	$16.5	$15.5
		No Disease 70%	75 Survive	$1	$22.5	$21.5
Added Cost: $1,000						

EXPECTED MONETARY VALUE (EMV) = $19.7 ***[See below how calculated]***

EXPECTED MONETARY VALUE OF PLAN "A" =

(Net Benefit for Disease x 30%) + (Net benefit for No Disease x 70%) \
($15.5 x .3) + ($21.5 x .7)
= **$4.59** + **$15.05** **= $19.64**
[Round up to 19.7]

BENEFIT : COST RATIO = 6.2 ***[See below how calculated]***

BENEFIT : COST RATIO OF PLAN "A" is:

$$\frac{\text{(Expected Value of Plan "A" - Expected Value of Baseline)}}{\text{Cost of Plan "A"}}$$

PLAN "B"

PROGRAM OPTIONS	Expected Result after lst 3 months	Risk Situation & Probability in remaining time	Expected Outcome After 1 year	Total Cost* 000's	Total Benefit 000's	Net Benefit 000's
				ANTICIPATED PAYOFF		
PLAN "B" VACCINATION + VITAMINS	90 Survive	Disease 30%	70 Survive	$2	$21	$19
		No Disease 70%	90 Survive	$2	$27	$25
Added Cost: $2,000						

EXPECTED MONETARY VALUE (EMV) = $23.2

EXPECTED MONETARY VALUE OF PLAN "B" =

(Net Benefit for Disease x 30%) + (Net benefit for No Disease x 70%)
($19 x .3) + ($25 x .7)
$5.7 + $17.5 = $23.2

BENEFIT : COST RATIO = 4.85

BENEFIT : COST RATIO OF PLAN "B" is:

(Expected Value of Plan "B" - Expected Value of Baseline)
Cost of Plan "B"

$23.2 - $13.5 [000's] / $2 = $9.7 / $2 = **4.85** **[Round up to 4.9]**

Thus, in Summary, for ease of comparison, the options are:

OPTION	ADDITIONAL COST ($000's)	EMV	BCR
Baseline	**n/a**	**$13.5**	**n/a**
Plan A	**$1**	**$19.7**	**6.2**
Plan B	**$2**	**$23.2**	**4.9**

For decision-making purposes – ***if investment funding beyond the baseline cost is available*** **– Plan "A" would be the best alternative for the available capital, while Plan "B" would provide the maximum return for the additional amount invested.**

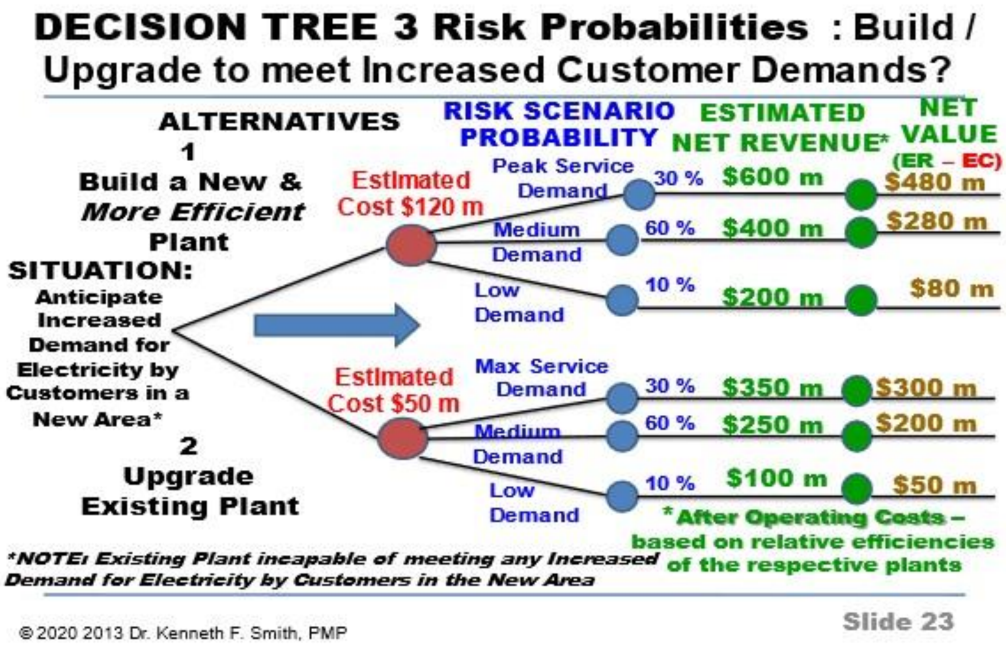
2. ALTERNATIVES FOR IMPROVING A POWER PLANT TO MEET ANTICIPATED INCREASED DEMAND

In this example, the Baseline Situation is no longer viable, so **only two options** are under consideration. Note also that the cost estimates for:

