

REVIC II: Converting the REVIC Model to COCOMO II

Dan Strickland
Dynerics, Inc.
990 Explorer Blvd.
Huntsville, AL 35806
(256) 964-4619
daniel.strickland@dynerics.com

Nhuchi Khong
THAAD Project Office
ATTN: SFAE-AMD-THA
P.O. Box 1500
Huntsville, AL 35807
(256) 955-2084
khongn@thaad.redstone.army.mil

DISTRIBUTION A: Approved for public release; distribution unlimited.

REVIC II: Converting the REVIC Model to COCOMO II

Webster's New College Dictionary defines a synapse as "the point at which a nerve impulse is transmitted from an axon of one neuron to another." The synapse acts as a bridge, carrying information between two distinct cell bodies to make the system work as a whole. Like the synapse, connecting the software cost models Revised Intermediate COCOMO (REVIC) and Constructive Cost Model (COCOMO) II results in a system that can use the distinct benefits of both models. In cost scenarios where REVIC calibrations are an accurate starting point and there is a need to use the flexibility of the COCOMO II, REVIC II provides the connection between the two models.

The REVIC Model

REVIC is a software cost and schedule model calibrated using data from Department of Defense (DoD) projects. REVIC 9.2 is based on the Intermediate COCOMO model developed by Dr. Barry Boehm [BOE81, KIL94, RKK97]. Where COCOMO was calibrated using commercial, government, and military projects, REVIC uses completed DoD projects only. As a result, the REVIC calibrations for each software development mode are as follows:

(Organic)

$$PM = 3.4644 * (SIZE)^{1.05} * \Pi (\text{Environmental Factors})$$

$$TDEV = 3.65 * (PM)^{0.38}$$

(Semidetached)

$$PM = 3.97 * (SIZE)^{1.12} * \Pi (\text{Environmental Factors})$$

$$TDEV = 3.8 * (PM)^{0.35}$$

(Embedded)

$$PM = 3.312 * (SIZE)^{1.2} * \Pi (\text{Environmental Factors})$$

$$TDEV = 4.376 * (PM)^{0.32}$$

The schedule and effort exponent values of COCOMO and REVIC are the same, but the difference in calibration data causes differences in the models' schedule and effort multipliers as shown in Table 1.

Table 1: REVIC and COCOMO Multiplier Comparisons

	Effort Multiplier		Schedule Multiplier	
	REVIC	COCOMO	REVIC	COCOMO
Organic	3.4644	3.2	3.65	2.5
Semidetached	3.97	3	3.8	2.5
Embedded	3.312	2.8	4.376	2.5

The development phases of the REVIC software lifecycle include the traditional COCOMO phases with additional Requirements and Development Test and Evaluation (DT&E) phases. Like COCOMO, REVIC distributes the effort and schedule based on percentages. The REVIC percentages by phase are listed in Table 2.

Table 2: REVIC Phase Distribution

Phase	Effort	Schedule
RQ	12%	30%
PD	23%	39%
DD	29%	25%
CT	22%	15%
IT	26%	21%
DT	22%	28%

The Requirements and DT&E phases add an additional “tax” to the effort and schedule of the estimate. The total effort and schedule values are higher than the classic development phases (Preliminary Design through Integration and Testing), rising from 100% to 132% and 158% respectively. Any implementations of REVIC must incorporate the additional phases and percentages.

The first step in consolidating the COCOMO II and REVIC models is incorporate the additional phases and changes from REVIC into a COCOMO model. Since REVIC was based on the Intermediate COCOMO model, it is beneficial to see how to change the Intermediate/COCOMO 87 to produce REVIC model results. The DT&E phase is combined with the IT phase from COCOMO and can be extrapolated as needed. The DT&E phase adds 22% to the effort formula and 28% to the schedule formula of COCOMO 87. The base formulas become:

$$PM = (1.22) * A (SIZE)^B$$
$$TDEV = (1.28) * C (PM/1.22)^D$$

The formulas by Development Mode become:

(Organic)

$$PM = 4.227 * (SIZE)^{1.05} * \Pi (\text{Environmental Factors})$$
$$TDEV = 4.382 * (PM)^{0.38}$$

(Semidetached)

$$PM = 4.843 * (SIZE)^{1.12} * \Pi (\text{Environmental Factors})$$
$$TDEV = 4.562 * (PM)^{0.35}$$

