Using a Combined Technology in High Maturity Process Improvement

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I Introduction

- According to a holistic view to a process engineering environment, a combined technology should be used and this environment should be composed of several systems.
- Among these systems, they should be organically-integrated, interactively-supported, closely-cooperated, and harmonious-coexisted each other.

Several Systems - 1

- This environment could be composed of the following 5 systems:
  - Cost management system: It includes Personal daily timesheet system, Project weekly report system and Resource model constructing system. Based on extracted information from Personal daily timesheet system, Project weekly report system is automatically generated, and then both project-level and organizational-level Resource models are automatically constructed. If cost threshold-value is given for each project, cost control can be performed.
  - Schedule management system: It includes Project management system coupled with Project-tool, show project team workload assignment and planned schedule, and then based on extracted information from Project weekly report system, practical schedule is generated. If project schedule threshold-value is given, schedule can be tracked and controlled based on earned-value principle.
  - Quality management system: By using recorded Testing and Peer review, etc. 6 kinds of defects data, defects analysis is automatically performed. It can show process benefits of each phase and whole lifecycle. If quality control threshold-value is given, quality control can be performed.

Several Systems - 2

- Process modeling system: Using a visualized language to construct process model from different perspective, which can be used to automatically detect non-reachable node, livelock and deadlock of the model investigated, to detect consistency among a set of models, and to perform parallelism analysis of the process model investigated.
- Process optimization system: Based on simulation execution results of a process model, synthetically consider preassigned schedule control threshold-value, cost control threshold-value, quality control threshold-value and project team assignable resource, select and perform optimized process, and perform proactive risk management during performing the process.

- In the following, Resource model and Process optimization are deeply discussed.

II Resource Model

- Resource Model (RM) is defined as the consuming model of human beings efforts, which can be used to determine:
  - The percentage of each phase time period to the total time period of lifecycle, and the percentage distribution
  - The percentage of each phase effort to the total effort of lifecycle, and the percentage distribution.
  - The percentage of each task type effort to the total effort of each phase, and the percentage distribution.

II.1 Basic Characteristics of RM - 1

No.	Basic Characteristics	Descriptions of the characteristics
1	System common characteristics	System name
		Working language (such as C++, Java, etc.)
		Successful level of the project
2	System type	Simple, Moderate, Embedded
		New development, Assembling from components, Maintenance
		Operating system, Compiler, Tool development and Applications
	Product size	Requirements number/Function point/Lines of code/Class number/Use case number, etc.
		Micro, small, middle, large, huge
	Lifecycle type	Such as Waterfall, USDP, etc.
	Project team size	Micro, small, middle, large, huge (in person number)

Basic Characteristics of RM - 2

No.	Basic Characteristics	Descriptions of the characteristics
3	Total effort	Micro, small, middle, large, huge (in person week/person month)
		The percentage of each phase effort to the total effort of lifecycle
		The percentage of each task type effort to the total effort of each phase
	Project duration	The time period of the whole project (in week/month/year)
		The percentage of each phase time period to the total time period of lifecycle
4	System complexity	Program complexity (MaCabe/HalStead)
		Computing complexity
	Technology novelty level selected	Team member's expertise to selected working language
	Team member status	Expertise level, devotion spirit, morale, healthy status, etc.

II.2 Personal Timesheet - an Example

	Task Type	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sum	Comments
1	Reqmts	0	2	2	2	0	0	0	6	
2	Design	0	0	0	2	2	2	0	6	
3	Implement	0	0	0	1	1	1	0	3	
4	Testing	0	0	0	0	0	0	0	0	
5	PM	2	2	1	1	0	0	0	6	
6	CM	0	0	0	0	0	0	0	0	
7	QA	0	0	1	0	1	0	0	2	
8	Measmt	0	0	0	0	0	0	0	0	
9	Review	0	0	0	0	2	2	2	6	
10	Train	0	0	0	0	0	0	0	0	
11	Others	0	1	1	0	0	0	0	2	
Sum		2	5	5	6	6	5	2	31	
Summary										

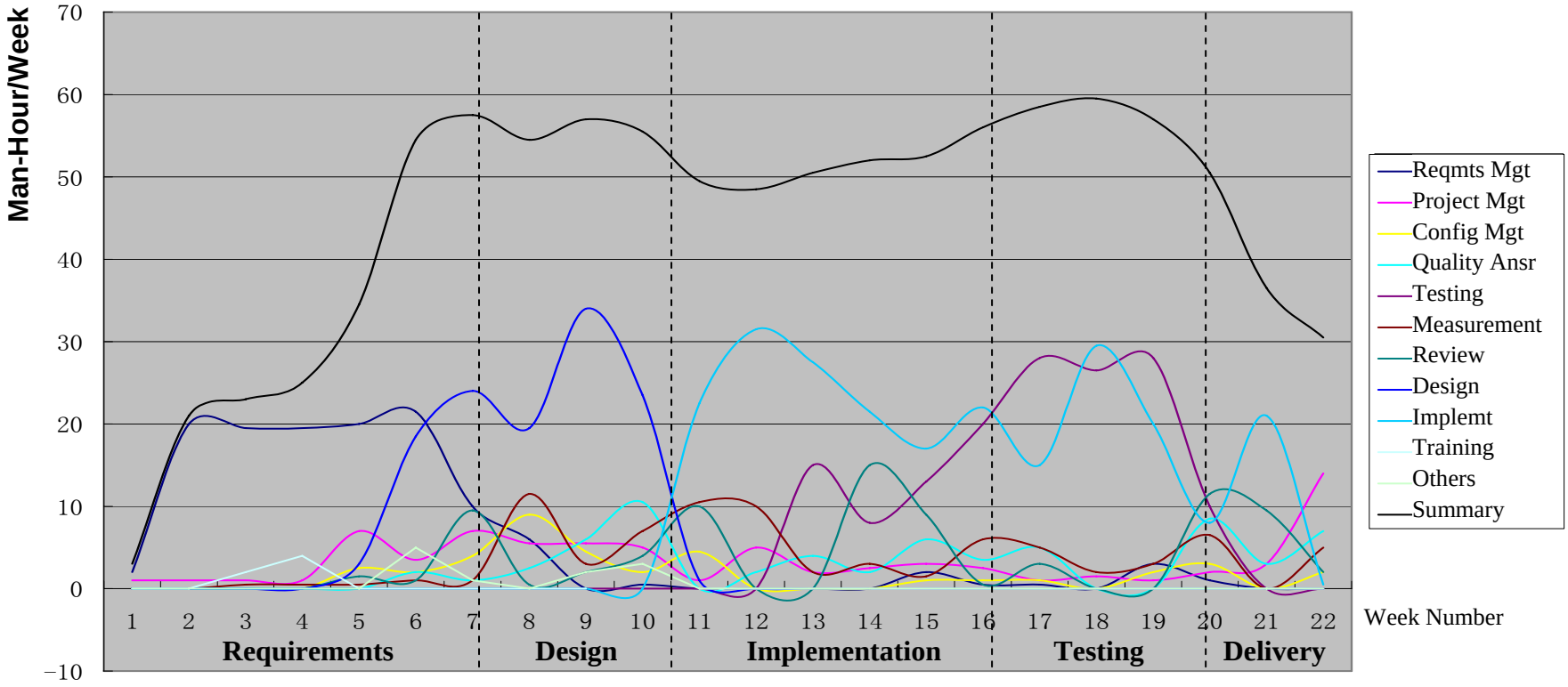
- It is very important to keep the reality of data.
- Each person should daily fill-in his/her workload data.
- At weekend, he/she should summarize personal progress based on earned-value principle.

