COPROMO v0.3 Spreadsheet Reference Manual

The Constructive Process-Improvement Model (COPROMO) focuses on estimating the cost effectiveness of allocations of investment resources, like new technologies, to improve productivity.

COPROMO is a Software Engineering Senior Management strategic planning decision assistant model. It is supported by a technology impact evaluation tool and an implementation approach. The model is based on the use of COCOMO II[1] and CORADMO[2] as valuation mechanisms. The implementation approach uses a representative application from a domain of concern to the senior management, and the identification of technology drivers and time frames. One version of the tool, COPROMO 0.3, has been implemented and used in the evaluation the Knowledge Based Software Assistant[3].

COPROMO has a demonstrated approach, an adaptable implementation of an evaluation tool and supporting constructive models: COCOMO II.2000, an industry accepted parametric cost-estimation modeling; COPSEMO, the effort and schedule distribution model and CORADMO, the RAD techniques oriented extended schedule estimation model. CORADMO estimates the schedule (months, M), personnel (P), and adjusted effort (person-months, PM) based on the distribution of effort and schedule of the various phases done by COPSEMO, and the impacts of selected RAD-related schedule driver ratings on the M, P, and PM of each phase. Finally, the COPROMO contribution is that it shows estimated productivity improvement through technology impact evaluation.

1. Background and Rational

COPROMO is a different kind of “extension” than those in the previous sections. It is a systematic structured application of multiple models coupled with methods for indicating driver values.

As a strategic planning tool, COPROMO assesses the impact of proposed technology or process improvement investments. It uses industry accepted parametric models to evaluate the impact on a development project. In order to show impact, a baseline development project must be selected.

The current COPROMO 0.3 execution approach is to identify an application, time frames and specific technologies that are expected to impact productivity for the archetypal application over the time frames selected. The representative application should be one that is representative of the domain of concern of the senior management. The time frames should be long enough to have the selected technology mature and come into use, spanning at least eight to fifteen years. The specific technologies should be identifiable and have relatively clearly scoped, even if still evolving, definition and content. One of the technologies should always be the commercial and milieu specific (e.g. DoD) technologies that will evolve independently of the specific technologies.

The valuation model’s parametric drivers include COCOMO II’s effort scale factors and multipliers, which cover process, product, platform, personnel and project, and CORADMO’s drivers that modify estimated schedule and effort multipliers. Each of the drivers’ values are

[1] Constructive Cost Model, version II, 2000 calibration.

[2] Constructive RAD-schedule Model, a currently uncalibrated extension to COCOMO II.

[3] KBSA Report Ref & URL.

then gathered for the current baseline or assessed into the future using engineering judgement based on the assumed impacts of the selected, specific technologies.

All of the information on the drivers, their evolution over time and their rationale(s), are then inputted into a spreadsheet tool. The tool, called COPROMO 0.3, consists of multiple, parallel COCOMO II and CORADMO parametric model executions. The tool graphically displays each of the drivers' values over time to allow reasoning and discourse about their values and evolution over time. The tool also provides fields for the capture of the rationales for each of the drivers' values and evolution on the same page as the tabular and graphic display of values. Finally, the tool displays a comprehensive set of graphs showing the impact of the selected technologies over time for the issues of concern: effort, schedule and corresponding staffing level.

2. Relation To COCOMO II

As mentioned above, COPROMO is a USER of the COCOMO II, COPSEMO and CORADMO models. The full parametric model of COCOMO II is used in its entirety. The new "schedule (M) as a function of effort (PM or person months)" equation of COPSEMO is its primary contribution; however, the default distribution of effort and schedule to phases is also used. The entire CORADMO model, to the extent it was specified in 1999, is used by COPROMO. It has no additional drivers or calculations.

Because of the impracticality of invoking and controlling multiple instances of COCOMO II, COPSEMO AND CORADMO, COPROMO tools does not use any of them. Instead, it implements the core parts of the molds in spreadsheets. Its only additional capabilities are the abilities to enter driver values over time numerically; to display those values; and direct graphing of results.

3. Model Overview

The COPROMO logical model is essentially multiple parallel invocations of the COCOMO II, COPSEMO and CORADMO models. It is shown in Figure 5.35.

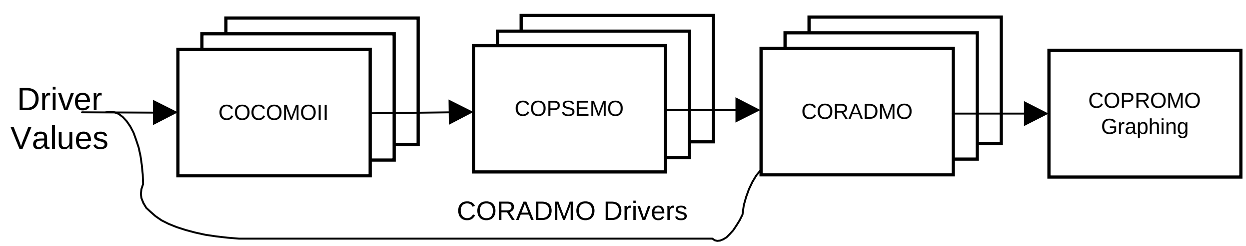


Figure 5.35 A Logical Model of COPROMO

COPROMO activities include identifying the domain of interest, an application archetype, initial driver values, time frames, and specific technologies. These activities are shown in a UML activity model in Figure 5.36.

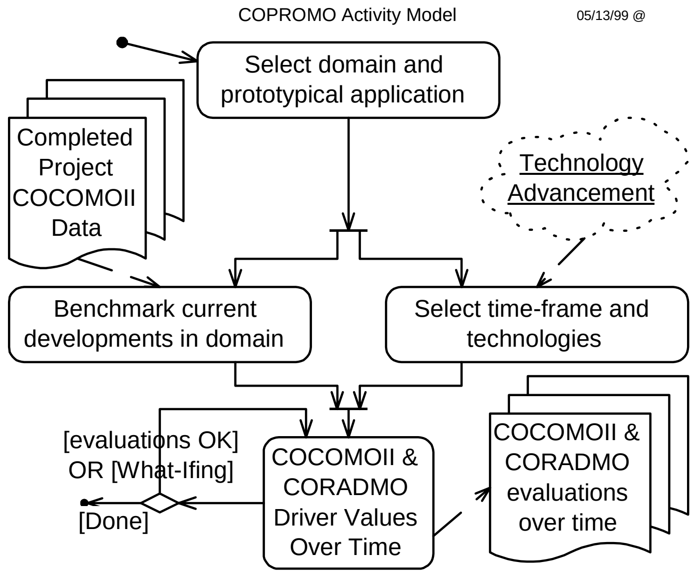


Figure 5.36 COPROMO Activity Model

One of the technologies should be the commercial and milieu specific (e.g. DoD) technologies that will evolve independently of the specific technologies identifiable and have relatively clearly defined, even if still evolving, content.

4. Scope And Lifecycle Presently Addressed

At present, the COPROMO Model covers the same scope as CORADMO. The CORADMO model presently excludes both COTS impacts (COCOTS) and the quality extensions (COQUALMO). CORADMO does include and use the COPSEMO model for effort and schedule re-distribution. However, the percentage allocations per phase are fixed (not allowed to vary over time or technology).

COPROMO currently has the same restriction on lifecycle models as CORADMO. While CORADMO is currently lifecycle model independent, since it works with data between anchor points, it expresses the phases using the MBASE/RUP lifecycle terminology. Only the first three phases, Inception, Elaboration and Construction are affected by CORADMO. These are the same three phases that COPROMO reports on.

At present there is only a single COPROMO point solution. It was developed to evaluate the lifecycle implication of the Knowledge Based Software Assistant (KBSA), an Air Force sponsored software engineering/development research program.

5. Model Details

This section discusses in more detail the activities and logical structuring of the models. COPROMO is as much method or technique as it is parametric model.

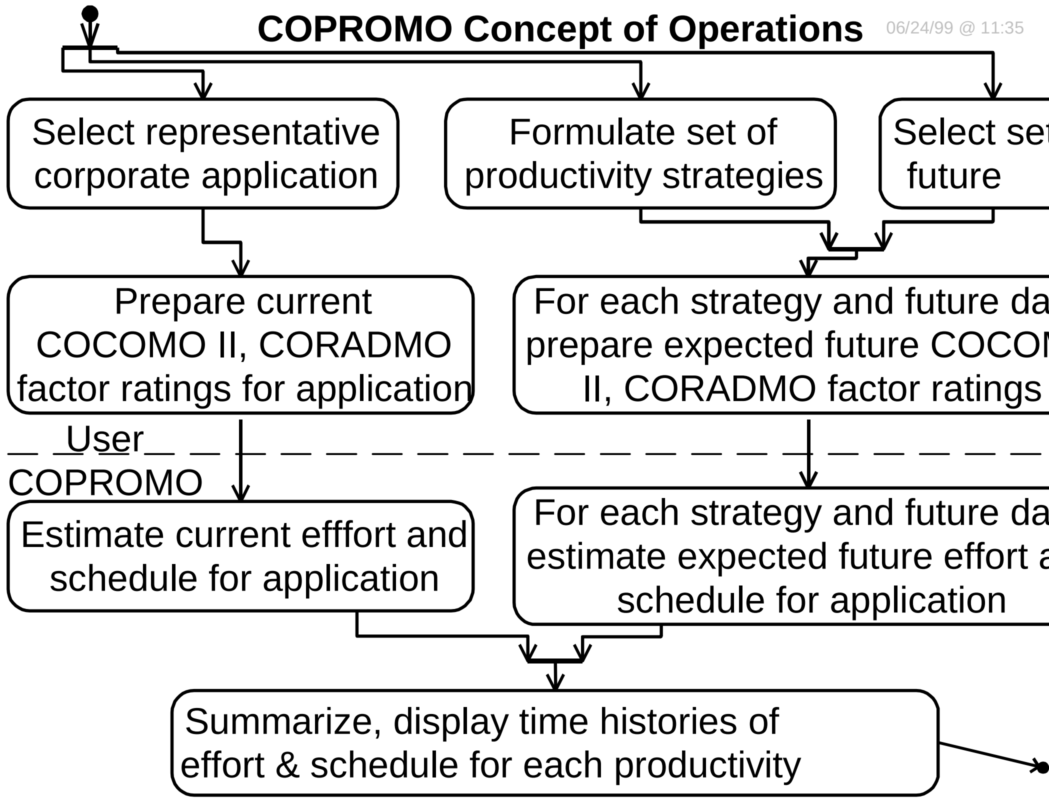


Figure 5.37 COPROMO Activities based on a Concept of Operations

The activities shown in Figure 5.37 represent the steps necessary to implement a COPROMO 0.3 estimation. Many can happen in parallel. Preparing the future ratings can only happen after both of its predecessors have been completed. Finally, the primary result, the summary of time histories, can only happen after both of its two predecessors have been completed.

Selecting the representative application should be on the organizational level for which the future productivity is desired. It should be representative of the domain on which that the organization focuses. It should be both typical and average for the sizes in both that domain and for the organization. The size range for the domain and organization should be plus or minus 50% of this average.

The productivity improvement strategies can include tools, techniques, or process improvements. They should be relatively clearly defined and understood. One "strategy" should encompass the expected commercial and milieu advances that will happen independently of any specially selected strategies.

The time frames for the future dates should be long enough to have technologies evolve and mature, if new technologies are involved in the estimation. In this case, the time frames would typically be eight and fifteen years. Other considerations depend on the life-cycle of the strategies, e.g. 2 to 3 years for a CMM-level process improvement increase. In the latter's case, the time frames might be 3 and 7 years.

Identifying the current COCOMO II and CORADMO driver ratings is essentially a benchmarking activity using recently completed projects. A COCOMO II should be performed for each of the completed projects, and a COCOMO II local calibration using all these projects would be wise too. An analysis of the ratings should be oriented towards selecting representative (or average) values which then become the baseline for the estimation.