(Embedded)

$$PM = 4.041 * (SIZE)^{1.2} * \Pi (\text{Environmental Factors})$$
$$TDEV = 5.254 * (PM)^{0.32}$$

The added phase forces a redistribution of the percentages for effort and schedule. If the software development phases for a REVIC model include Requirements through DT&E, the original REVIC percentages need to be recalculated to include two extra phases. The phase percentages, Requirements through DT&E, should sum to 100%. The new percentages can be expressed as:

$$\text{New Percentage} = (\text{Old Percentage} / 100 + \text{DT\&E addition})$$

The new phase distribution percentages for effort are shown in Table 3.

Table 3: COCOMO Effort Phase Distribution Including DT&E

Phase	Formula	New %
RQ	(12%/122%)	10%
PD	(23%/122%)	19%
DD	(29%/122%)	24%
CT	(22%/122%)	18%
IT + DT&E	(48%/122%)	39%

Note that the IT and DT&E phases are combined for migration into COCOMO 87 models. The new phase distribution percentages for schedule are shown in Table 4.

Table 4: COCOMO Schedule Phase Distribution Including DT&E

Phase	Formula	New %
RQ	(30%/128%)	23%
PD	(39%/128%)	30%
DD	(25%/128%)	20%
CT	(15%/128%)	12%
IT + DT&E	(49%/128%)	38%

REVIC uses the COCOMO 87 cost drivers with a few exceptions. REVIC uses Requirements Volatility (RVOL), Platform Risk (RISK), and Virtual Machine Volatility (VIRT) as additional cost drivers to the COCOMO 87 set. VIRT replaces Virtual Machine Volatility: Host (VMVH) and Virtual Machine Volatility: Target (VMVT). The values for these cost drivers are shown in Table 5 below.

Table 5: Additional REVIC Cost Driver Values

	XL	VL	LO	NM	HI	VH	XH
RVOL	0.00	0.00	0.91	1.00	1.19	1.38	1.62
RISK	1.00	1.20	1.40	1.60	1.80	2.00	2.20
VIRT	0.00	0.00	0.87	1.00	1.15	1.30	1.49

RVOL is a measure of the product design and development rework resulting from changes in the software requirements. RISK allows for a higher cost associated with extra work due to the software platform (Ground systems, manned airborne systems, etc.). VIRT is the amount of changes made in target and host computer systems combined during design and development phases.

The changes to the cost drivers, the addition of the DT&E software development phase, and the difference in cost/schedule multipliers differentiates the REVIC model from its COCOMO 87 counterpart.

REVIC II Single Model

The REVIC II Single Model replicates the calibration of REVIC using the flexibility of COCOMO II in a single model. Since REVIC cost/schedule multipliers and exponents are based on development mode, a way of replicating the modes in COCOMO II is needed for the single model to work. The REVIC software development modes can be replicated through manipulation of the COCOMO II Skill Factors, as noted in *The Rosetta Stone: Making COCOMO 81 Files Work With COCOMO II* [REI98]. Since COCOMO II has updated the Cost Drivers to reflect modern programming practices, it is beneficial to keep them unchanged in the REVIC II model [BOE97].

The *Rosetta Stone's* suggested values for Scale Factors to replicate the COCOMO 87 (and REVIC) development modes are shown in Table 6.

Table 6: Rosetta Stone Suggested Scale Factors

	Organic	Semidetached	Embedded
PREC	XH	H	L
FLEX	XH	H	L
RESL	XH	H	L
TEAM	XH	VH	N
PMAT	MODP	MODP	MODP

The COCOMO II formulas for cost and schedule are shown below:

$$PM = 2.94 * EAF * (SIZE)^{(0.91 + 0.01 * \Sigma \text{Scale Factors})}$$

$$TDEV = 3.67 * \text{Effort}^{(0.28 + 0.002 * \Sigma \text{Scale Factors})}$$

Assuming a MODP artifact value of NM, the sum of the Scale Factors mapped to the development modes would be 4.68 for Organic, 13.12 for Semidetached, and 22.63 for Embedded. The resulting COCOMO II equations would be:

(Embedded) $PM = 2.94 * EAF * (SIZE)^{(1.136)}$
 $TDEV = 3.67 * \text{Effort}^{(0.325)}$