Project Weekly Report - an Example

	Task Type	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sum	Comments
1	Reqmts	0	2	2	2	0	0	0	6	
2	Design	0	2	2	5	5	5	0	19	
3	Implement	0	1	1	1	1	1	0	5	
4	Testing	0	0	0	0	0	0	0	0	
5	PM	2	2	1	1	0	0	0	6	
6	CM	0	0	1	1	1	1	2	6	
7	QA	1	1	1	1	1	2	0	7	
8	Measmt	1	1	1	1	1	0	0	5	
9	Review	0	0	0	0	4	4	4	12	
10	Train	0	2	2	0	0	0	0	4	
11	Others	0	1	1	2	2	2	0	8	
Sum		4	12	12	14	15	15	6	78	
Summary										

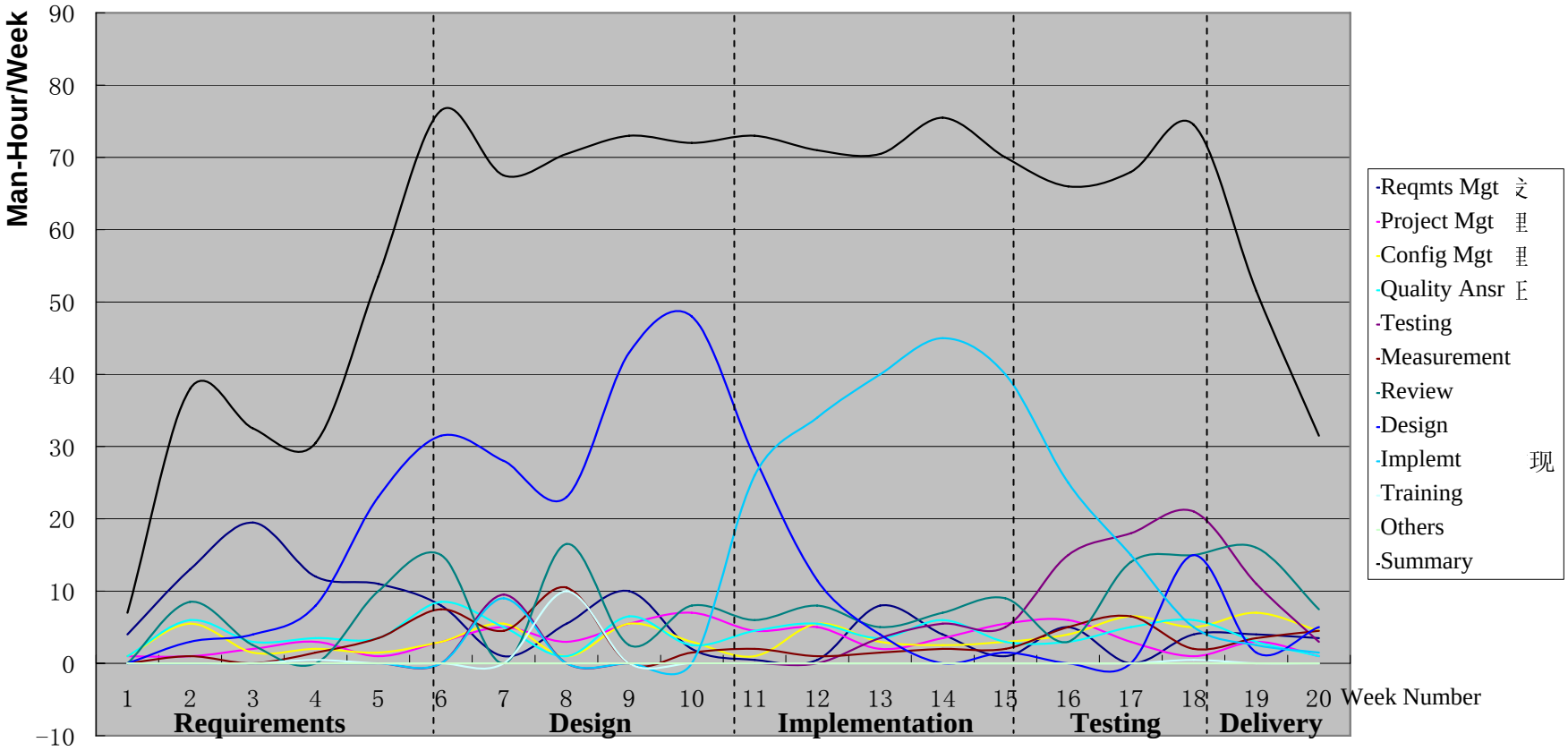
- Where task type is classified into 11 categories as an example.
- Project weekly report is automatically generated from extracted data from Personal timesheet.
- Weekly extracted data from Project weekly report can be used to construct project level RM, and so both cost and schedule can be weekly reported, tracked, and controlled.

II.3 Resource Model of Project 1



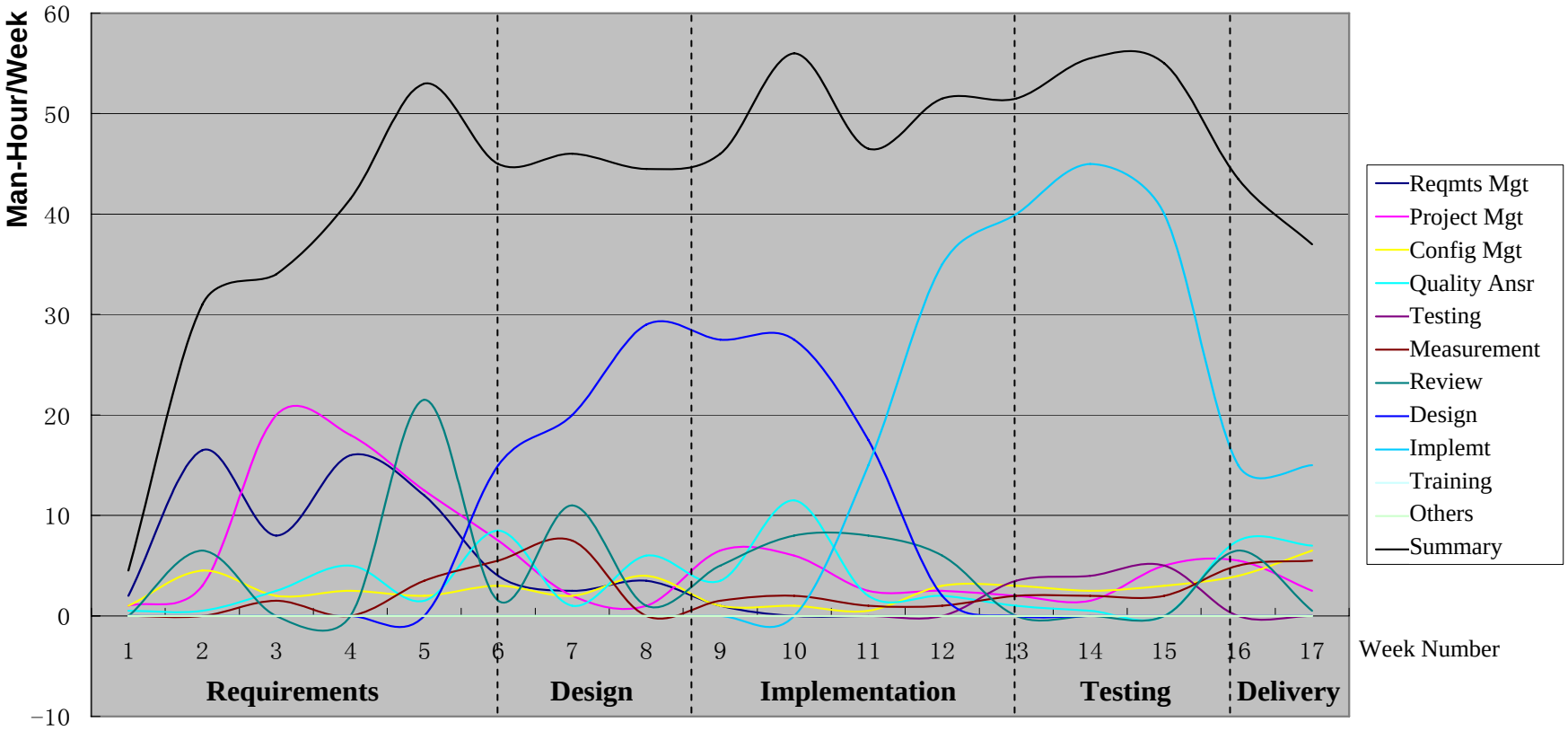
- This is a project-level RM of Project 1 from case study. It should be noticed that (the same for RMs of other projects):
  - For each project it owns an independent itself RM.
  - basic characteristics (as described before) should be given.
  - RM is depicted weekly.