1. Building a new plant
2. Upgrading the existing plant,
3. Customer Demand, and
4. Revenues after operating costs

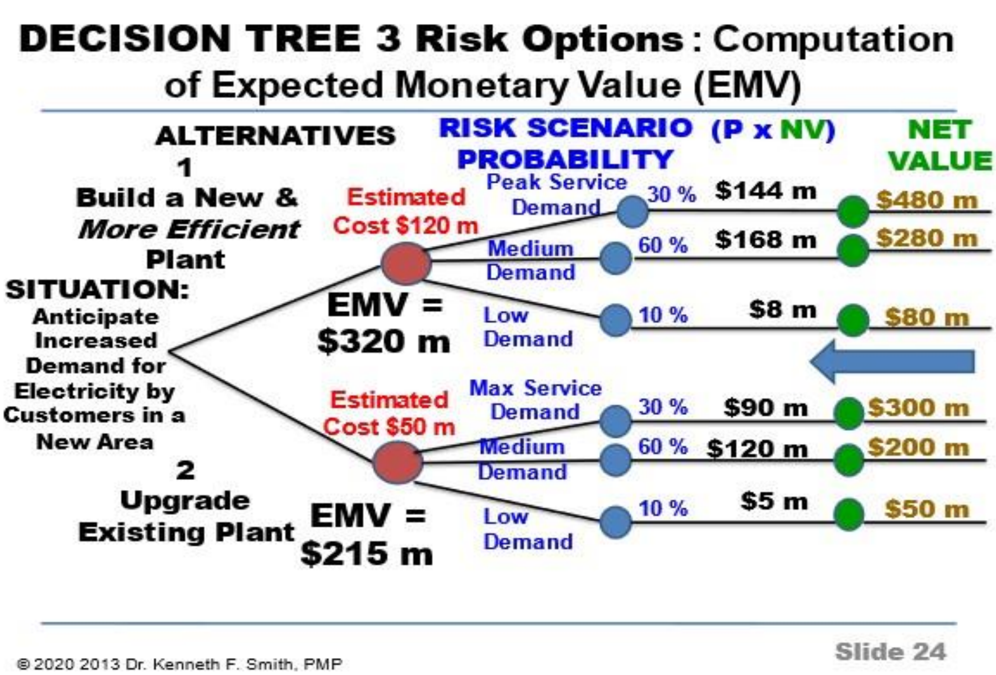
are each provided by different stakeholders from their own area of subject matter expertise.

FIGURE 1



[Note: This is an embellishment – *with a "Best Case, Most Likely Situation, and Worst Case" Risk analysis, and explanation* -- of an example provided in an earlier Project Management Institute (PMI) 'Guide to the Project Management Body of Knowledge' (PMBOK).**]**

FIGURE 2



The computations – by a program economist, or other team member -- are then routine.

The foregoing examples -- with a **single risk** scenario applicable -- illustrate the simplest form of decision tree analysis. **More complex** situations – i.e. ***with multiple risks across all options and templates to facilitate analysis --*** can be developed with this technique (such as the one illustrated on the following page), as well as the example in my aforementioned 'Buffering' article;[5] ***or even different risks applicable to some alternatives***; but they are beyond the scope of this article.

FIGURE 3

THE DECISION TREE ANALYSIS TECHNIQUE FOR COMPARING THE BENEFIT/ COST
& EXPECTED MONETARY VALUE (EMV) OF A BASELINE & UP TO FIVE ALTERNATIVE SCENARIOS
– Given Three Options for Inputs and up to Two Risks.
DECISION TREE ANALYSIS EXAMPLE - PHILIPPINE "Makasama" RICE PROJECT
Individual Small Farmer Production & Benefit/Cost Analysis
© 2020, [1999 Lotus 123], Excel 2013 Dr. Kenneth F. Smith, PMP
Enter Data in the Yellow Cells below. The BCR & EMV will then be calculated and appear in the Green Cells

			POSSIBLE STRATEGIES		COST	EXPECTED IMPACT	UNCONTROLLED RISK EVENTS	PROBA-BILITY	EXPECTED IMPACT
SUPPORT PRICE OF RICE / Cavan		600							
CURRENT YIELD: CAVANS/HECTARE		65	*QUANTITY*	*TYPE*					
HECTARES INVOLVED:		2	3	Bag Fertilizer per hectare	P3,600	100.00%	Locust / Pest infestation	30%	-60%
FARMERS INVOLVED:		100	6	Bags Fertilizer per hectare	P7,200	215.00%			
INPUT COSTS:							Typhoon	40%	-60%
Bag Fertilizer per hecta	Cost per bag	P600							
Can of Pesticide /ha	Cost per Ha Application	P500	1	Can of Pesticide /ha	P1,000	20.00%			