(Semidetached) $PM = 2.94 * EAF * (SIZE)^{(1.041)}$
 $TDEV = 3.67 * \text{Effort}^{(0.306)}$

(Organic) $PM = 2.94 * EAF * (SIZE)^{(0.957)}$
 $TDEV = 3.67 * \text{Effort}^{(0.289)}$

The formulas produced by the *Rosetta Stone* are geometrically and exponentially lower than the REVIC counterparts. The difference is probably due to the change in model exponent multipliers. In the COCOMO II.1999.0 model, the effort formula is:

$$PM = 2.94 * EAF * SIZE^{(0.91 + 0.01 (\Sigma \text{Scale Factors}))}$$

$$TDEV = 3.67 * TDEV^{(0.28 + 0.02 (\Sigma \text{Scale Factors}))}$$

As opposed to the original COCOMO II model's effort formula:

$$PM = 2.94 * EAF * SIZE^{(1.01 + 0.01 (\Sigma \text{Scale Factors}))}$$

$$TDEV = 3.67 * TDEV^{(0.28 + 0.02 (\Sigma \text{Scale Factors}))}$$

The difference in models causes a need to use different values for the Scale Factors to replicate the REVIC development modes.

The exponent values for the cost and schedule formulas in COCOMO II are dependent on the sum of the Scale Factors. In COCOMO II, the cost and schedule exponent values are directly proportional to the sum of the Scale Factors and to each other. However, in REVIC, the Organic mode has the smallest cost exponent and the largest schedule exponent of the three development modes. The REVIC Embedded mode has the largest cost exponent and the smallest schedule exponent of the three modes. In order to get a single model that can represent the REVIC modes via Scale Factor manipulation, the cost and schedule exponent formulas must be in an inversely proportional relationship. The schedule and effort exponents can be expressed in the form:

$$X + Y * (\Sigma \text{Scale Factors}) = \text{effort exponent}$$

$$A + B * (\Sigma \text{Scale Factors}) = \text{schedule exponent}$$

The target effort exponents are 1.2 (Embedded), 1.12 (Semidetached), and 1.05 (Organic). The target schedule exponents are 0.32 (Embedded), 0.35 (Semidetached), and 0.38 (Organic). If X and Y remain in

their original COCOMO II forms (0.91 and 0.01 respectively), the following equations for the REVIC development modes are solved:

$$\begin{aligned} 0.91 + 0.01 (SF1) &= 1.2 \text{ (Embedded)} \\ 0.91 + 0.01 (SF2) &= 1.12 \text{ (Semidetached)} \\ 0.91 + 0.01 (SF3) &= 1.05 \text{ (Organic)} \end{aligned}$$

as:

$$\begin{aligned} SF1 &= 29 \text{ (Embedded)} \\ SF2 &= 21 \text{ (Semidetached)} \\ SF3 &= 14 \text{ (Organic)} \end{aligned}$$

The sum of Scale Factors values used in the effort and schedule equations for the three development modes yields the following six equations:

$$\begin{aligned} X + 29Y &= 1.2 \text{ (Embedded Effort)} \\ X + 21Y &= 1.12 \text{ (Semidetached Effort)} \\ X + 14Y &= 1.05 \text{ (Organic Effort)} \\ A + 29B &= 0.32 \text{ (Embedded Schedule)} \\ A + 21B &= 0.35 \text{ (Semidetached Schedule)} \\ A + 14B &= 0.38 \text{ (Organic Schedule)} \end{aligned}$$

The above can be solved for four unknowns using matrix division. The result is:

$$\begin{aligned} X &= 0.91 \\ Y &= 0.01 \\ A &= 0.435 \\ B &= -0.004 \end{aligned}$$

Replacing the above values into the COCOMO II exponent equation produces the Scale Factor corrected REVIC II Single Model:

$$\begin{aligned} PM &= 2.94 * EAF * (SIZE)^{(0.91 + 0.01 * \Sigma \text{Scale Factors})} \\ TDEV &= 3.67 * PM^{(0.435 - 0.004 * \Sigma \text{Scale Factors})} \end{aligned}$$

Table 7 shows the corrected Scale Factor values for REVIC II.