To select the expected future COCOMO II driver ratings, a wide-band delphi [Boehm, 1981] is suggested. Initially, such phrases as "some", "moderate", "solid", "significant", and "major" might be used to describe the gains. This might be followed by agreements in the magnitude or percentage of increase or decrease corresponding to each of the driver values. Clearly, both the COCOMO II Scale Factors and Effort Multipliers must be specified. Also, the impacts on the SIZE of the product due to the strategies should be assessed. Since some of the strategies may be complementary or interfering, these situations should be taken into account too. Finally, both the driver values over time and their rationales should be recorded, preferably in the COPROMO 0.3 tool.

Similar selection activities should be undertaken for the expected COPSEMO distribution percentages and for the CORADMO drivers. At the present time, the COPSEMO distribution percentages are not variable over time, but clearly the CORADMO drivers, rightfully, are. Again, both the driver values over time and their rationales should be recorded, preferably in the COPROMO 0.3 tool.

After all the drivers and rationales have been entered into COPROMO 0.3, the spreadsheet summarizes the results of the parallel runs of COCOMO II and CORADMO. Summary charts of the time history of the drivers and the impact on effort and schedule are shown by the tool.

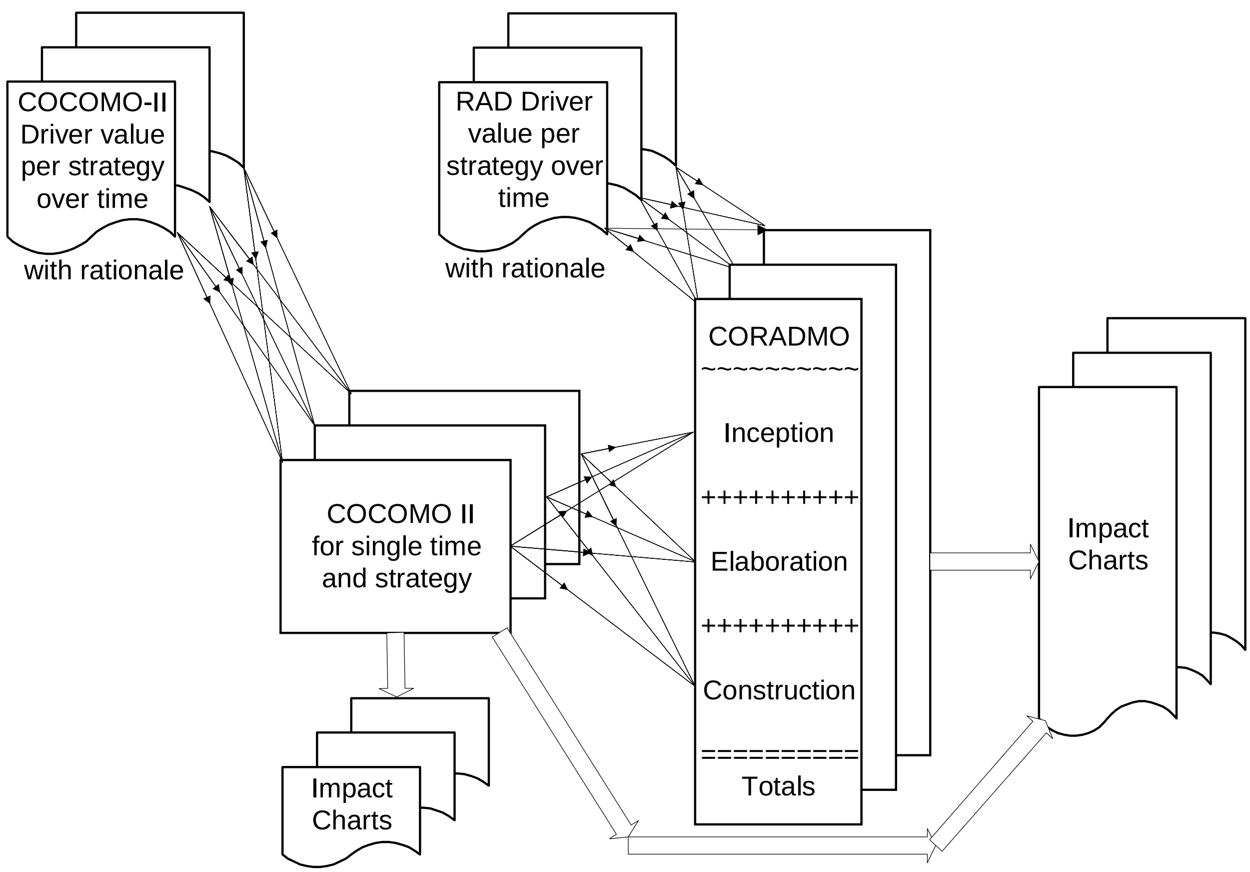


Figure 5.38 Evaluator logical structure

The above model shows the multiple COCOMO II (1) and CORADMO inputs (4). For COCOMO II, there are 24 parameters for each of the set of combinations of productivity improvement strategies at each of the dates selected. The 24 COCOMO II parameters include the five scale factors, the 17 effort multipliers, the schedule parameter, and size. In the example shown later, there are 13 combinations of strategies and dates, leading to a total of 312 parameters. For CORADMO, there are four new schedule drivers, with the fifth driver (RESL) having the same rating as it does in COCOMO II. Although the CORADMO tool does not support it, each of the five drivers can have different values for the different phases. The following table 5.38 indicates there are ten (10) different CORADMO drivers to be set. Again for the example shown later, there are 13 combinations of strategies and dates, leading to a total of 130 parameters representing the CORADMO driver ratings. There are an additional four more parameters for the COPSEMO effort and schedule distribution, however in COPROMO 0.3 these are held fixed over the combinations of strategies and dates.

CORADMO driver	**Multipliers per set of strategies**		**Phases per set of strategies**		**Multipliers and Phases per set of strategies**
	Number	Reason	Number	Reason	
RVHL	1	Schedule value = Effort value	2	Inception & Elaboration phases (No Construction impact)	2
DPRS	1	Schedule value = Effort value	2	Inception & Elaboration (=Construction)	2
CLAB	1	Schedule value = Effort value	3	Inception, Elaboration & Construction	3
RESL	1	Schedule value = Effort value	1	Only Construction	1
PPOS	2	separate Schedule & Effort values	1	Inception = Elaboration = Construction	2
				Total	10

Table 5.38 CORADMO Drivers

For each of the 13 set of combinations of productivity improvement strategies at each of the dates selected, there is a complete calculation of the COCOMO II.2000 effort and schedule (2) and CORADMO effort, schedule and staffing (5). The results of these calculations are used to produce the COCOMO II and COCOMO II plus CORADMO impact charts (3 and 6, respectively) of effort and schedule for review and analysis.

6. Spreadsheet Model Overview

The COPROMO 0.3 tool is a multi-worksheet Excel workbook that has been developed to show the impacts of the COCOMO II and CORADMO drivers projected over time and technology type on a selected domain's typically sized application. The first worksheet includes a description of all the other worksheets and the COCOMO II.2000 calibration values and ranges for reference. The other worksheets are for the COCOMO II and CORADMO driver inputs, calculation of their outputs, and graphical displays of the impacts.

The COPROMO 0.3 workbook also has several protected worksheets which are used for the detailed layout of the drivers to facilitate the graphs shown in the “Drivers” sections. There are also protected worksheets for the default values (i.e. the USC Center for Software Engineering assessed values) of the COCOMO II.2000 and CORADMO drivers.

The next sections identify the different worksheets, and identify their place in the Logical Structure of the COPROMO 0.3 Model (Figure 5.38).

6.1. COCOMO II Drivers, Calculations and Impacts

There are three sets of data in this grouping. The first, CII SF&EM Drivers, has the projected drivers over time. The second, CII SF&EM Data, aggregates the driver data and does the COCOMO II.2000 calculations. The third, CII E&S Impact, has graphs showing the effort and schedule impact of the COCOMO II.2000 drivers projected over time.

"CII SF&EM Drivers" shows assessed values for each of the drivers projected over time and the corresponding rationales. It allows the input of new values and additional or modified rationales. A graph of the current values of the driver projected over time is included; the data points on this graph change when new values are entered.

"CII SF&EM Data" has the assessed COCOMO II.2000 drivers, both scale factors and effort multipliers, organized in a compact, single page worksheet along with the calculations of the COCOMO II effort and schedule. The calculations use the COCOMO II.2000 model equations for effort and the COPSEMO equations for schedule (different schedule formulas for three ranges of months: 0 to 16; 16 to 64; and 64 and up). Each data column of the table performs the full set of COCOMO II.2000 calculations for a particular year and one technology-type combination.

6.2. CORADMO Drivers, Calculations and Impacts

Like the COCOMO II worksheets, there are three worksheets in this grouping. The first, RAD Drivers, has the projected drivers over time. The second, CORADMO Data, aggregates the driver data and does the CORADMO calculations. The third, RAD SM Impact, has graphs showing the resulting impacts of the COCOMO II.2000 and CORADMO drivers projected over time.

"RAD Drivers" has our assessed values for each of the CORADMO schedule multiplier drivers projected over time and our rationale, and also allows the input of new values and additional or modified rationales. A graph of the current values of the driver projected over time is included; the data points on this graph change when new values are entered.

"CORADMO Data" distributes the COCOMO II of effort and schedule to the various phases as specified in the COPSEMO model. The calculations use the COPSEMO model equations to distribute effort and schedule based on the selected percentage allocations and the schedule multiplier driver ratings. The worksheet aggregates the CORADMO drivers, both schedule and effort multipliers, organized in a compact, single page worksheet along with the calculations of the CORADMO effort and schedule per phase. Each PM & M pair of data columns of the table performs the full set of CORADMO calculations for a particular year and one technology-type combination.

"RAD SM Impact" has graphs showing the effort, schedule and Full-time Software Personnel (FSP) impacts of the entered CORADMO drivers projected over time and technology applied to the corresponding COCOMO II effort and schedule. All three impacts are shown for each phase (Inception, Elaboration, and Construction) since the CORADMO multipliers can impact both effort and schedule. The FSP values are then simply the result of dividing effort (in person months) of a phase by its duration (in months).

6.3. Technical Impact Final Results

At the end of the "RAD SM Impact" worksheet, following the RAD impacts by phase, are the summary charts for effort and schedule by technology over time that result from the COCOMO II and CORADMO driver changes over time. The data for these charts is actually shown on the second page of the "CORADMO Data" worksheet. The effort and schedule results are generated by adding the effort or schedule, respectively, for all three phases. Since COCOMO II.2000 only calculates the effort and schedule for development, a second set of summary charts was generated so the COCOMO II.2000 model results could be easily compared to the CORADMO model results. The second set of charts totals effort and schedule only for the Elaboration and Construction phases. Along with each chart are copies of the rows of the appropriate data from "CORADMO Data" worksheet.

7. Example of Use

While most of the elements of the **COPROMO 0.3** tool have been discussed, the following will help to put the detailed description of the **COPROMO 0.3** tool into perspective.

7.1. Example - AFRL Research Contract Objectives and Approach

The *objective*: A 1998 CSE research contract with the US Air Force Rome Laboratories was to develop and validate technical approaches for evaluating the effects of Knowledge Based Software Assistant (KBSA) process concepts and technology on software development effort and schedule, and to use these approaches to perform comparative evaluations of KBSA and other sources of software technology.

The research *approach* involved three tasks that provide background or are directly relevant to **COPROMO 0.3**.

Task 1. Characterize KBSA and other sources of software technology in the context of recent and emerging software trends.

We provided a summary of KBSA technology, concentrating on the KBSA Advanced Development Model developed by Andersen Consulting. We also summarized two other comparative sources of software technology: the commercial marketplace and the DARPA/AFRL Evolutionary Design of Complex Software (EDCS) program.

Task 2. Develop models and an evaluation framework for assessing the effects of KBSA and other sources of software technology on software development effort and schedule.

The recently developed and calibrated COCOMO II.2000 model provided an approach for evaluation based on the effects of alternative software technologies on the model's effort-driver parameters. The model's calibration to over 100 1990's software projects also provided a 1990's baseline from which to evaluate the technologies' effects.