Resource Model of Project 2



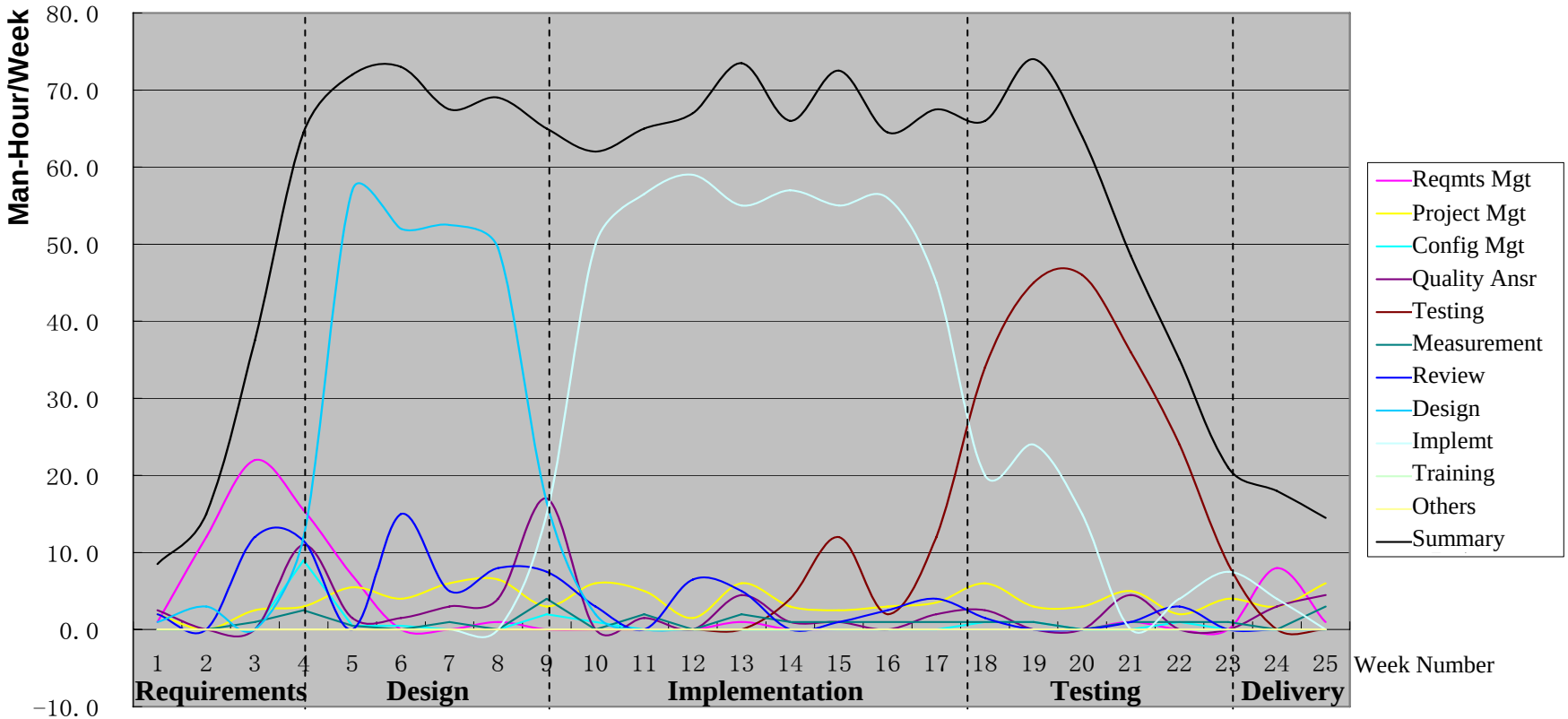
- This is a project-level RM of Project 2 from case study.

Resource Model of Project 3



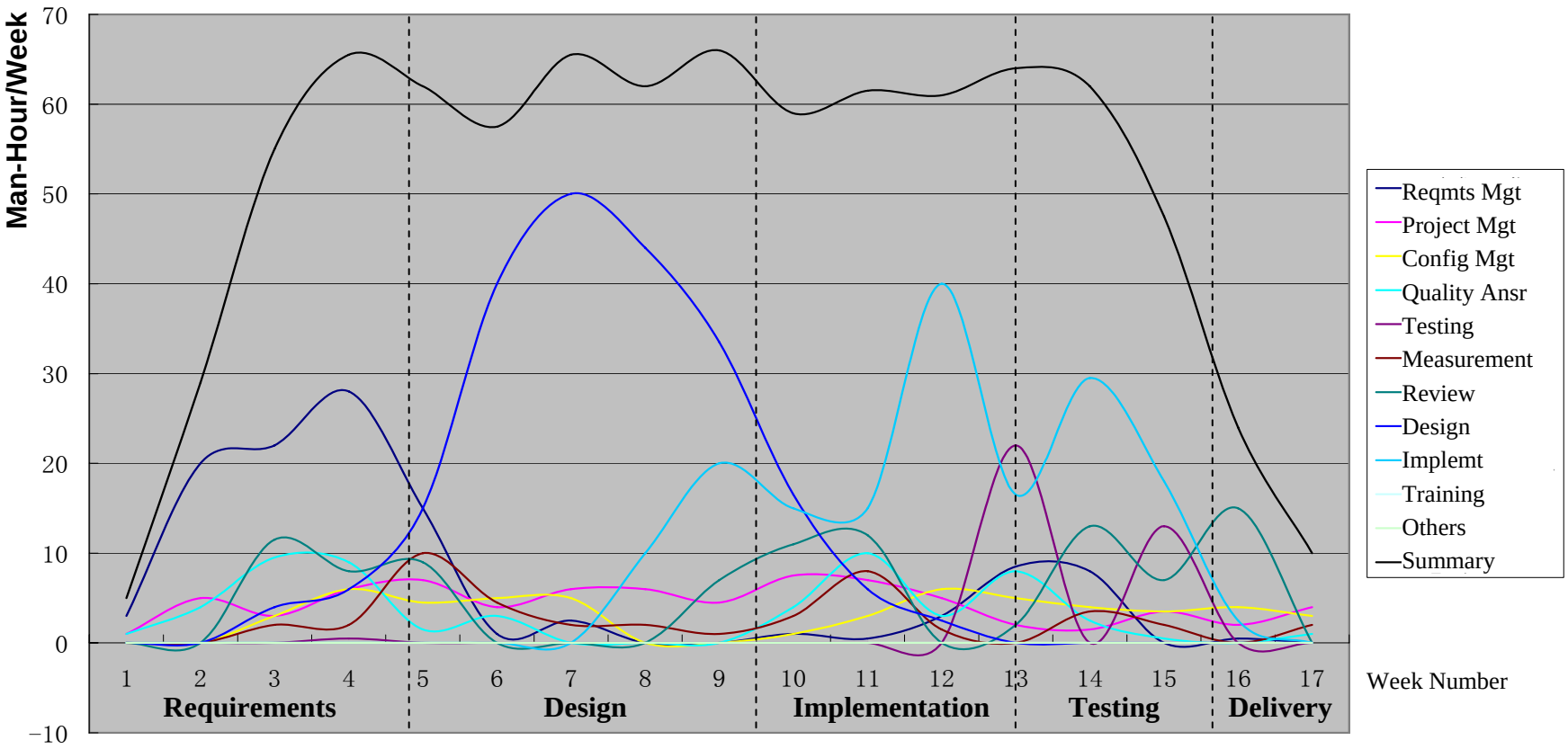
- This is a project-level RM of Project 3 from case study.