Table 7: REVIC II Corrected Scale Factors

	Organic	Semidetached	Embedded
PREC	HI	NM	VL
FLEX	HI	LO	VL
RESL	NM	NM	VL
TEAM	HI	LO	LO
PMAT	HI	NM	LO

The values for the sum of Scale Factors from Table 7 are 28.96 (Embedded), 21.07 (Semidetached), and 14.06 (Organic).

The addition of the DT&E phase from REVIC changes the REVIC II Single Model formula and the phase distribution. Assuming the REVIC values for DT&E (22% effort and 28% schedule), the same changes that were made to the COCOMO 87 model above can be made to REVIC II to add the DT&E phase. The phase distribution percentages are changed to match the schedule and cost percentages listed in Tables 3 and 4. The resulting formulas including DT&E schedule and effort are:

$$\begin{aligned} PM &= 3.59 * EAF * (SIZE)^{(0.91 + 0.01 * \Sigma \text{Scale Factors})} \\ TDEV &= 3.85 * PM^{(0.435 - 0.004 * \Sigma \text{Scale Factors})} \end{aligned}$$

The resultant formula is correct exponentially, but low geometrically. Since REVIC II Single Model only has one equation representing all modes, there is no way to use the correct REVIC multipliers, as each mode's multiplier is a different value. In the Embedded mode equivalent, REVIC II Single Model is 12.5% low in effort and 43% low in schedule. In the Semidetached mode equivalent, REVIC II Single Model is 34% low in effort and 30% low in schedule. The REVIC II Single Model Organic mode equivalent is 17% low in effort and 21% low in schedule. Since there is no clear correlation between the variable portion of the model (sum of Scale Factors) and the geometric multiplier, the yeoman's share of the work is left to the user. The corrected formulas would read:

$$PM = (EMM) * 3.59 * EAF * (SIZE)^{(0.91 + 0.01 * \Sigma \text{Scale Factors})}$$

$$TDEV = (SMM) * 3.85 * PM^{(0.435 - 0.004 * \Sigma \text{Scale Factors})}$$

where the mode multipliers are as shown in Table 8.

Table 8: Effort and Schedule Mode Multipliers

Mode	EMM	SMM
Embedded	1.125	1.43
Semidetached	1.34	1.3
Organic	1.17	1.21

The REVIC II Single Model replicates the calibration of the REVIC model in a single COCOMO II model. By adding the DT&E phase, setting the Scale Factors that match development modes, and changing the exponential portion of the schedule equation, COCOMO II can be changed to replicate REVIC.

REVIC II Multiple Model

The REVIC II Multiple Model captures the calibration of REVIC in a flexible COCOMO II environment using three separate models. For each of the development modes, a separate model is used with the Scale Factors set as before.

Correcting the effort and schedule exponential equations will calibrate the COCOMO II model to perform exponentially like REVIC. The exponents are expressed as:

$$X + Y * (\Sigma \text{Scale Factors}) = \text{effort exponent}$$

$$A + B * (\Sigma \text{Scale Factors}) = \text{schedule exponent}$$

Using the corrected REVIC II sum of Scale Factors values (Table 7) for the development modes, the cost and schedule exponent formulas are:

$$X1 + 29 * Y1 = 1.2 \text{ (Embedded Effort)}$$

$$X2 + 21 * Y2 = 1.12 \text{ (Semidetached Effort)}$$

$$X3 + 14 * Y3 = 1.05 \text{ (Organic Effort)}$$

$$A1 + 29 * B1 = 0.32 \text{ (Embedded Schedule)}$$

$$A2 + 21 * B2 = 0.35 \text{ (Semidetached Schedule)}$$

$$A3 + 14 * B3 = 0.38 \text{ (Organic Schedule)}$$

The values for all X's and Y's are kept at the default COCOMO II values of 0.91 and 0.01 respectively. If all A's are set to the default COCOMO II value of 0.28 and the schedule exponent formulas are solved for all B's, the result for REVIC II is:

$$0.28 + B1 (29) = 0.32 \text{ (Embedded Schedule)}$$

$$0.28 + B2 (21) = 0.35 \text{ (Semidetached Schedule)}$$

$$0.28 + B3 (14) = 0.38 \text{ (Organic Schedule)}$$

where

$$\begin{aligned} B1 &= 0.00138 \\ B2 &= 0.00333 \\ B3 &= 0.00714 \end{aligned}$$