For assessing schedule effects, another model, CORADMO, and its pre-processor COPSEMO, were used to evaluate the effects of rapid application development (RAD). The evaluation framework also included a domain focus: DoD warfighting systems; and a particular evaluation example: a representative embedded, high-assurance, real-time (EHART) missile software project. A spreadsheet version of the evaluation model, a precursor to

COPROMO 0.3, was also developed. This spreadsheet was designed to enable technology decision makers to perform tradeoff and sensitivity analyses of alternative software technology investment strategies.

Task 3. Use the models to evaluate KBSA, EDCS, and commercial technology with respect to the baseline.

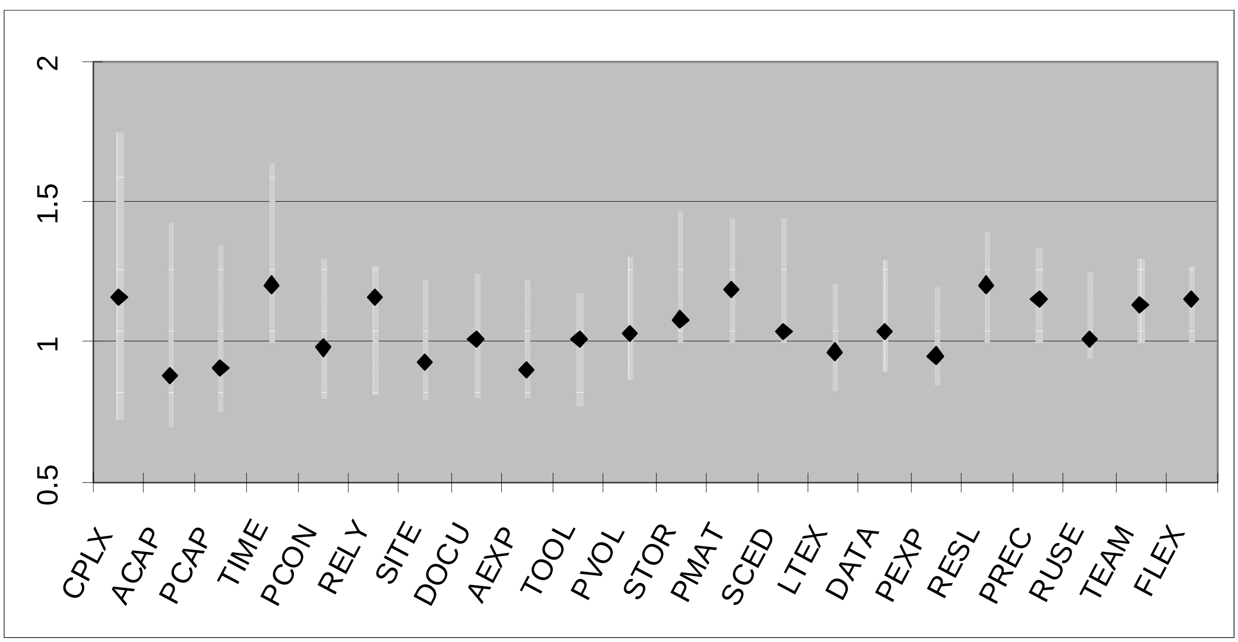
The primary result of the research compared the technologies' relative effects on development effort, using relatively conservative assumptions. It showed that commercial technology is likely to reduce development effort of the EHART 1998 baseline project by a factor of 2.5 in 8 years (2006) and another factor of 3 in 15 years (2013). Relative to commercial technology, a fully-supported mix of KBSA and EDCS technologies could reduce development effort by another factor of 3 in 8 years and another factor of 6 in 15 years.

7.2. Example's Values Used

Each of the major factors for the **COPROMO 0.3** evaluation of the KBSA and other technologies are described in this section.

Since the Knowledge Based Software Assistant was developed under a US Air Force contract, an embedded, high-assurance real-time (EHART) application was selected as the representative "corporate application". Such applications are critical to DoD weapons. Also, the commercial technology investment that is directly in this domain is relatively low. A typical size of 100K SLOC was selected.

As a baseline, a subset of 106 of the 161 1990's projects for which there is calibration data was selected. These 106 projects reflected current practice in the domains related to an EHART application (projects normalized for 100 KSLOC applications.) The range and average for the COCOMO II drivers is shown in Figure 5.39. The average values used as the baseline are shown in Table 5.39 and Table 5.40.



♦ Average Multiplier for 1990's projects

Figure 5.39 Productivity multipliers

SF	PREC	FLEX	RESL	TEAM	PMAT
Mean	3.06	3.15	3.97	2.7	3.72

Table 5.39

EAF	RELY	DATA	CPLX	RUSE	DOCU	TIME	STOR	PVOL	ACAP	PCAP	PCON	APEX	PLEX	LTEX	TOOL	SITE	SCED
Mean	1.06	1.04	1.16	1.01	1.01	1.08	1.03	1.03	0.88	0.91	0.98	0.9	0.95	0.97	1.01	0.93	1.04

Table 5.40

These are considered to be conservative ratings since those with well-collected data, data necessary for inclusion in the COCOMO II calibration set, are generally more advanced. This is also tempered by the fact that the average year of completion of the calibration data was 1994.

The selected dates for the example were 2006 and 2013. These relatively long time frames of eight and fifteen years were selected because of the recognition for how long it takes technologies like KBSA to be fielded and generally adopted.

The primary focus of the Productivity Improvement estimation was potential impact of the overall KBSA technology, not just the current version of the tool. The overall technology had two major components: application generation and knowledge based development project decision support. The application generation portion included the knowledge base domain engineering. The decision support capability is typical of emerging Software Engineering Decision Assistants concepts. A related software technology development activity was going on in the Evolutionary Development of Complex Systems (EDCS), and this technology was also factored in to the Productivity Improvement estimates.

The following named sets of combined technologies were selected for inclusion in the estimate:

CD: for the combination of Commercial technology and DoD general practice;

KG: for KBSA applications Generations technologies combined with CD;

KD: KBSA project Decision support technologies combined with CD;

K: for the combination of both KG and KD, because there might be synergies, and CD;

E: for the EDCS technologies combined with CD;

EK: both EDCS and KBSA (the full K), which also thus included CD.

The driver value selection and rationales that were developed were based initially on Dr. Barry Boehm's expert engineering judgment. Modifications were in the driver value selections made based on feedback from two knowledgeable and respected individuals. After the driver values had settled, the rationales were updated to reflect the consensus on the values.

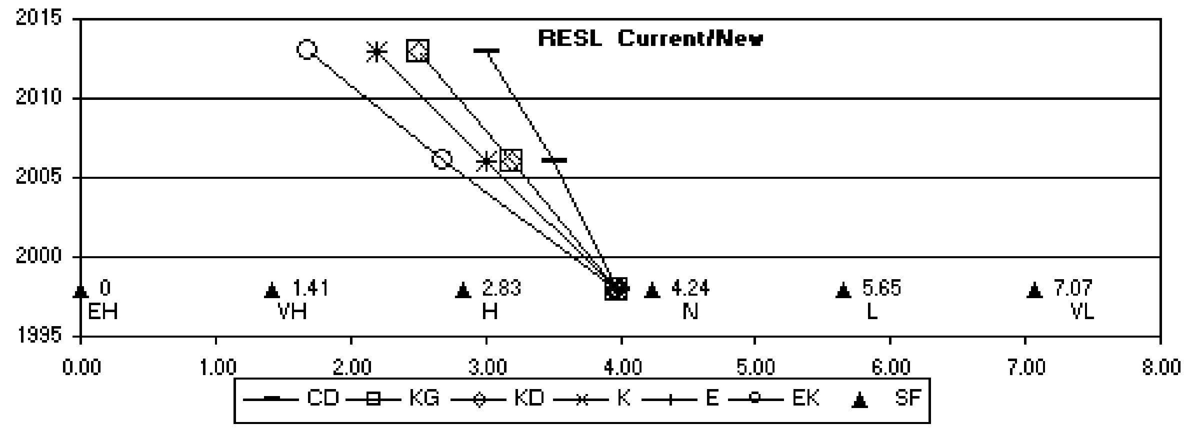
7.3. Examples of COCOMO Driver Ratings selections and Rationales

The next sections show a few of the driver ratings rationales as supported by the **COPROMO 0.3** tool.

7.3.1. *RESL: Architecture/Risk Resolution*

RESL: Architecture/Risk Resolution

Driver		Baseline	CD@+8	CD@+15	KG@+8	KG@+15	KD@+8	KD@+15	K@+8	K@+15	E@+8	E@+15	EK@+8	EK@+15
RESL	default	3.97	3.50	3.00	3.20	2.50	3.20	2.50	3.00	2.20	3.00	2.20	2.70	1.70
RESL	new													



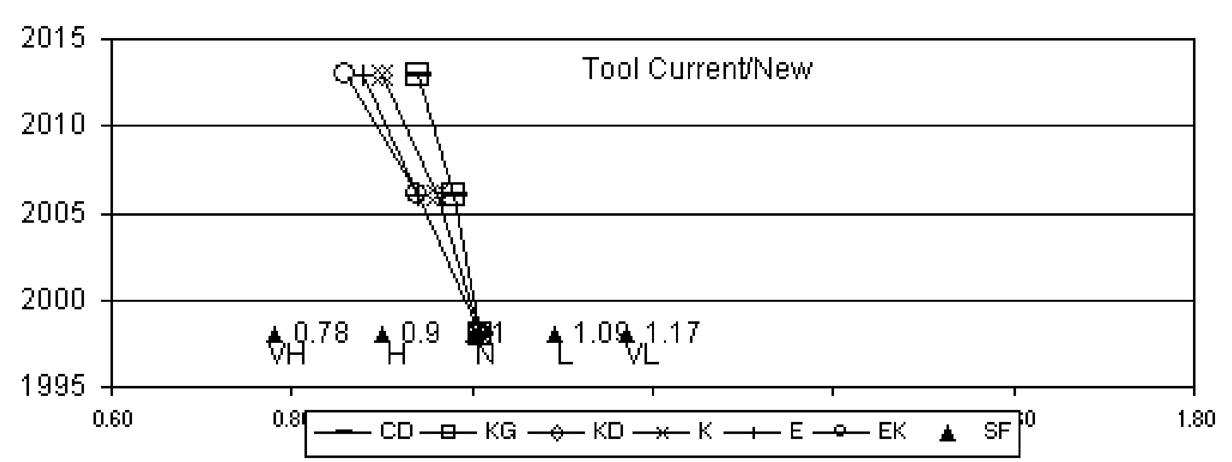
CD:	Significant gains due to open systems technology, commercial OO architecture technology and DoD emphasis on risk management
KG:	Significant additional gains over CD via domain architectures
KD:	Significant additional gains over CD via architecture and risk advisor technology
K:	Complementary gains from KG and KD
E:	Major additional gains over CD via domain architecture, general architecture technology, high assurance technology, and rationale capture
EK:	Complementary gains from E and K

Figure 5.40 RESL: Architecture/Risk Resolution

7.3.2. *TOOL: Use of Software Tools*

TOOL: Use of Software Tools

Driver		Baseline	CD@+8	CD@+15	KG@+8	KG@+15	KD@+8	KD@+15	K@+8	K@+15	E@+8	E@+15	EK@+8	EK@+15
TOOL	default	1.01	0.98	0.94	0.98	0.94	0.96	0.90	0.96	0.90	0.94	0.88	0.94	0.86
TOOL	new													



CD:	Significant gains due to general tool technology capabilities
KG:	Same as CD
KD, K:	Solid gains over CD via KB decision support tools, particularly in longer term
E:	Significant gains over CD due to advanced EDCS tool capabilities, particularly in evolution support and EHART domain tools
EK:	Complementary combination.