Resource Model of Project 4



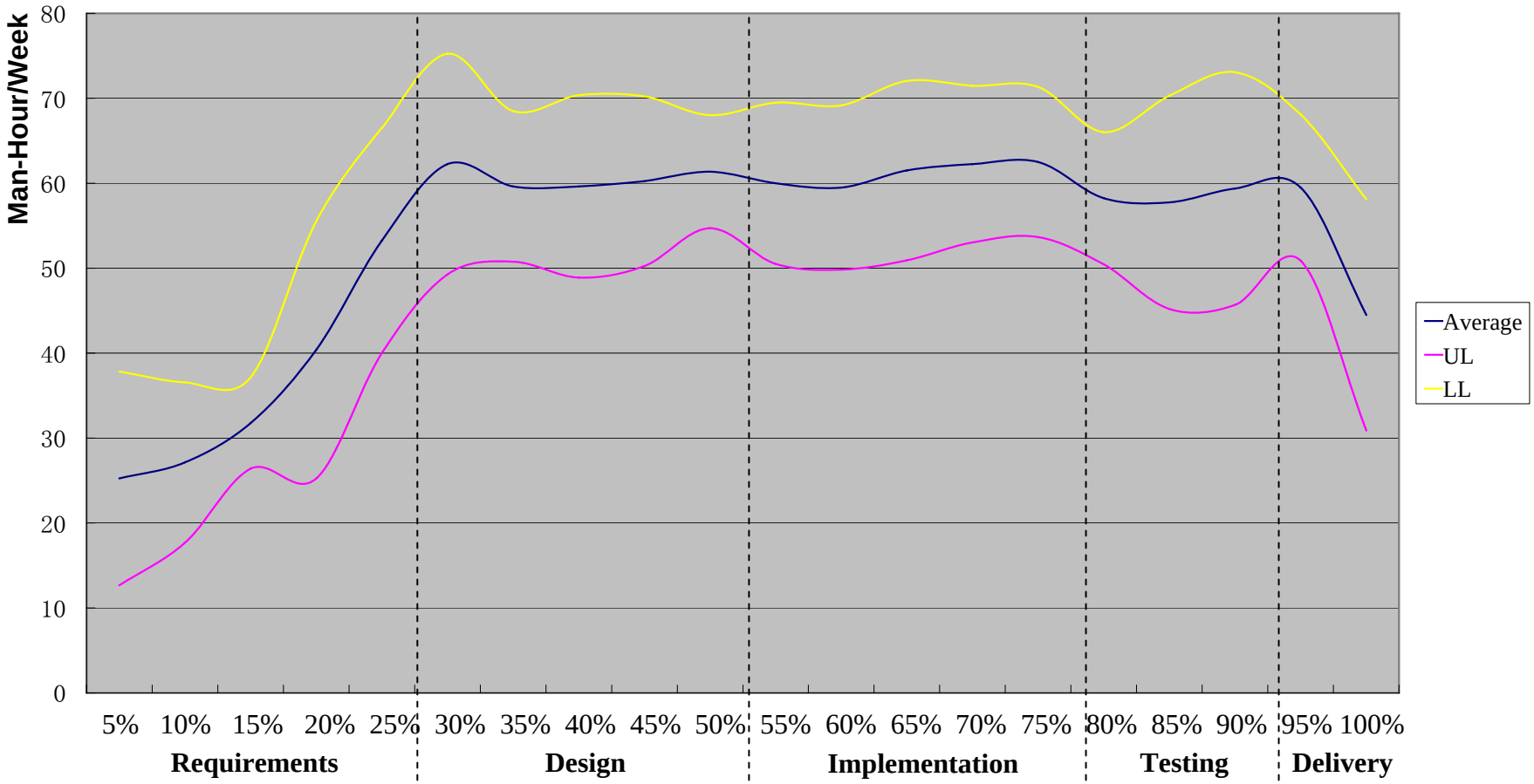
- This is a project-level RM of Project 4 from case study.

Resource Model of Project 5



- This is a project-level RM of Project 5 from case study.

II.4 RM at Organization Level



Where two kinds of curves are omitted: one is distribution curves of different task type effort; another is distribution curces of phase percentage.

II.5 Effort Weekly Distribution of Task Type

Phase \ Task Type	Week Number	Reqmts	PM	CM	QA	Test	Measmt	Review	Design	Train	Implemt	Others	Total
Requirements Phase	1	2.00	13.00	1.50	2.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50	22.00
	2	20.00	1.50	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	22.50
	3	19.50	1.00	0.00	0.00	0.00	0.50	0.00	0.00	2.00	0.00	0.00	23.00
	4	20.00	7.00	2.50	0.00	0.00	0.50	1.50	3.00	4.00	0.00	0.00	38.50
	5	20.50	4.50	10.50	2.00	0.00	1.00	17.50	18.50	0.00	0.00	5.00	79.50
	6	10.00	7.00	4.00	1.00	0.00	1.00	9.50	24.00	0.00	0.00	1.00	57.50
	7	5.00	6.50	9.00	2.50	0.00	10.00	0.50	19.50	0.00	0.00	0.00	53.00
Design Phase	8	0.00	5.50	4.50	6.00	0.00	3.00	2.00	34.00	0.00	0.00	2.00	57.00
	9	0.00	5.50	2.00	10.50	0.00	7.00	4.00	23.50	0.00	0.00	3.00	55.50
	10	0.00	1.00	4.50	0.00	0.00	10.50	0.00	1.00	0.00	22.50	0.00	39.50
Implementation Phase	11	0.00	1.00	4.50	0.00	0.00	10.50	0.00	1.00	0.00	22.50	0.00	39.50
	12	0.00	1.00	0.00	0.00	0.00	4.50	0.00	0.00	0.00	31.50	0.00	37.00
	13	0.00	2.00	0.00	4.00	1.00	2.00	0.00	0.00	0.00	27.50	0.00	36.50
	14	0.00	2.50	0.00	2.00	0.00	3.00	7.00	0.00	0.00	21.50	0.00	36.00
	15	1.50	3.50	1.00	6.00	13.00	1.50	9.00	0.00	0.00	17.00	0.00	52.50
	16	0.50	4.00	2.50	5.00	20.00	5.00	3.00	0.00	0.00	15.00	0.00	55.00
Testing Phase	17	0.00	1.50	0.00	0.00	26.50	2.00	0.00	0.00	0.00	29.50	0.00	59.50
	18	0.00	7.00	2.00	0.00	28.00	5.00	0.00	0.00	0.00	20.00	0.00	62.00
	19	1.00	2.00	3.00	8.50	10.00	6.50	11.50	0.00	0.00	8.00	0.00	50.50
	20	0.00	3.00	0.00	3.00	0.00	0.00	9.50	0.00	0.00	21.00	0.00	36.50
Delivery Phase	21	2.00	14.00	2.00	7.00	3.00	4.00	12.00	0.00	0.00	0.50	0.00	44.50
	22	1.00	14.00	3.00	7.00	1.00	3.00	9.00	0.00	0.00	0.60	0.00	38.60

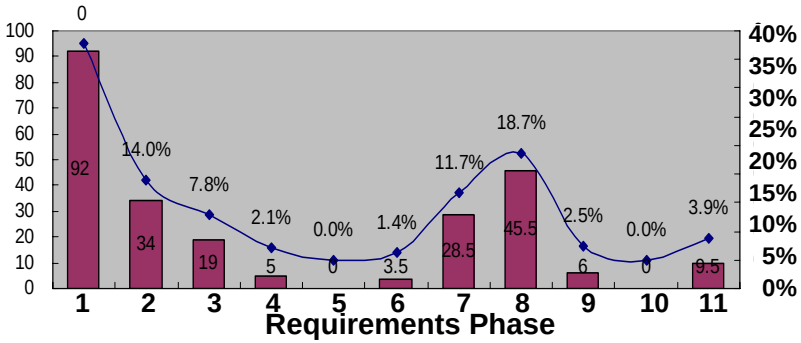
- The efforts summary of task types and the corresponding percentage are given in the next page.
- Some issues could be found according to the data (spotted with red color), and then further investigation could be performed.