NOTE: ***ANALYSIS is on a PER FARMER Basis***

PROJECT		DESCRIPTION	EXPECTED YIELD FROM Bag Fertilizer per hectare ONLY	Fertilizer + PESTICIDE	PROBABILITY Locust / Pest NONE	EXPECTED YIELD CA/HA Locust / Pest NONE	PROBABILITY Typhoon NONE	EX YIELD CA/HA Typhoon NONE	NET BENEFIT [Sale-Cost]	EX VALUE BEFORE Typhoon	EX VALUE BEFORE Typhoon TOTAL	EX VALUE BEFORE Typhoon Locust / Pe	EX VALUE BEFORE Typhoon Locust / Pest	BENEFIT / COST RATIO Compared to BASE LINE
BASELINE SITUATION		**DO NOTHING NEW**	65	65	30%	26	40%	13.00	P15,600	P6,240	P24,960	P7,488	**P51,168**	
							60%	26.00	P31,200	P18,720				
					70%	65	40%	32.50	P39,000	P15,600	P62,400	P43,680		
							60%	65.00	P78,000	P46,800				
Alternative Combinations Considered														
ALTERNATIVE 1	3	Bag Fertilizer per hectare	130	130	30%	52	40%	26.00	P27,600	P11,040	P46,320	P13,896	**P98,736**	13.21
ADDED COST		only (Same as "G8")					60%	52.00	P58,800	P35,280				
P3,600.00					70%	130	40%	65.00	P74,400	P29,760	P121,200	P84,840		
							60%	130.00	P152,400	P91,440				
ALTERNATIVE 2	6	Bags Fertilizer per hectare	204.75	204.75	30%	81.9	40%	40.95	P41,940	P16,776	P71,424	P21,427	**P153,979**	14.28
ADDED COST		only (Same as "G10")					60%	81.90	P91,080	P54,648				
P7,200.00					70%	204.75	40%	102.38	P115,650	P46,260	P189,360	P132,552		
							60%	204.75	P238,500	P143,100				
ALTERNATIVE 3	3	Bag Fertilizer per hectare	130	156	30%	62.4	40%	31.20	P32,840	P13,136	P55,304	P16,591	**P118,203**	14.57
ADDED COST		(Same as "G8") plus					60%	62.40	P70,280	P42,168				
P4,600.00		PESTICIDES			70%	156	40%	78.00	P89,000	P35,600	P145,160	P101,612		
							60%	156.00	P182,600	P109,560				
ALTERNATIVE 4	6	Bags Fertilizer per hectare	204.75	245.7	30%	98.28	40%	49.14	P50,768	P20,307	P86,149	P25,845	**P185,215**	16.35
ADDED COST		(Same as "G10") plus					60%	98.28	P109,736	P65,842				
P8,200.00		PESTICIDES			70%	245.7	40%	122.85	P139,220	P55,688	P227,672	P159,370		
							60%	245.70	P286,640	P171,984				
ALTERNATIVE 5		Can of Pesticide /ha	65	78	30%	31.2	40%	15.60	P17,720	P7,088	P28,952	P8,686	**P60,402**	9.23
ADDED COST		only (Same as "G13")					60%	31.20	P36,440	P21,864				
P1,000.00					70%	78	40%	39.00	P45,800	P18,320	P73,880	P51,716		
							60%	78.00	P92,600	P55,560				

Conclusion

Remember, the Project Manager is not expected to be the expert to construct the decision tree for alternatives, but rather to appreciate and *recognize where an application is appropriate;* call for subject matter expertise to apply the process, and then oversee the stakeholder interaction to ensure the process is conducted as objectively and free from bias as possible.

[5] See Smith, K. (2020). Risk Exposure, Murphy's Law & Management Reserve, *PM World Journal*, Vol. IX, Issue IX, September. https://pmworldlibrary.net/wp-content/uploads/2020/08/pmwj97-Sep2020-Smith-risk-exposure-murphys-law-and-management-reserve.pdf

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Initially a US Civil Service Management Intern, then a management analyst & systems specialist with the US Defense Department, Ken subsequently had a career as a senior foreign service officer -- management & evaluation specialist, project manager, and in-house facilitator/trainer -- with the US Agency for International Development (USAID). Ken assisted host country governments in many countries to plan, monitor and evaluate projects in various technical sectors; working 'hands-on' with their officers as well as other USAID personnel, contractors and NGOs. Intermittently, he was also a team leader &/or team member to conduct project, program & and country-level portfolio analyses and evaluations.

Concurrently, Ken had an active dual career as Air Force ready-reservist in Asia (Japan, Korea, Vietnam, Thailand, Indonesia, Philippines) as well as the Washington D.C. area; was Chairman of a Congressional Services Academy Advisory Board (SAAB); and had additional duties as an Air Force Academy Liaison Officer. He retired as a 'bird' colonel. After retirement from USAID, Ken was a project management consultant for ADB, the World Bank, UNDP and USAID.

He earned his DPA (Doctor of Public Administration) from the George Mason University (GMU) in Virginia, his MS from Massachusetts Institute of Technology (MIT Systems Analysis Fellow, Center for Advanced Engineering Study), and BA & MA degrees in Government & International Relations from the University of Connecticut (UCONN). A long-time member of the Project Management Institute (PMI) and IPMA-USA, Ken is a Certified Project Management Professional (PMP®) and a member of the PMI®-Honolulu and Philippines Chapters.

Ken's book -- **Project Management PRAXIS** (available from Amazon) -- includes many innovative project management tools & techniques; and describes a "**Toolkit**" of related templates available directly from him at kenfsmith@aol.com on proof of purchase of PRAXIS.

To view other works by Ken Smith, visit his author showcase in the PM World Library at https://pmworldlibrary.net/authors/dr-kenneth-smith/