Figure 5.41 TOOL: Use of Software Tools

7.3.3. *SIZE: KSLOC*

KSLOC	Baseline	CD 8	15	KG 8	15	KD 8	15	K 8	15	E 8	15	EK 8	15
SIZE	100	60	30	40	15	60	30	40	15	35	12	30	10

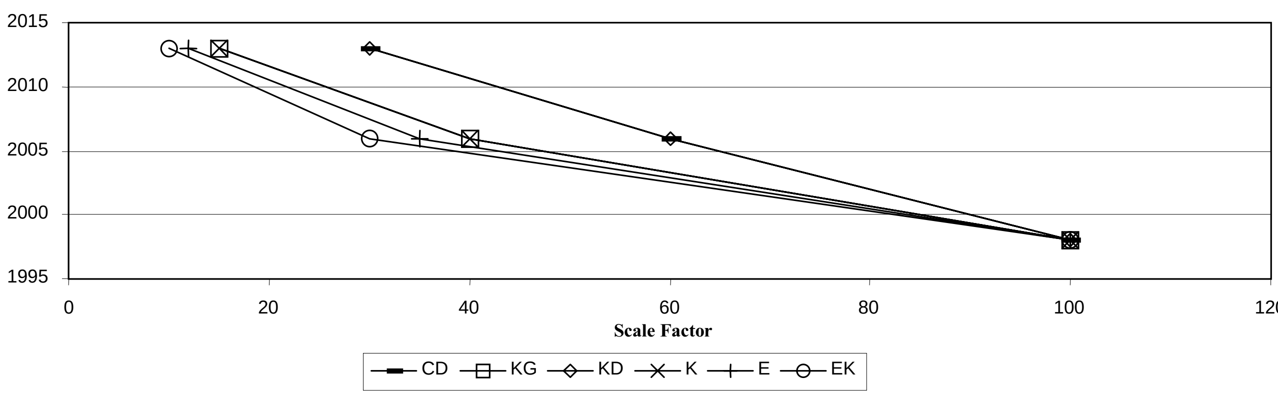


Figure 5.42 SIZE: KSLOC

Size (KSLOC) is the primary determinant of software effort in COCOMO II (and other software cost estimation models). For COCOMO II, effective size is a function of KSLOC or FP, REVL, ADSI, DM, CM, IM, SU, and UNFM. The baseline value was the 100 KSLOC embedded, high-assurance, real-time (EHART) software application.

The rationales for the values over time and technologies are shown in Table 5.41.

CD	"Commercial technology will provide better reuse infrastructure (e.g. ORBs) and some of the componentry technology need for EHART applications. Better requirements technology will reduce breakage somewhat. The overall effects for EHART applications will be less than the effects for mainstream commercial applications since much of the commercial technology will not fit EHART applications. Significant gains will come from existing DoD initiatives such as the SEI Product Line Systems program.
KD	Same as CD
KG & K	Significant gains over CD due to EHART domain-specific architectures, reuse, and application generators
E	Similar domain-specific gains, plus additional reduced breakage due to requirements and rationale capture technology, and reduced software understanding penalties due to software understanding technology
EK	Gains over E due to stronger KB application generator technology

Table 5.41 Rationales for the SIZE factor value over time and technologies.

7.4. Examples of CORADMO Driver Ratings selections and Rationales

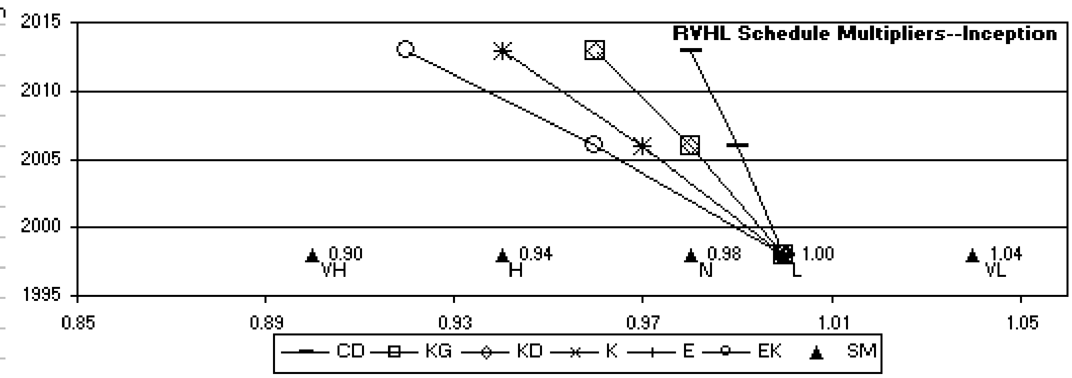
The next section shows a few of the CORADMO driver ratings and rationales as supported by the COPROMO 0.3 tool. As mentioned earlier, not all the drivers for all the phases are relevant.

7.4.1. *RVHL: Reuse and Very High Level Language*

Schedule RVHL: Reuse and Very High Level Language Inception

Inceptio		Baseline	CD@+8	D@+15	KG@+8	G@+15	KD@+8	D@+15	K@+8	K+@15	E@+8	E@+15	EK@+8	K@+15
RVHL-M	defau	1.00	0.99	0.98	0.99	0.98	0.98	0.96	0.98	0.96	0.99	0.98	0.98	0.96
RVHL-M	new													

Inception



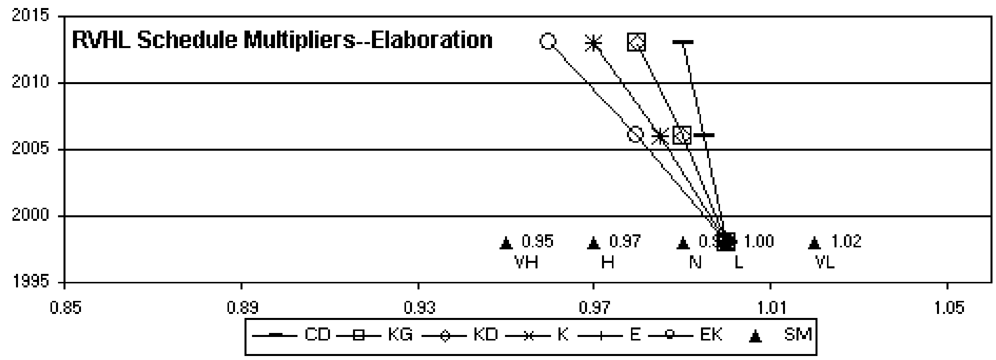
RVHL Projection Rationales

Baseline	Relatively low current capability and experience in EHART domain (standard 3GL module reuse)
CD:	As indicated under SIZE in the Effort impact analysis, commercial technology and DoD EHART domain initiatives will provide some but not much improvement over standard 3GL module reuse
KD:	Some gains over CD via domain oriented reuse asset identification and decision support
KG:	Some gains over CD via domain oriented prototype applications generation
K:	Complementary gains from KD and KG
E:	Significant gains over CD via domain architecture technology and associated prototype applications generation
EK:	Some complement any gains from E and K

Figure 5.43 RVHL: Resuse and Very High Language (Inception)

Schedule	RVHL: Reuse and Very High Level Language													Elaboration
Elaboration		Baseline	CD@+8	D@+15	KG@+8	G@+15	KD@+8	D@+15	K@+8	K+@15	E@+8	E@+15	EK@+8	K@+15
RVHL-M	default	34.14	25.15	17.38	21.36	4.70	23.72	4.70	20.35	4.68	18.97	4.69	17.42	4.62
RVHL-M	new													

Elaborati



RVHL Projection Rationales (Repeated)	
Baseline	Relatively low current capability and experience in EHART domain (standard 3GL module reuse)
CD:	As indicated under SIZE in the Effort impact analysis, commercial technology and DoD EHART domain initiatives will provide some but not much improvement over standard 3GL module reuse
KD:	Some gains over CD via domain oriented reuse asset identification and decision support
KG:	Some gains over CD via domain oriented prototype applications generation
K:	Complementary gains from KD and KG
E:	Significant gains over CD via domain architecture technology and associated prototype applications generation
EK:	Some complement any gains from E and K

Figure 5.44 RVHL: Resuse and Very High Language (Elaboration)

The next figures show some of the charts generated by the COPROMO 0.3 tool.