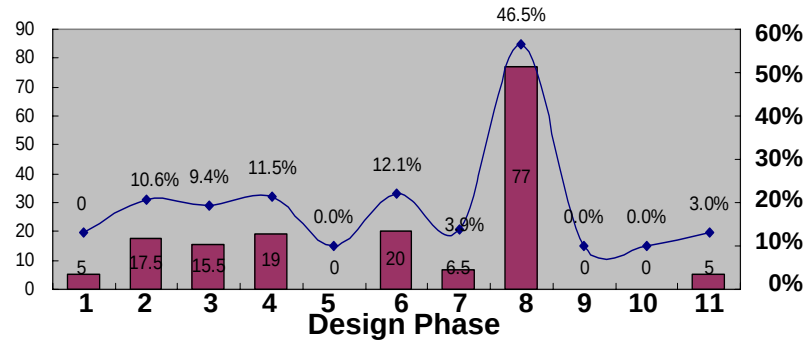
Effort Phase Distribution of Task Type

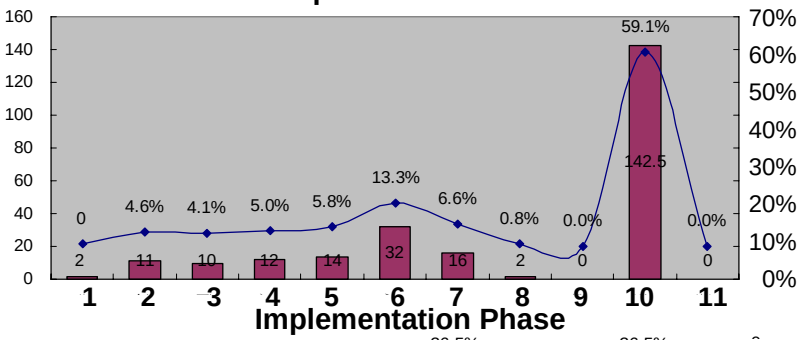
Phase Name &Work Hours/Percentage \ Task Type		Reqmts	PM	CM	QA	Test	Measmt	Review	Design	Train	Implemt	Others	Total
Requirements Phase	Man-Hour	92.00	34.00	19.00	5.00	0.00	3.50	28.50	45.50	6.00	0.00	9.50	243.00
	%	37.9%	14.0%	7.8%	2.1%	0.0%	1.4%	11.7%	18.7%	2.5%	0.0%	3.9%	25.38%
Design Phase	Man-Hour	5.00	17.50	15.50	19.00	0.00	20.00	6.50	77.00	0.00	0.00	5.00	165.50
	%	3.0%	10.6%	9.4%	11.5%	0.0%	12.1%	3.9%	46.5%	0.0%	0.0%	3.0%	17.28%
Implementation Phase	Man-Hour	1.50	11.00	10.00	12.00	14.00	32.00	16.00	2.00	0.00	142.50	0.00	241.00
	%	0.6%	4.6%	4.1%	5.0%	5.8%	13.3%	6.6%	0.8%	0.0%	59.1%	0.0%	25.17%
Testing Phase	Man-Hour	1.50	14.50	7.50	13.50	84.50	18.50	14.50	0.00	0.00	72.50	0.00	227.00
	%	0.7%	6.4%	3.3%	5.9%	37.2%	8.1%	6.4%	0.0%	0.0%	31.9%	0.0%	23.71%
Delivery Phase	Man-Hour	2.00	17.00	2.00	10.00	3.00	4.00	21.50	0.00	0.00	21.50	0.00	81.00
	%	2.5%	21.0%	2.5%	12.3%	3.7%	4.9%	26.5%	0.0%	0.0%	26.5%	0.0%	8.46%
Total Effort	Man-Hour	102.00	94.00	54.00	59.50	101.50	78.00	87.00	124.50	6.00	236.50	14.50	957.50
	%	10.7%	9.8%	5.6%	6.2%	10.6%	8.1%	9.1%	13.0%	0.6%	24.7%	1.5%	100.0%

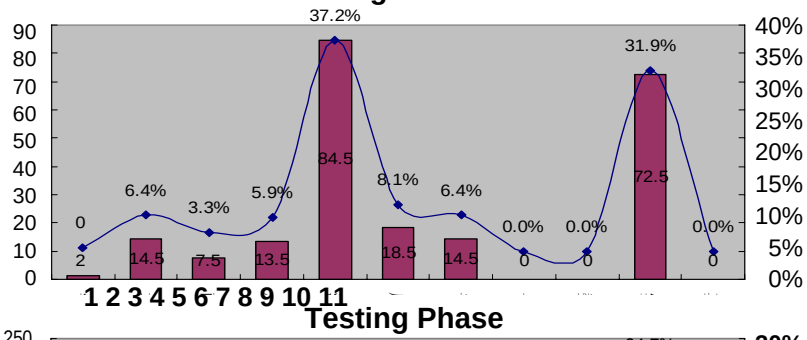
- The efforts summaries of both task types and phases, and their corresponding percentages, are given in the this table.
- Some issues could be pointed out according to the data shown, and then further investigation could be performed, such as some data spotted with red color.

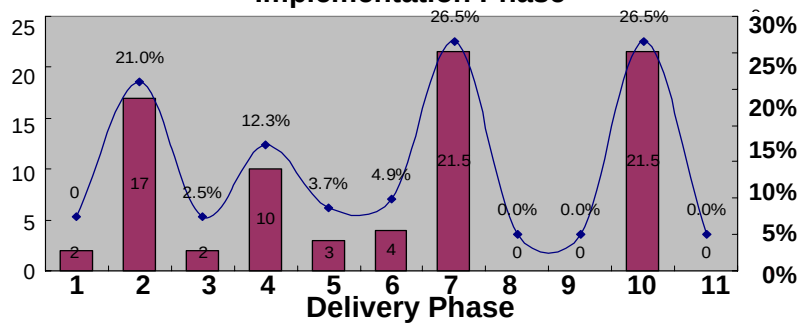
Effort Phase Distribution Diagram

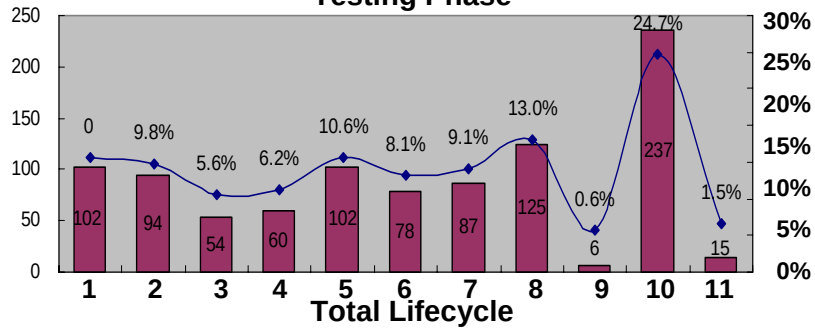












Task Types (the same issues can be spotted from the diagram):
1 Reqmts; 2 Project Mgt; 3 Confg Mgt; 4 QA; 5 Testing; 6 Measurement;
7 Review; 8 Design; 9 Training; 10 Implemt; 11 Others.

II.6 Phase Duration Distribution

Duration Phase	Low Limit (Week)	Average (Week)	Upper Limit (Week)	Sigma (Week)	Duration Stabilization
Reqmts Phase	3.10	5.00	6.90	0.63	12.65%
Design Phase	1.54	4.60	7.66	1.02	22.17%
Implemet Phase	1.53	5.60	9.67	1.36	24.22%
Testing Phase	1.20	3.60	6.00	0.80	22.22%
Delivery Phase	0.20	2.60	5.00	0.80	30.77%
Total		21.40			

- Phase duration distribution is from previous data table. Where the average values, the corresponding Low limits, Upper limits, Sigma, and the percentage can be seen.
- It can be seen from Delivery phase distribution value, its duration stabilization is not good enough and is needed to be improved.

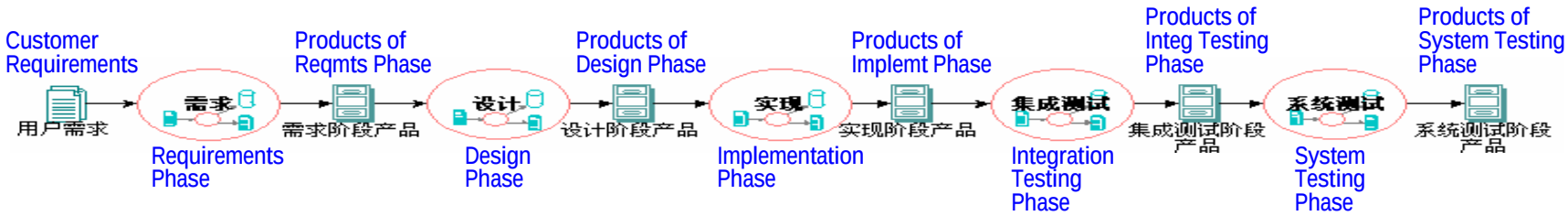
Effort Weekly Distribution

Week No.	Low Limit (hour)	Average (hour)	Upper Limit (hour)	Sigma (hour)	Weekload Stabilization
1	12.658	25.250	37.842	4.197	16.62%
2	17.675	27.125	36.575	3.150	11.61%
3	26.382	31.750	37.118	1.789	5.64%
4	25.232	40.375	55.518	5.048	12.50%
5	39.991	53.250	66.509	4.420	8.30%
6	49.248	62.250	75.252	4.334	6.96%
7	50.762	59.625	68.488	2.954	4.95%
8	48.887	59.625	70.363	3.579	6.00%
9	50.266	60.250	70.234	3.328	5.52%
10	54.729	61.375	68.021	2.215	3.61%
11	50.507	60.000	69.493	3.164	5.27%
12	49.837	59.500	69.163	3.221	5.41%
13	50.941	61.500	72.059	3.520	5.72%
14	53.027	62.250	71.473	3.074	4.94%
15	53.661	62.500	71.339	2.946	4.71%
16	50.468	58.250	66.032	2.594	4.45%
17	45.188	57.750	70.312	4.187	7.25%
18	45.671	59.375	73.079	4.568	7.69%
19	50.890	59.500	68.110	2.870	4.82%
20	30.885	44.500	58.115	4.538	10.20%

From this table we can see that workload weekly stabilization are quite good, only 4 weeks workloads are needed to investigate.