In the REVIC II Multiple Model, there is a separate model for each development mode, eliminating the need to change the COCOMO II exponent formula to match REVIC. The REVIC II Multiple Model exponent-corrected formulas are:

$$\begin{aligned} (\textit{Embedded}) \quad & PM = 2.94 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 3.67 * PM ^ (0.28 + 0.00138(\Sigma\textit{Scale Factors})) \\ (\textit{Semidetached}) \quad & PM = 2.94 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 3.67 * PM ^ (0.28 + 0.00333(\Sigma\textit{Scale Factors})) \\ (\textit{Organic}) \quad & PM = 2.94 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 3.67 * PM ^ (0.28 + 0.00714(\Sigma\textit{Scale Factors})) \end{aligned}$$

The equations above are correct exponentially, but incorrect geometrically. Since the three development modes are represented through three separate equations, there is no problem with replacing the multipliers with the REVIC equivalents. The REVIC II Multiple Model formulas become:

$$\begin{aligned} (\textit{Embedded}) \quad & PM = 3.312 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 4.376 * PM ^ (0.28 + 0.00138(\Sigma\textit{Scale Factors})) \\ (\textit{Semidetached}) \quad & PM = 3.97 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 3.8 * PM ^ (0.28 + 0.00333(\Sigma\textit{Scale Factors})) \\ (\textit{Organic}) \quad & PM = 3.4644 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 3.65 * PM ^ (0.28 + 0.00714(\Sigma\textit{Scale Factors})) \end{aligned}$$

The REVIC II Multiple Model accounts for the REVIC DT&E phase in the same way as the Single Model. An extra 22% is added to the effort and 28% is added to the schedule. The REVIC II Multiple Model formulas including DT&E are:

$$\begin{aligned} (\textit{Embedded}) \quad & PM = 4.041 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 5.254 * PM ^ (0.28 + 0.00138(\Sigma\textit{Scale Factors})) \\ (\textit{Semidetached}) \quad & PM = 4.843 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 4.562 * PM ^ (0.28 + 0.00333(\Sigma\textit{Scale Factors})) \\ (\textit{Organic}) \quad & PM = 4.227 * EAF * (\textit{SIZE}) ^ (0.91 + 0.01(\Sigma\textit{Scale Factors})) \\ & TDEV = 4.382 * PM ^ (0.28 + 0.00714(\Sigma\textit{Scale Factors})) \end{aligned}$$

In REVIC II Multiple Model, the distribution percentages are changed to match the additional DT&E phase. Again, the effort and schedule distribution percentages are changed to match the percentages listed in Tables 3 and 4 above.

REVIC II Multiple Model replicates the REVIC model in a COCOMO II environment using three separate models. Since most COCOMO II tools offer a way to change the effort and schedule formulas, REVIC II Multiple Model puts the burden of responsibility on the tool, not the user.

Summary and Conclusions

REVIC II offers a solution for users who like the flexibility and modern software practices of COCOMO II, but need the DoD calibration and phasing of REVIC. REVIC II benefits programs that have used REVIC successfully in the past or defense software programs that don't have the luxury of past performance metrics for calibration. REVIC II offers both a Single Model and Multiple Model solution for converting REVIC to COCOMO II, preserving the calibration and phasing of the former. REVIC II provides a synaptic bridge between two successful software cost models.

References

[BOE81] Boehm, Barry W. (1981), *Software Engineering Economics*, Prentice-Hall, Englewood Cliffs, NJ.

[BOE97] Boehm, B., et. al., (1997), *COCOMO II.1999.0 Model Definition Manual*,
ftp://ftp.usc.edu/pub/soft_engineering/COCOMOII/cocomo99.0/modelman.pdf, University of Southern California, Los Angeles, CA.

[KIL94] Kile, Ray, (1994), *REVIC Software Cost Estimating Model User's Manual, Version 9.2*, Air Force Cost Analysis Agency, Arlington, VA.

[REI98] Reifer, Donald J., Barry W. Boehm, and Sunita Chulani (1998), "The Rosetta Stone: Making COCOMO 81 Files Work With COCOMO II," <http://sunset.usc.edu/TechRpts/Papers/usccse98-516/usccse98-516.pdf>, University of Southern California, Los Angeles, CA.

[RKK97] RKK Enterprises, (1997), *SoftEst Version 1.1*, Air Force Cost Analysis Agency, Arlington, VA.