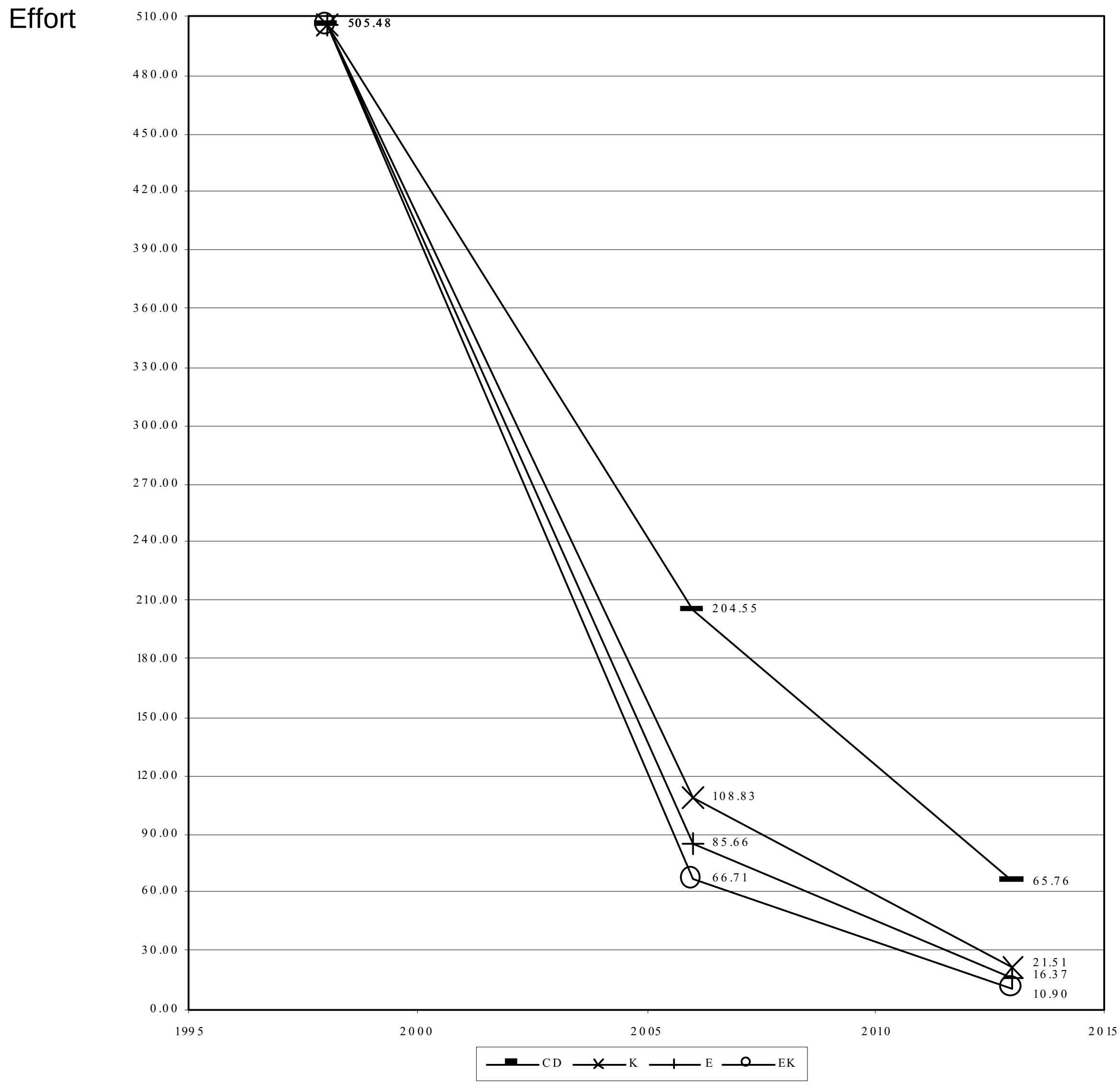


Figure 5.45 Impact of Technologies on Software Effort or Cost

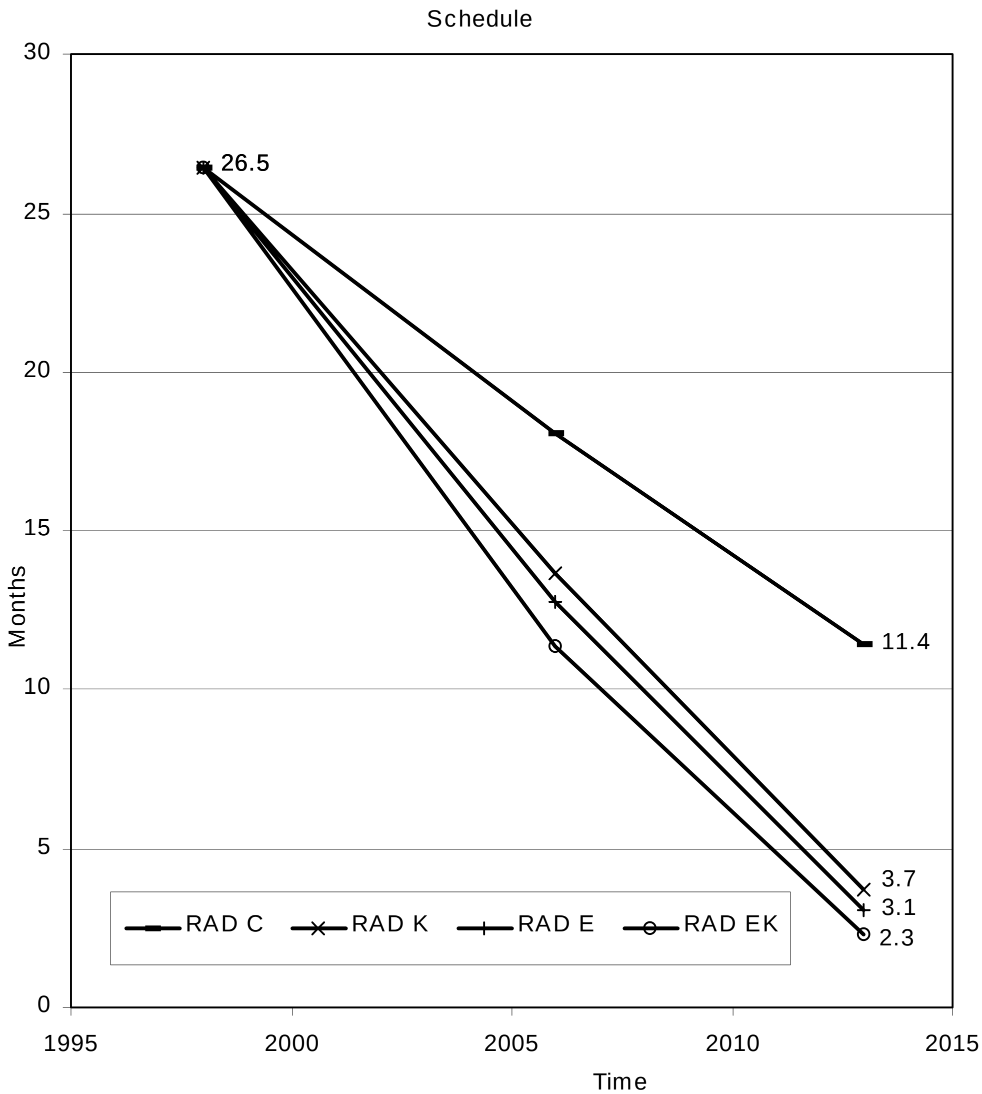


Figure 5.46 Impact of Technologies on Software Schedule

Results are conservative, particularly for EDCS, as maintenance savings would be greater than development savings, due to reductions in amount of software understanding, redesign, recode, and retest effort. This is especially true as when incremental development and delivery techniques are applied to analysis and development, and considering the new verification technologies.

7.4.2. *Sensitivity Analysis for KBSA Evaluation*

The effects of a 50% reduction in the factors on effort improvement were performed as an engineering check. Such sensitivity analyses are useful in showing the faithfulness of the evaluation. One summary of the results is shown in Figure 5.47.

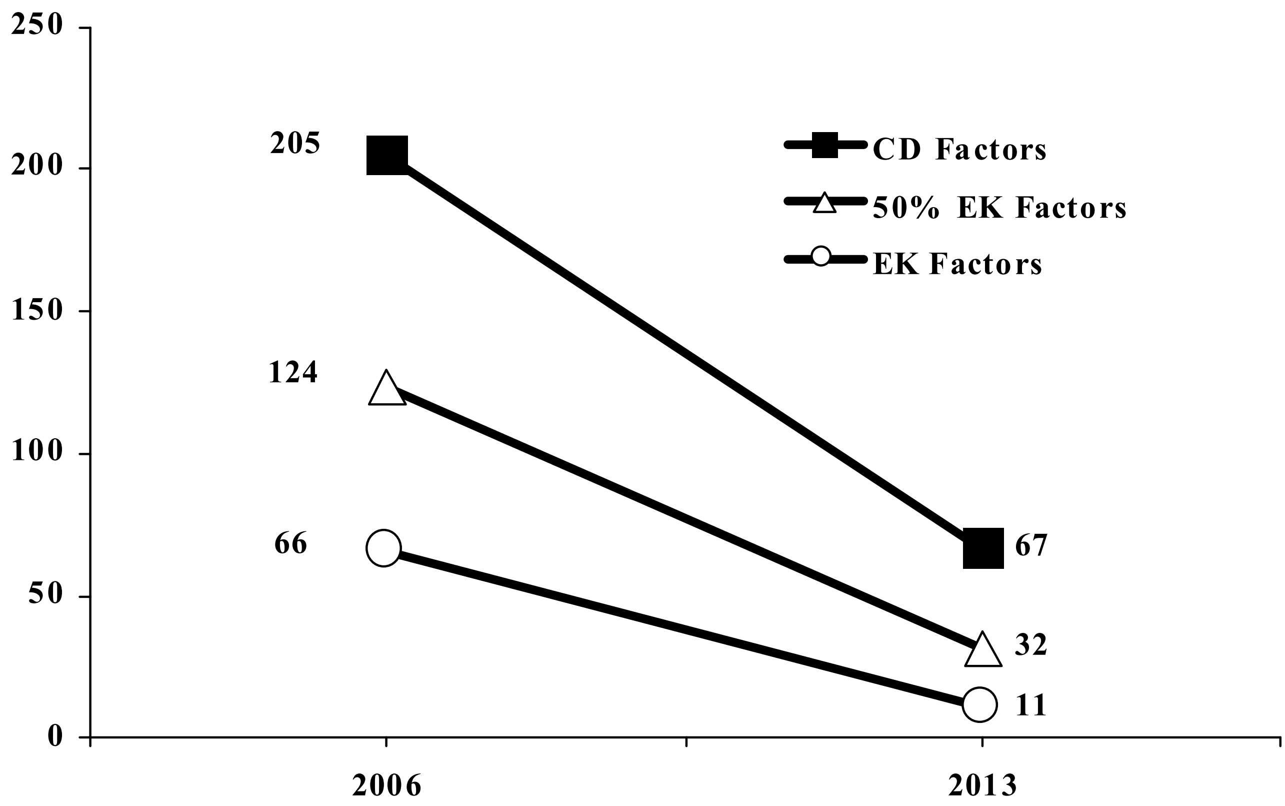


Figure 5.47 50% EK Reduction Relative to CD and EK***Technical Reviews Feedback***

A technical review of the results of the KBSA Lifecycle Impact Evaluation was favorable. COCOMO II Affiliates exposed to the concept during development started to consider how they might proceed into the future. It was obvious that **COPROMO 0.3** represented a useful tool for both corporate benchmarking and strategic planning. The Office of Defense Department Research and Evaluation (ODDR&E) personnel who reviewed the report saw its value as a general support for DoD guidelines on investment.

8. Detailed Spreadsheet Model

Each of the worksheets defined above, plus others that are part of the COPROMO 0.3, tool are described below.

8.1. Tool Overview

The COPROMO 0.3 is a multi-worksheet Excel Workbook that shows the impacts of the COCOMO II and CORADMO drivers projected over time and technology-type on a selected domain's typically sized application. The worksheets include an overview and worksheets for the COCOMO II.2000, COPSEMO and CORADMO drivers, data and their impacts.

The overview worksheet includes abbreviations and descriptions of the other worksheets on the first page, Figure 5.48.

Techonology Impact Analyzer Abbreviations

CD=	Commercial technology and DoD general practice	CII=	CoCoMo II-1998
KBSA=	Knowledge Based Software Assistant	SF=	Scale Factor
		EM=	Effort Multiplier
KG=	KBSA Applications Generators, including KB domain engineering (+CD)	RAD=	CoRADMo (schedule & effort)
KD=	KBSA Project Decision Support (SE decision assistant concept) (+CD)	SM=	Schedule Multiplier
K=	Both KG & KD	PM=	Person Months
E=	EDCS or Evolutionary Delivery of Complex Software Sysetms	M=	Months
EK=	both EDCS & KBSA (KG & KD)	FSP=	Fulltime Software Personnel
EHART=	Embedded, High Assurance, Real Time [baseline application domain]	SSE=	Staged Schedule and Effort
			I=Incepstion E=Elaboration C=Construction

The Techonology Impact Analyzer Workbook has several worksheets covering

- Technoloy Impact Analyzer Overview Sheet ("TIA" tab): This sheet with
  1. Abbreviations and worksheet overviews
  2. COCOMOII-1998 Calibration values and ranges
- COCOMOII-1998 Scale Factor & Effort Multiplier Drivers
  - COCOMOII-1998 Scale Factor & Effort Multiplier Drivers projected over time ("CII Drivers" tab)
    - Individual parameters displayed with default and new/current numeric values, and graph of current values.
  - COCOMOII-1998 Scale Factor & Effort Multiplier Data ("CII Data" tab)
    1. Parameters organized in a compact, single page for review, along with schedule & effort calculation.
    2. Calculates effort according to the COCOMOII-98 rules and schedule according COSSEMO rules (different schedule formulas for three ranges of months--0 to 16; 16 to 64; and 64 and up).
  - COCOMOII-1998 Effort and Schedule Impact ("CII Impact" tab)
    - Displays the Effort & Schedule impacts that result from the driver values' change over time.
- COSSEMO: Stage (Inception, Elaboration and Construction) percentage distribution of Schedule and Effort ("SSE %" tab)
  1. Input of inception, elaboration and constrution stages' schedule and effort percentages
  2. Chart of distribution of schedule and effort impacts on the current COCOMO II calculations
- CORADMO: Schedule and Effort Multipliers Projected Over Time for KBSA Evaluator
  - CoRADMo Drivers projected over time ("RAD Drivers" tab)
    - Individual parameters displayed with default and new/current numeric values, and graph of current values.
  - CoRADMo Drivers projected over time ("RAD Data" tab)
    1. Parameters Organized in compact single page for review
    2. Calculates effort, schedule & FSP according CORADMO rules after distribution of effort & schedule per COSSEMO rules.
  - CoRADMo Schedule and Effort Multipliers Impact ("RAD Impact" tab)

Final Results:===> Displays the Effort, Schedule and FSP impacts that result from the driver values' change over time

TIA / CII Drivers / CII Data / CII Impact / SSE % / RAD Drivers / RAD Data / RAD Impact

Figure 5.48 Technology impact analyzer.

The COPROMO 0.3 abbreviations from Figure 5.48 are shown alphabetically below in Table 5.42 together with some other abbreviations used throughout COPROMO 0.3

C=	Construction
CD=	Commercial technology and DoD general practice
CII=	COCOMO II.2000
E=	EDCS or Evolutionary Delivery of Complex Software Systems
E=	Elaboration
EHART=	Embedded, High Assurance, Real Time [baseline application domain]
EK=	Both EDCS & KBSA (KG & KD)
EM=	Effort Multiplier
FSP=	Fulltime Software Personnel
I=	Inception
K=	Both KG & KD
KBSA=	Knowledge Based Software Assistant
KD=	KBSA Project Decision Support (SE decision assistant concept) (+CD)
KG=	KBSA Applications Generators, including KB domain engineering (+CD)
M=	Months
PM=	Person Months
PSE=	Phase Schedule and Effort
RAD=	CoRADMo (schedule & effort)
SF=	Scale Factor
SM=	Schedule Multiplier

Table 5.42 Alphabetic Listing of Abbreviations used in **COPROMO 0.3**.