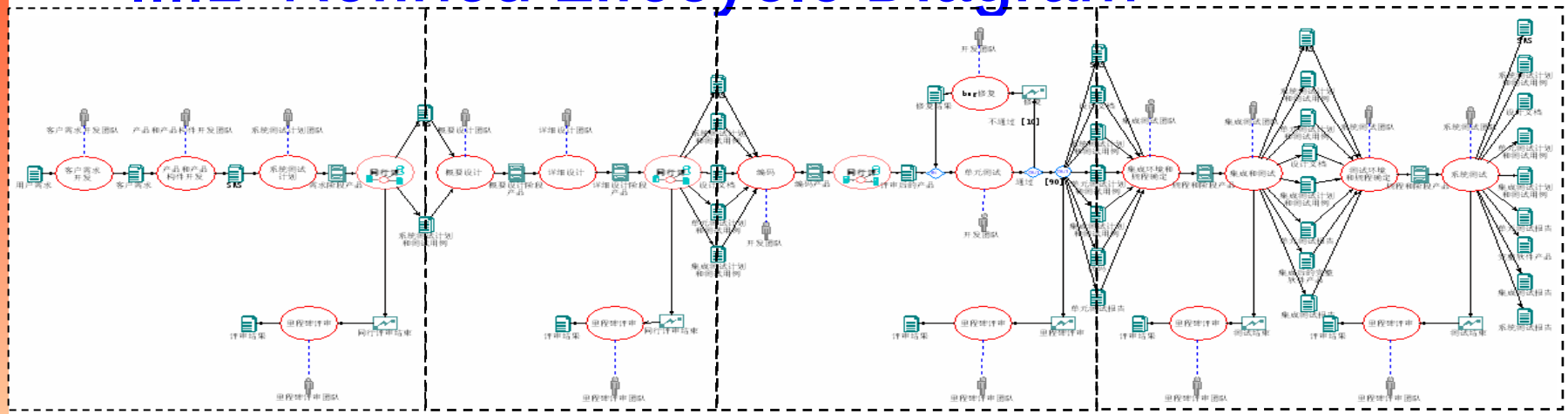
III Model Simulation Using EPMS

- EPMS is an Enterprise Process Modeling System developing in Chinese (The names of composite activities and composite products have been translated into English here).



  - It is a software development process diagram, including 5 phases: Requirements, Design, Implementation, Integration testing and System testing phases.
  - Each phases has input products of satisfying entry criteria and output products of satisfying exit criteria. As depicted there, there are 6 composite products: Customer Requirements, Products of Reqmts Phase, Products of Design Phase, Products of Implementation Phase, Products of Integrating Testing Phase, and Products of System Testing Phase.

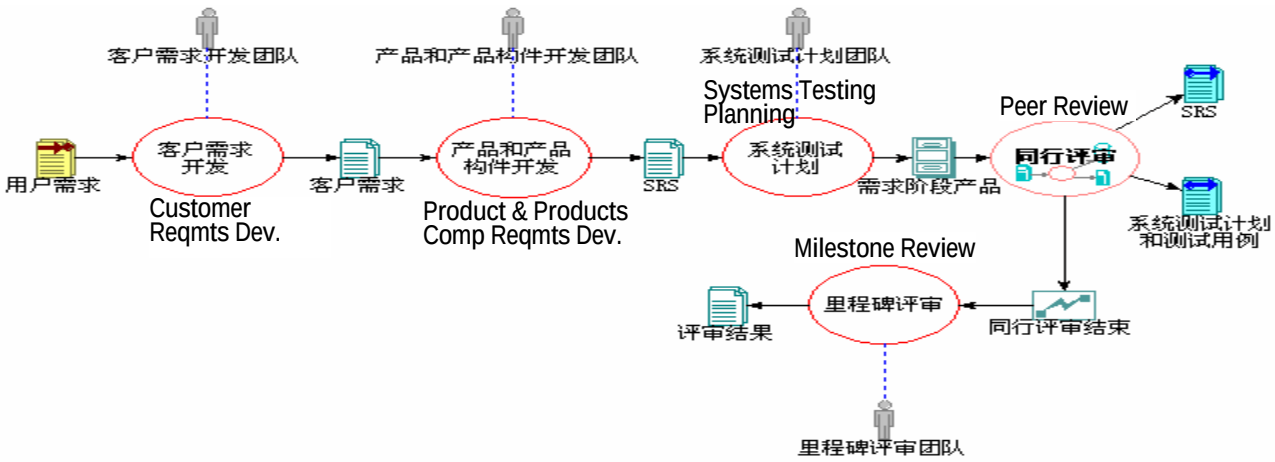
III.1 Refined Lifecycle Diagram



- As shown in diagram, the lifecycle includes 5 phases: Reqmts, Design, Implementation, Integrating Testing, and System testing phases. For the sake of simplicity after considering Review, the last two phases are combined as Testing phase later on.
- In supporting high maturity process improvement, Requirements review, Design review, and Implementation (code) review could be selected under statistical process control and optimization simulation as an example.

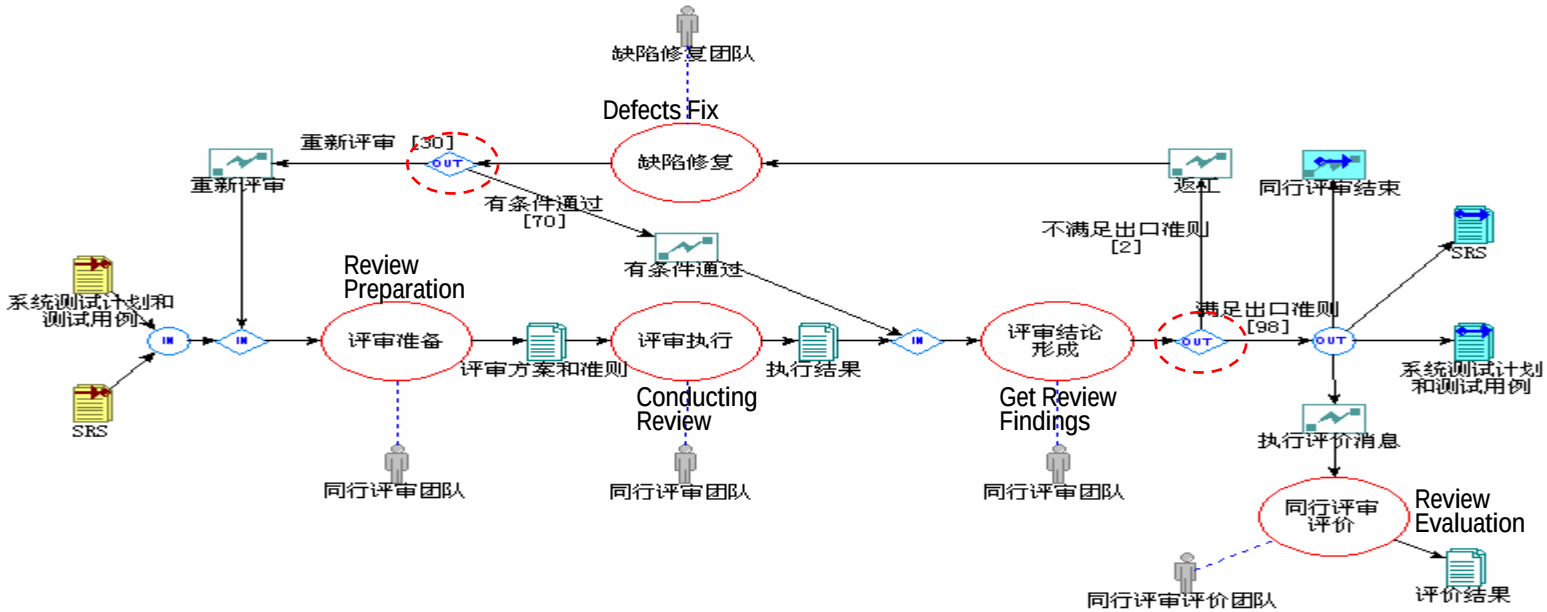
Requirements Phase

- Requirements Phase is composed of 5 Activities: Customer requirements development, Product and Product components developments, System testing planning, Peer review, and Milestone Review.
  - Requirements Peer Review is a composite activity, others are simple activities. Requirements Review does not be selected under statistical process control during this case study.
  - The input products and output products for each activity are depicted in the diagram.