8.2. *COCOMO II Drivers, Calculations and Impacts*

There are three worksheets in this grouping. The first, CII Drivers, has the current projected scale factors and effort multipliers drivers over time and allows for changing the default values to their new values. The second, CII Data, aggregates the driver data and does the COCOMO II.2000 calculations. The third, CII Impact, has graphs showing the effort and schedule impact of the COCOMO II.2000 drivers projected over time. Only “CII Drivers” allows input. More information on “CII Drivers” is available the next section.

8.3. *COPSEMO Schedule and Effort Percentage Distributions per Phase*

This worksheet, PSE %, allows the input of percentage distributions of effort and schedule to the various phases, Inception, Elaboration, and Construction, as required for the COCOMO II Phase Schedule and Effort Model (COPSEMO). The impact of these distributions on the COCOMO II.2000 baseline results is shown in the chart at the end of the worksheet.

8.4. *CORADMO Drivers, Calculations and Impacts*

Like the COCOMO II.2000 worksheets, there are three worksheets in this grouping. The first, RAD Drivers, shows the new or default projected drivers over time. The second, RAD Data, aggregates the driver data and does the CORADMO calculations. The third, RAD Impact, has graphs showing the resulting impacts of the CORADMO drivers projected over time when applied to the corresponding COCOMO II.2000 results with the COCOMO drivers projected over time. At the end of the page of the "RAD Data" worksheet are the summary calculations for totals of schedule and effort across phases allowing comparison with the results of COCOMO II.2000. Only “RAD Drivers” allows input. More information on “RAD Drivers” is available the next section.

8.5. *Technical Impact Final Results*

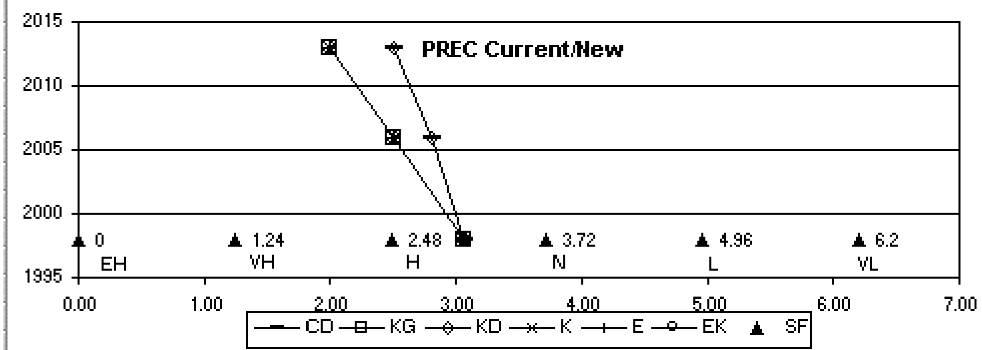
At the end of the "RAD Impact" worksheet, following the nine RAD impacts by phase charts, are the summary charts for effort and schedule by technology over time that result from the COCOMO II.2000 and CORADMO driver changes over time. The effort and schedule results are generated by adding the effort or schedule, respectively, for either all three phases or just for the Elaboration and Construction phases. More information on this worksheet is available in Appendix C.

8.5.1. *COCOMO II Drivers Display, Modification and Rationale*

The worksheet with the "CII Drivers" shows all of our assessed values and our rationale for each of the scale factor or effort multiplier drivers, projected over time and technology. Each page of this worksheet has the current projected COCOMO II.2000 drivers and allows changing the default (assessed) values to their new values. The rationales for the default settings of the drivers are included; they should be modified when “new” values are provided. Figure 5.49 shows the scale factor PREC’s information.

PREC: Precedentedness

Driver		Baseline	CD@+8	CD@+1	KG@+8	KG@+1	KD@+8	KD@+1	K@+8	K@+15	E@+8	E@+15	EK@+8	EK@+15
PREC	default	3.06	2.80	2.50	2.50	2.00	2.80	2.50	2.50	2.00	2.50	2.00	2.50	2.00
PREC	new													



CD:	Some gains due to better general understanding of EHART domains, but not large
KG:	Solid gains due to stronger domain understanding and technology, but offset by continuing need for more advanced systems
KD:	No additional domain gains over CD
K:	Same as KG
E:	No additional domain gains over KG
EK:	Same as E and K

Figure 5.49. PREC Driver Entry, Modification and Display

The default and current values of the driver, projected over time and technology, are shown in a small table above the chart of the current values. The last row of this table accepts the input of new values of the driver, projected over time and technology. The chart below the table shows the driver's current values over time for each technology combination. The data points on this graph change when new values are entered.

Since each value of a driver should have a rationale, the rationales for the default values (our assessed values) are shown below the chart. The area below the rationales for the default values allows the input of additional or modified rationales.

8.5.2. *COPSEMO Distribution of Schedule and Effort per Phase*

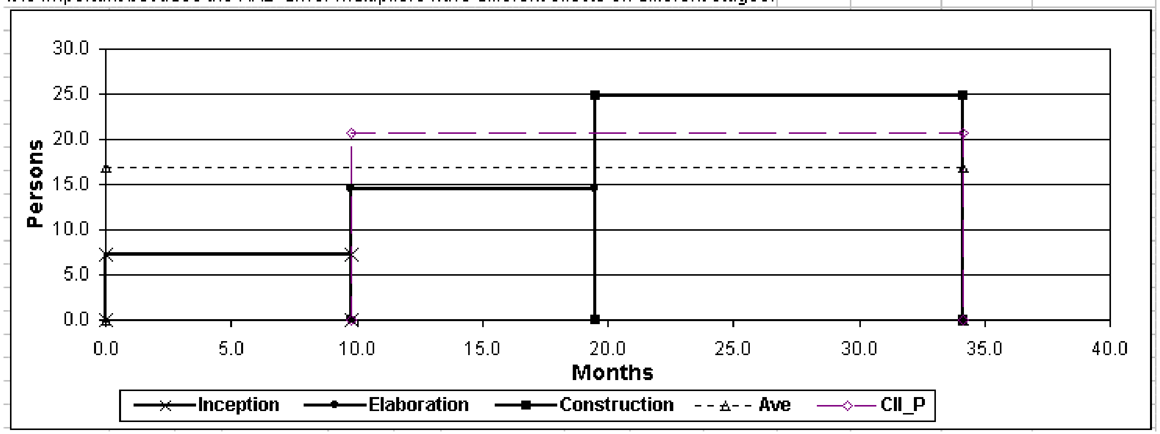
There are two parts to this worksheet: 1) Input of inception, elaboration and construction phases' schedule and effort percentages; and 2) Chart of distribution of schedule and effort impacts on the current COCOMO II.2000 calculations.

Input of schedule and effort percentage distributions per phase, Inception, Elaboration, and Construction, is required for the COCOMO II Phase Schedule and Effort Model (COPSEMO). To help visualize these distributions, their impact on the COCOMO II.2000 100K EHART baseline is displayed in the chart at the end of the worksheet. Figure 5.50 shows the entire content of this worksheet.

Staged Schedule and Effort Percentages

% Effort Inception	**14**	% Effort Elaboration	**28**	% Effort Construction	**72**	Need to pickup changed refs
Incept. eff. default%=	*14*	*Elab. eff. default%=*	*28*	*Con. eff. def%=*	*72*	
%Schedule Inception	**40**	%Schedule	**40**	%Schedule Construction	**60**	
Incp. sched. default%=	*40*	*Elab. sched. default%=*	*40*	*Con. sch. def%=*	*60*	

The following chart shows the distribution of effort and schedule on the default baseline CoCoMo II values.
It is important because the RAD-driver multipliers have different effects on different stages.



Staged Schedule and Effort Percentages

% Effort Inception	**14**	% Effort Elaboration	**28**	% Effort Construction	**72**	Need to pickup changed refs
Incept. eff. default%=	*14*	*Elab. eff. default%=*	*28*	*Con. eff. def%=*	*72*	
%Schedule Inception	**40**	%Schedule	**40**	%Schedule Construction	**60**	
Incp. sched. default%=	*40*	*Elab. sched. default%=*	*40*	*Con. sch. def%=*	*60*	

The following chart shows the distribution of effort and schedule on the default baseline CoCoMo II values.
It is important because the RAD-driver multipliers have different effects on different stages.

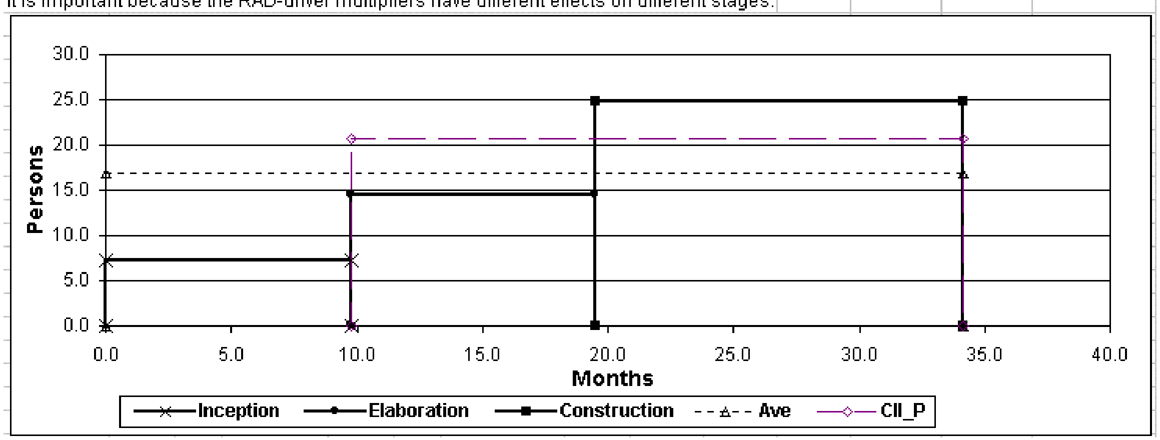


Figure 5.50. Phase Schedule and Effort Distribution

The values of the Inception and Elaboration percentages for schedule and effort are adjusted by clicking on the up/down arrows (spinners) shown to the right of their values. The current values are displayed in bold, along with the corresponding calculated values for the Construction phase. The default values for all the percentages are shown in italics.

8.5.3. *CORADMO Drivers Display, Modification and Rationale*

"RAD Drivers" has our assessed values for each of the relevant CORADMO schedule and effort multipliers projected over time and our rationale. It also allows the input of new values and additional or modified rationales. A graph of the current values of each driver projected over time and technology is included; the data points on this graph change when new values are entered. Figure 5.51 shows an example for the schedule (and effort) multiplier for the Inception phase.