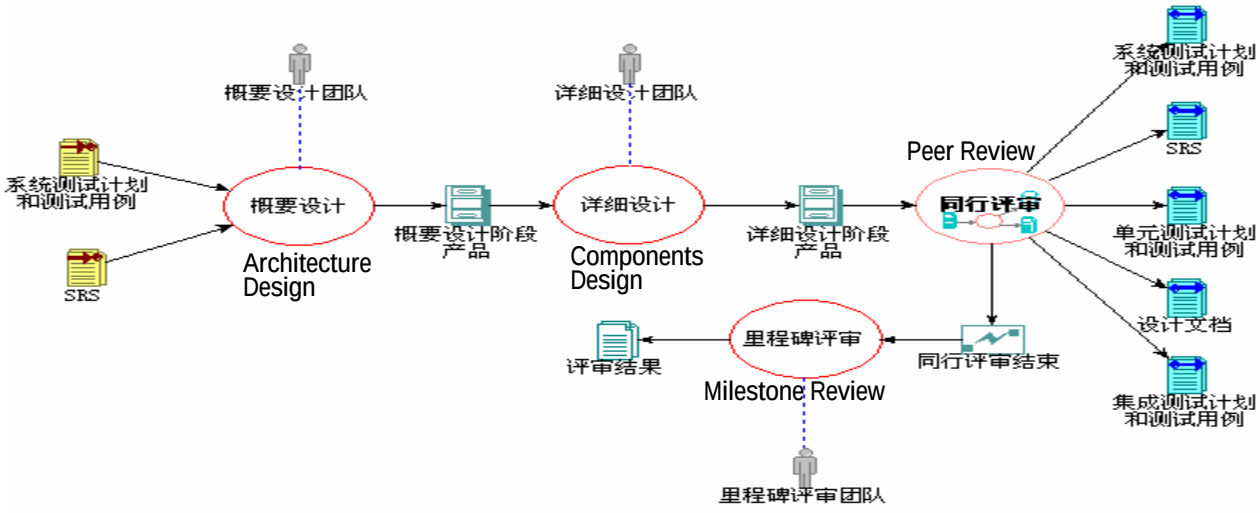
Requirements Peer Review Activities

- Requirements Peer Review is further composed of 5 activities: Review Preparation, Conducting Review, Get Review Findings, Defects Fix, and Review Evaluation.
- A special attention should be paid on the exit paths of two activities:
  - Get Review Findings: assume 2% needing rework and 98% passing to Review evaluation activity.
  - Defects Fix: 30% needing conducting review again and 70% passing to Get review findings activity.



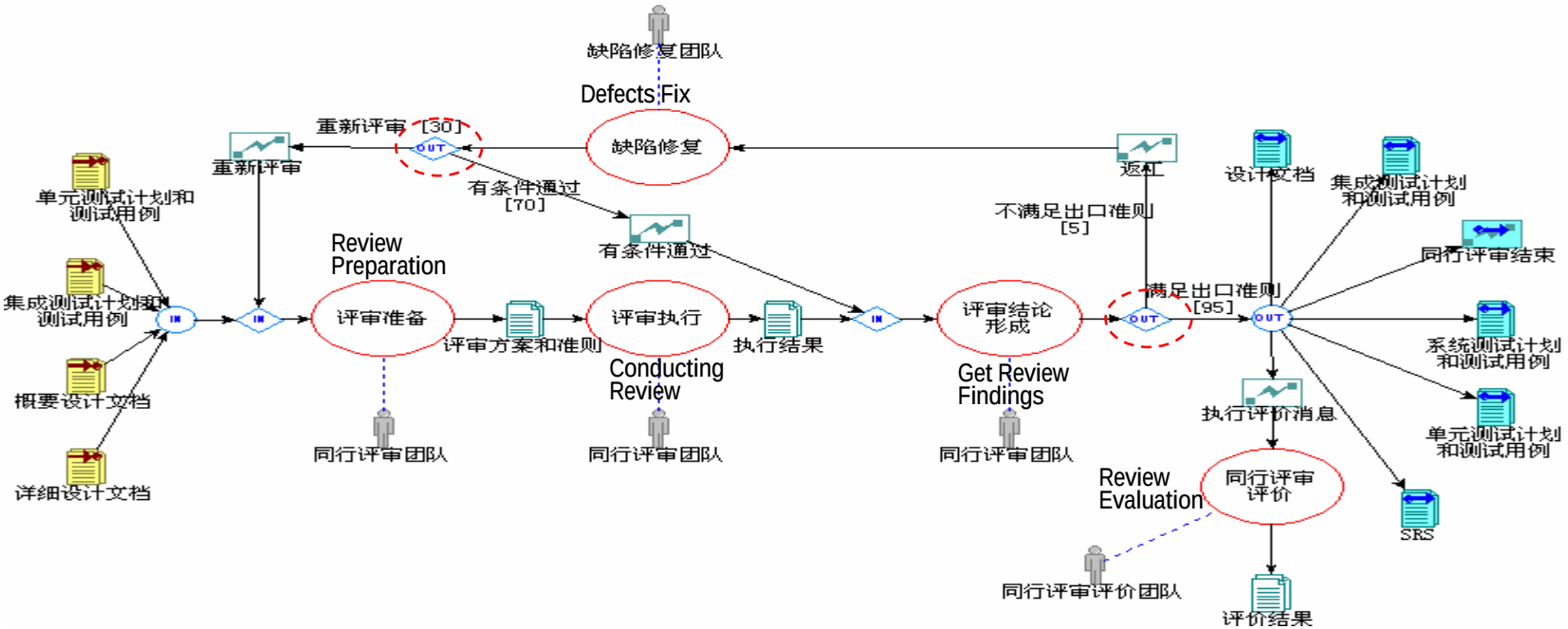
Design Phase

- Design Phase is composed of 4 Activities: Architecture design, Components design, Peer review, and Milestone Review.
  - Design Peer Review is a composite activity, others are simple activities. And Design Review is selected under statistical process control.
  - The input products and Output products for each activity are depicted in the diagram.