Schedule		RVHL: Reuse and Very High Level Language												Inception
Inception		Baseline	CD@+8	D@+15	KG@+8	G@+15	KD@+8	D@+15	K@+8	K+@15	E@+8	E@+15	EK@+8	K@+15
RVHL-M	defau	1.00	0.99	0.98	0.98	0.96	0.98	0.96	0.97	0.94	0.97	0.94	0.96	0.92
RVHL-M	new													

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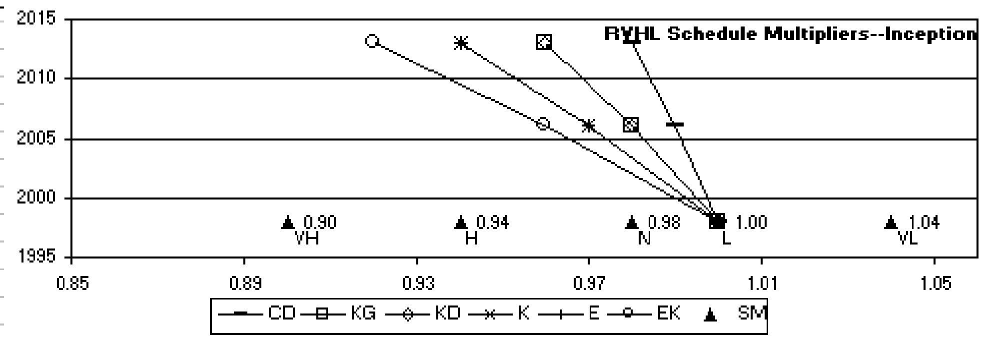

RVHL Projection Rationales

Baseline:	Relatively low current capability and experience in EHART domain (standard 3GL module reuse)
CD:	As indicated under SIZE in the Effort impact analysis, commercial technology and DoD EHART domain initiatives will provide some but not much improvement over standard 3GL module reuse
KD:	Some gains over CD via domain oriented reuse asset identification and decision support
KG:	Some gains over CD via domain oriented prototype applications generation
K:	Complementary gains from KD and KG
E:	Significant gains over CD via domain architecture technology and associated prototype applications generation
EK:	Some complement any gains from E and K
NOTE:	RVHL effects in construction accounted for with regular COCOMOII effort adjustment

Figure 5.51. RVHL Inception Stage Schedule Multiplier Driver Information

The default and current values of the driver, projected over time and technology, are shown in a small table above the chart of the current values. The last row of this table accepts the input of new values of the driver, projected over time and technology. The chart below the table shows the driver's values over time for each technology combination.

(Note: RVHL effects in construction were accounted for with regular COCOMO II effort adjustment.)

Since each value of a driver should have a rationale, the rationales for the default values (our assessed values) are shown below the chart. The area below the rationales for the default values allows the input of additional or modified rationales.

8.5.4. *Final Results: Technology Impacts*

At the end of the "RAD Impact" worksheet, following the nine RAD impacts by phase charts, are the summary charts for effort and schedule by technology over time that result from the COCOMO II.2000 and CORADMO driver changes over time. The “new/current” data for the summary charts is actually shown at the end of the "RAD Data" worksheet.

There are three different types of charts:

Overall (effort or schedule for all three phases or just for development (elaboration plus construction), with some of these having alternative axes layouts;

COCOMO II.2000 compared to CORADMO (final) results, with some of these charts showing only the major technology groupings (CD, K and EK);

Final results of default driver settings compared to new/current driver settings’ results.

The list of all the charts corresponding to final results is shown in the Table 5.43, below. More detailed information and examples of these charts are given in the KBSA Final Technical Report[i4] and the tool itself which is on the CD that accompanies this book.

Number	Title
1.	CORADMO Total Effort (effort on x axis)
2.	CORADMO Total Effort (years on x axis)
3.	CORADMO Total Effort (only for CD, K and EK)
4.	CORADMO Development (E+C) Effort with COCOMO II Development (E+C) Effort
5.	CORADMO Development (E+C) Effort with COCOMO II Development (E+C) Effort (only for CD, K and EK)
6.	CORADMO Total Schedule (schedule on x axis)
7.	CORADMO Development (E+C) Schedule with COCOMO II Development (E+C) Schedule(only for CD, K and EK)
8.	CORADMO Development (E+C) Schedule with COCOMO II Development (E+C) Schedule
9.	New/Current CORADMO Total (I+E+C) Effort with Default CORADMO Total (I+E+C) Effort
10.	New/Current CORADMO Total (I+E+C) Schedule with Default CORADMO Total (I+E+C) Schedule

Table 5.43 Final Results charts

8.6. Sensitivity Analysis Example

One of the reasons for allowing input of new values for the drivers is to permit sensitivity analysis. Suppose it is believed that the impact of reuse and very high level languages has been over estimated, and that only 50% of the originally estimated impact seems to be justified.

[4] [NEED--KBSA Official reference]

8.6.1. *COCOMO II.2000 Driver Modification*

First, the impacted COCOMO II.2000 drivers need to be adjusted. Since there is no explicit driver for reuse, the effective size is modified to reflect the increased amount of reuse and/or use of a very high level language. This can be accomplished by filling each cell in the "new" row except the baseline, which remains the same, by a formula that subtracts fifty percent of the difference between the baseline and the default. The new values are shown in Figure 5.52.

Schedule — RVHL: Reuse and Very High Level Language — Inception

Inception		Baseline	CD@+8	D@+15	KG@+8	G@+15	KD@+8	D@+15	K@+8	K+@15	E@+8	E@+15	EK@+8	K@+15
RVHL-M	defau	1.00	0.99	0.98	0.98	0.96	0.98	0.96	0.97	0.94	0.97	0.94	0.96	0.92
RVHL-M	new	1.00	1.00	0.99	0.99	0.98	0.99	0.98	0.99	0.97	0.99	0.97	0.98	0.96

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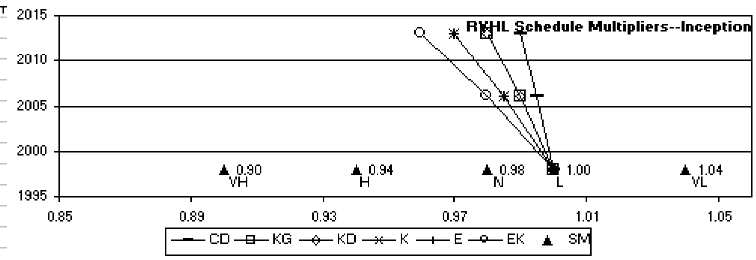

RVHL Projection Rationales

Baseline:	Relatively low current capability and experience in EHART domain (standard 3GL module reuse)
CD:	As indicated under SIZE in the Effort impact analysis, commercial technology and DoD EHART domain initiatives will provide some but not much improvement over standard 3GL module reuse
KD:	Some gains over CD via domain oriented reuse asset identification and decision support
KG:	Some gains over CD via domain oriented prototype applications generation
K:	Complementary gains from KD and KG
E:	Significant gains over CD via domain architecture technology and associated prototype applications generation
EK:	Some complement any gains from E and K
NOTE:	RVHL effects in construction accounted for with regular COCOMOII effort adjustment
ALL:	Only 50% impact as part of sensitivity analysis

Figure 5.53. RVHL Inception Stage Adjustment for 50% Impact

The "new" values, except baseline, in the table above the chart, like that in E632, were calculated with a formula like:

=$D659-($D659-E659)*(50/100).

The new values are reflected in Figure 5.52. Also, the rationale is noted in the section following the chart.

8.6.2. *CORADMO Driver Modification*

Since RVHL reflects the impacts of reuse and/or very high level languages, it is the only driver that needs to be adjusted. Figure 5.53 shows the new values for the RVHL schedule multiplier for the inception phase.

Schedule		RVHL: Reuse and Very High Level Language											Inception
Inception		Baseline	CD@+8	D@+15	KG@+8	G@+15	KD@+8	D@+15	K@+8	K+@15	E@+8	E@+15	EK@+8	K@+15
RVHL-M	defau	1.00	0.99	0.98	0.98	0.96	0.98	0.96	0.97	0.94	0.97	0.94	0.96	0.92
RVHL-M	new	1.00	1.00	0.99	0.99	0.98	0.99	0.98	0.99	0.97	0.99	0.97	0.98	0.96

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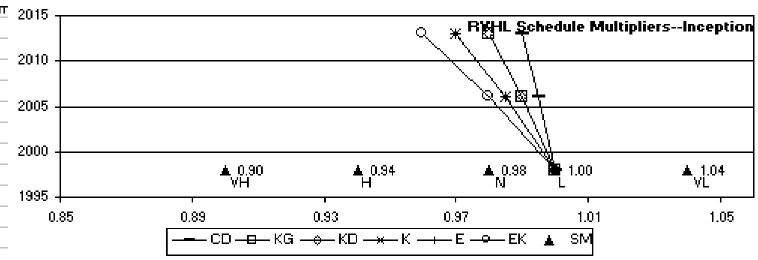

RVHL Projection Rationales

Baseline: Relatively low current capability and experience in EHART domain (standard 3GL module reuse)

CD: As indicated under SIZE in the Effort impact analysis, commercial technology and DoD EHART domain initiatives will provide some but not much improvement over standard 3GL module reuse

KD: Some gains over CD via domain oriented reuse asset identification and decision support

KG: Some gains over CD via domain oriented prototype applications generation

K: Complementary gains from KD and KG

E: Significant gains over CD via domain architecture technology and associated prototype applications generation

EK: Some complement any gains from E and K

NOTE: RVHL effects in construction accounted for with regular COCOMOII effort adjustment

ALL: Only 50% impact as part of sensitivity analysis

Figure 5.53. RVHL Inception Stage Adjustment for 50% Impact

The “new” values, except baseline, in the table above the chart, like that in E4, were calculated with a formula like: “=$D4-($D4-E4)*(50/100)”. The new values are reflected in the chart below. Also, the rationale is noted in the section following the chart.

Similarly, Figure 5.54 shows the new values for the RVHL schedule multiplier for the elaboration phase as well as the rationale for the modification.

Schedule		RVHL: Reuse and Very High Level Language											Elaboration
Elaboration		Baseline	CD@+8	D@+15	KG@+8	G@+15	KD@+8	D@+15	K@+8	K+@15	E@+8	E@+15	EK@+8	K@+15
RVHL-M	default	1.00	1.00	0.99	0.99	0.98	0.99	0.98	0.99	0.97	0.99	0.97	0.98	0.96
RVHL-M	new	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.98

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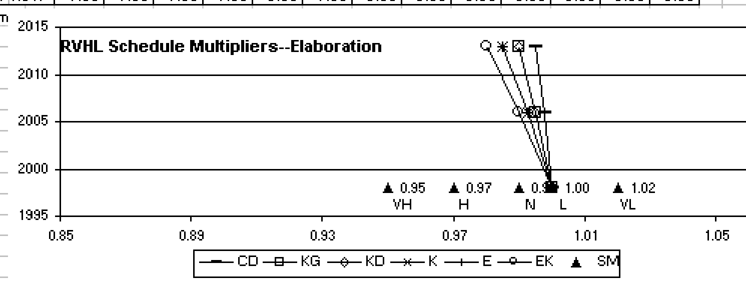

RVHL Projection Rationales (Repeated)

Baseline: Relatively low current capability and experience in EHART domain (standard 3GL module reuse)

CD: As indicated under SIZE in the Effort impact analysis, commercial technology and DoD EHART domain initiatives will provide some but not much improvement over standard 3GL module reuse

KD: Some gains over CD via domain oriented reuse asset identification and decision support

KG: Some gains over CD via domain oriented prototype applications generation

K: Complementary gains from KD and KG

E: Significant gains over CD via domain architecture technology and associated prototype applications generation

EK: Some complement any gains from E and K

NOTE: RVHL effects in construction accounted for with regular COCOMOII effort adjustment

ALL: Only 50% impact as part of sensitivity analysis

Figure 5.54. RVHL Elaboration Stage Adjustment for 50% Impact

8.6.3. *Sensitivity Analysis Results: Technology Impact Estimates*

The effort and schedule results after applying the COCOMO II.2000 and CORADMO driver modifications identified above are shown in Figure 5.55. This result can be compared to the default driver settings results shown in Figure 5.57. CORADMO Total Effort in Figure 5.55 refers to the same values as CORADMO Total (I+E+C) Effort in Figure 5.57.

Total (I+E+C) Effort	Baseline	CD+8	CD+1	KG+8	KG+1	KD+8	KD+1	K+8	K+15	E+8	E+15	EK+8	EK+15
PM	576.3	313.5	161.6	251.6	126.7	261.0	111.4	213.7	87.2	190.4	83.5	162.7	61.8

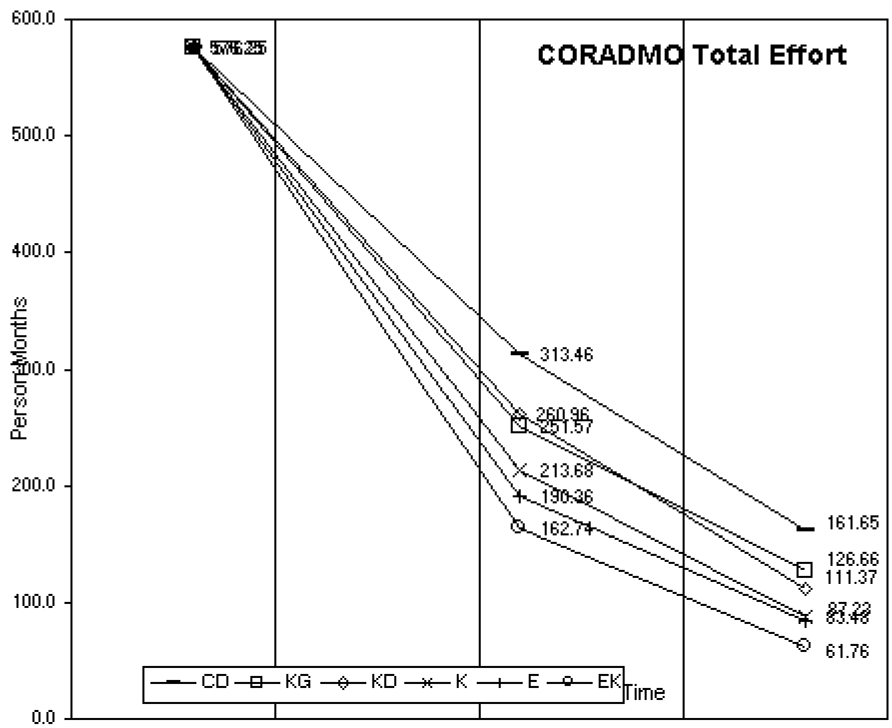

Figure 5.55. Total Effort after applying modified COCOMO II.2000 & CORADMO Drivers

8.6.4. *CORADMO Drivers*

Figure 5.56 shows a comparison of COCOMO II.2000 only results and the final CORADMO with only 50% of the reuse and high level language impact.

Effort	Baseline	CD+8	CD+15	KG+8	KG+15	KD+8	KD+15	K+8	K+15	E+8	E+15	EK+8	EK+15
CII with SSE: PM(E+C)	505.5	277.1	146.8	222.7	113.6	237.2	105.3	194.4	82.7	169.6	77.3	147.9	59.0
CORADMO: PM(E+C)	505.5	276.0	143.0	221.7	112.2	230.7	99.2	189.0	77.8	168.2	74.3	144.3	55.2

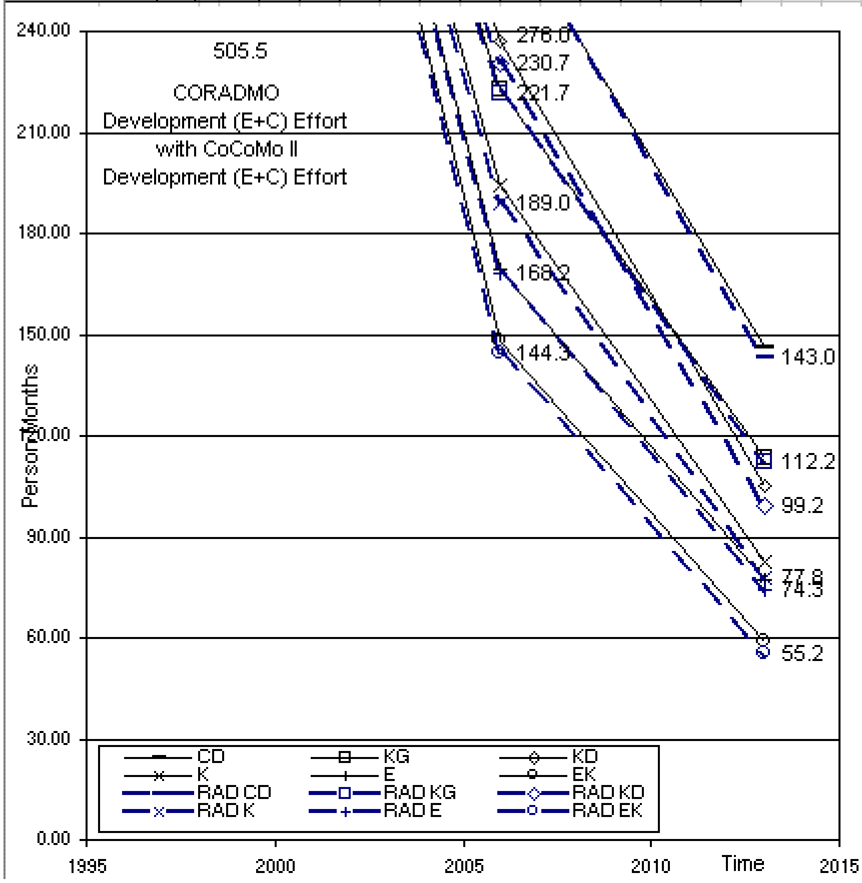

Figure 5.56. One of the comparisons of COCOMO II.2000 only results and Final Results

8.6.5. *Final Results*

Here, both the COCOMO II.2000 set of calculations and the final results calculations are shown in the table above the chart. Again, the final results row's values will contain the results based on the "current" CORADMO driver values, and thus may have changes any time there is input in the "new" row of the drivers. While only the data associated with the top row of the table, which contains the COCOMO II.2000 calculation results, is shown in the chart, the final results values are evident due to the dashed lines appearing in the chart.

For sensitivity analyses, the set of comparison charts is especially useful. They show the overall effort and schedule results using the default driver values and the new/current driver values. Along with each chart are copies of the rows of the appropriate data from "CORADMO Data" worksheet. Figure 5.57 shows a comparison of final CORADMO results for default and new drivers with the only driver change being SIZE (change amount reduced by 50%).

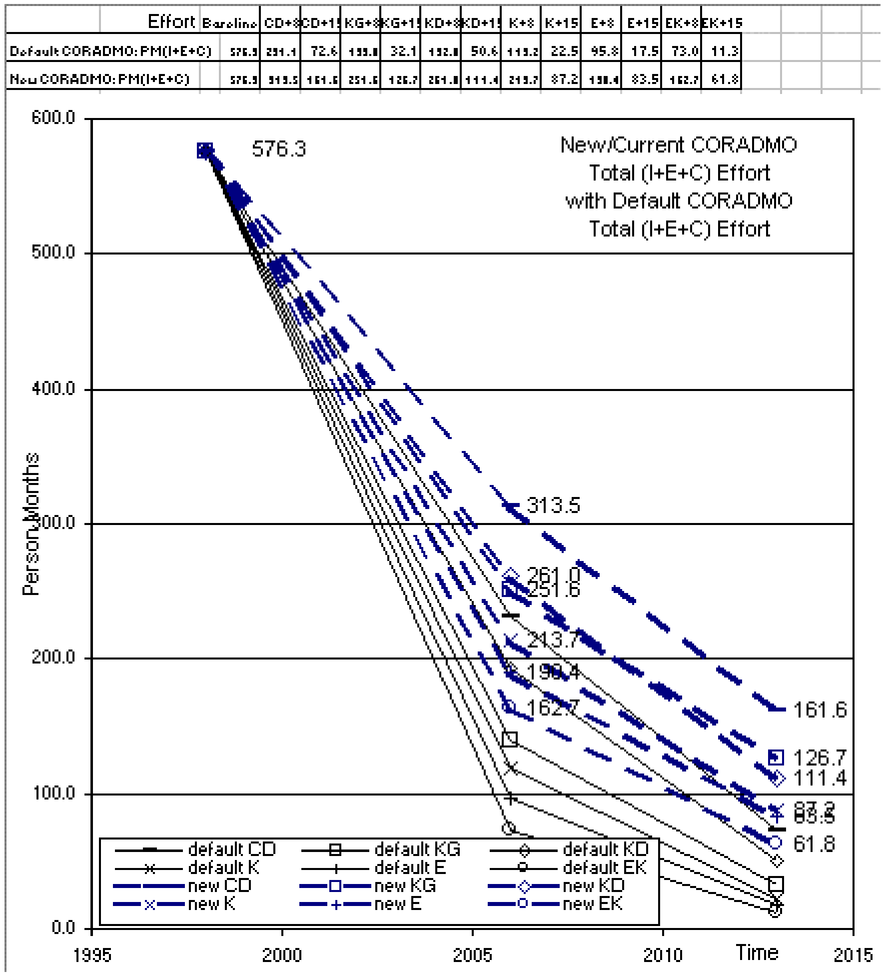

Figure 5.57. Comparisons of Effort Final Results for Default and New Drivers

Here, both the default and new final results calculations are shown in the table above the chart. Again, the new final results row's values will contain the results based on the "current" CORADMO driver values, and thus may have changes anytime there is input in the "new" row of the drivers. While only the data associated with the bottom row of the table, which contains the new calculation results, is shown in the chart, the default results values are evident due to the solid lines appearing in the chart.

The corresponding schedule final results comparison is shown in Figure 5.58.

Schedule (I+E+C)		Baselir	CD+8	CD+1	KG+8	KG+1	KD+8	KD+1	K+8	K+15	E+8	E+15	EK+8	EK+15
Default CORADMO: M(I+E+C)	M	33.8	23.0	14.3	18.9	6.7	20.7	9.6	17.3	4.9	16.1	4.1	14.3	3.08
New CORADMO: M(I+E+C)	M	33.8	25.3	18.5	22.7	16.2	22.8	14.8	20.8	13.3	20.0	13.5	18.3	10.5

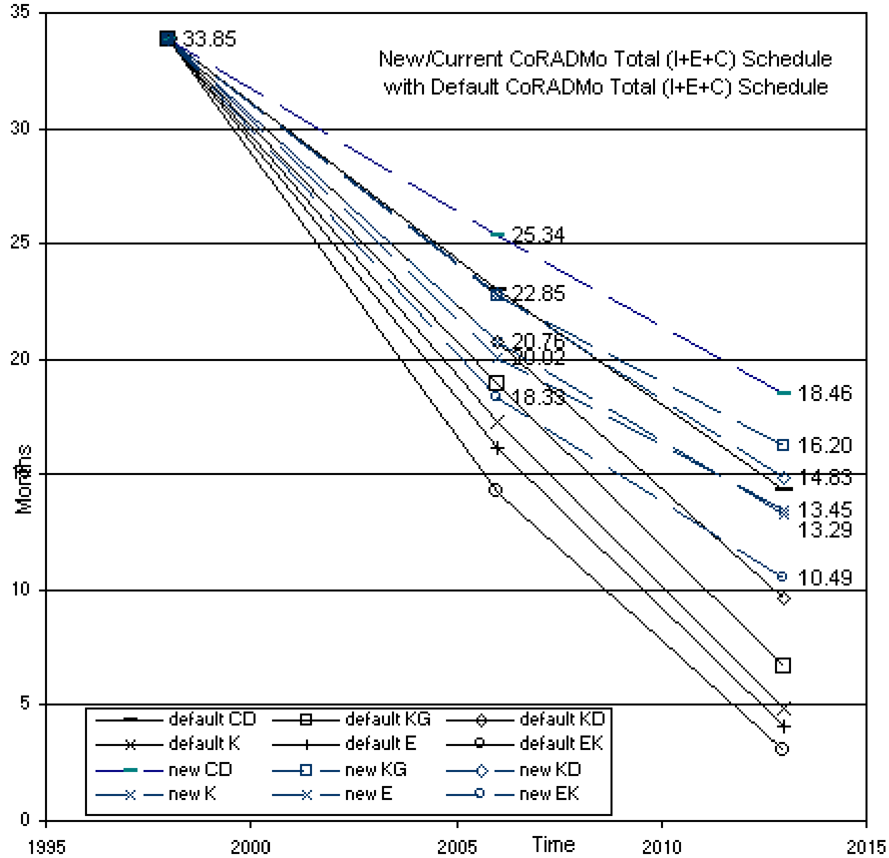

Figure 5.58. Comparisons of Schedule Final Results for Default and New Drivers