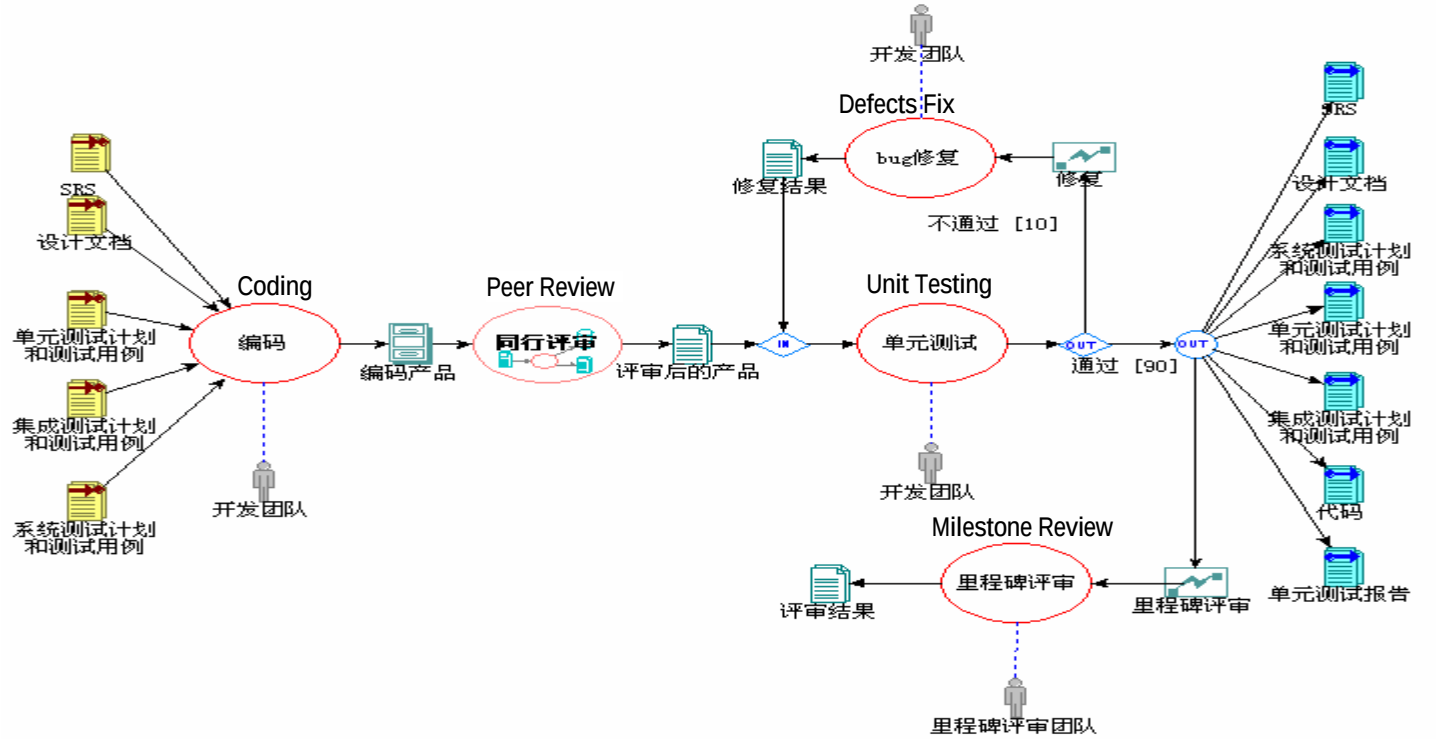
Design Peer Review Activities

- Design Peer Review is also composed of 5 activities: Review Preparation, Conducting Review, Get Review Findings, Defects Fix, and Review Evaluation.
- Also a special attention should be paid on the exit paths of two activities:
  - Get Review Findings: assume 5% needing rework and 95% passing to Review evaluation activity.
  - Defects Fix: 30% needing conducting review again and 70% passing to Get review findings activity.



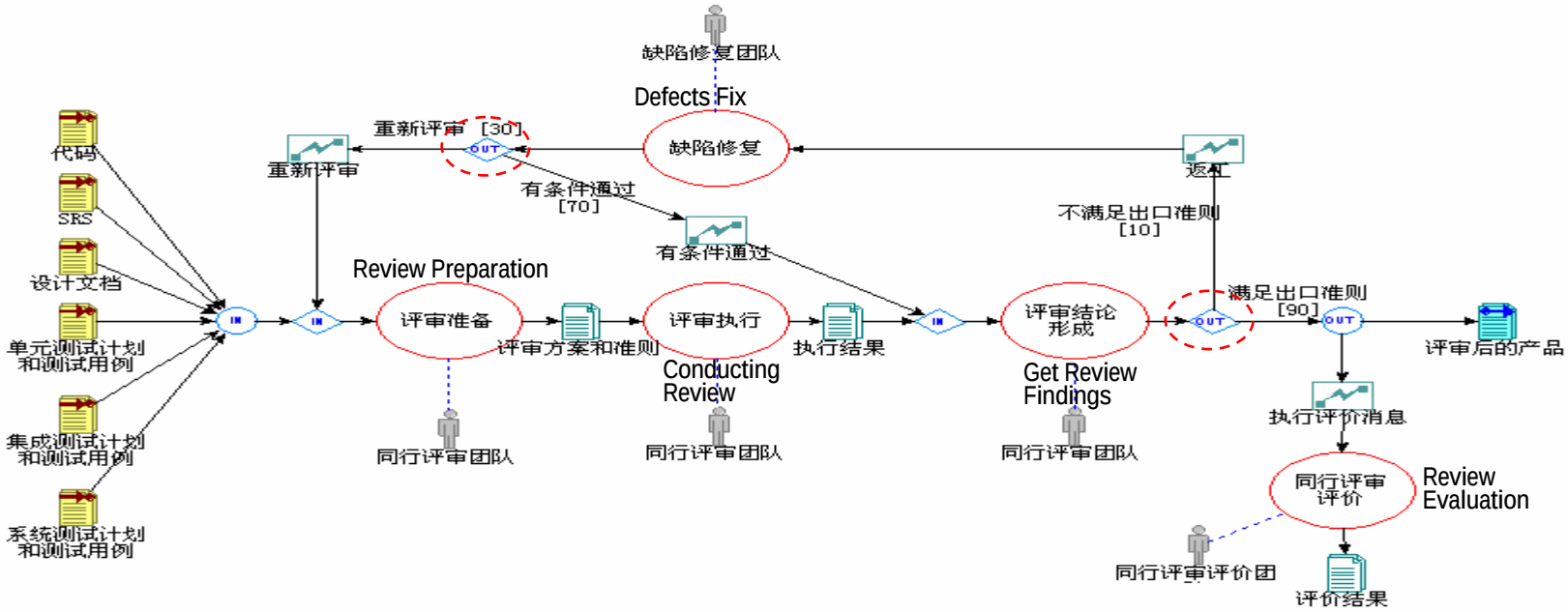
Implementation Phase

- Implementation Phase is composed of 5 Activities: Coding, Peer Review, Unit Testing, Defects Fix, and Milestone Review.
  - Implementation (Code) Peer Review is a composite activity, others are simple activities. And Code Review is selected under statistical control.
  - The input products and Output products for each activity are



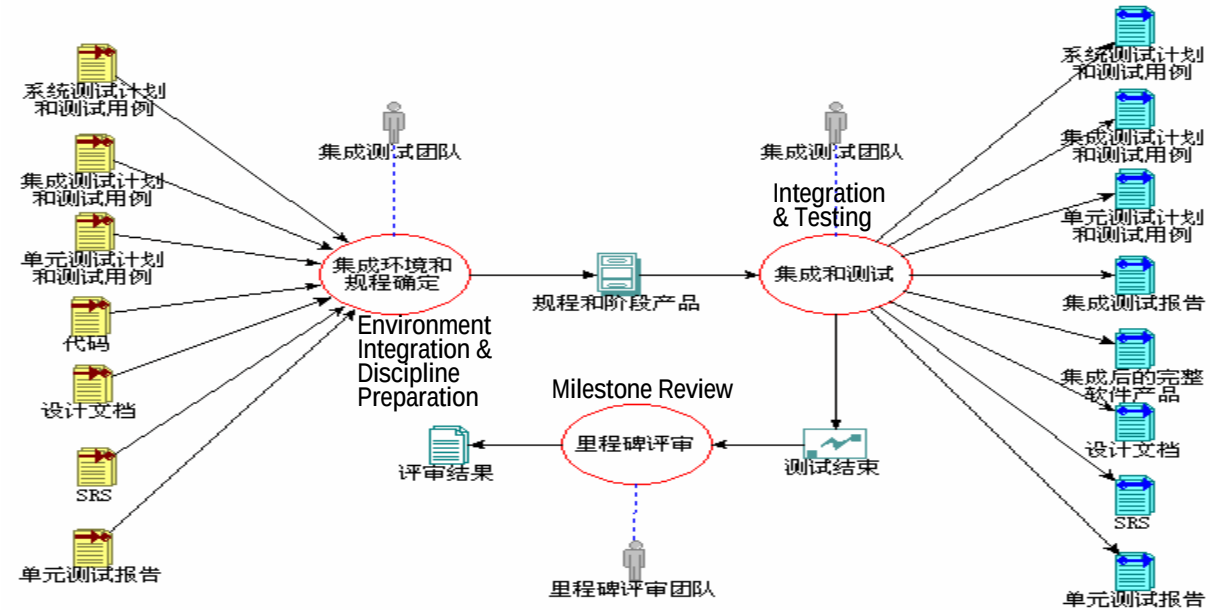
Implementation Peer Review Activities

- Implementation (Code) Peer Review is also composed of 5 activities: Review Preparation, Conducting Review, Get Review Findings, Defects Fix, and Review Evaluation.
- Also a special attention should be paid on the exit paths of two activities:
  - Get Review Findings: assume 10% needing rework and 90% passing to Review evaluation activity.
  - Defects Fix: 30% needing conducting review again and 70% passing to Get review findings activity.



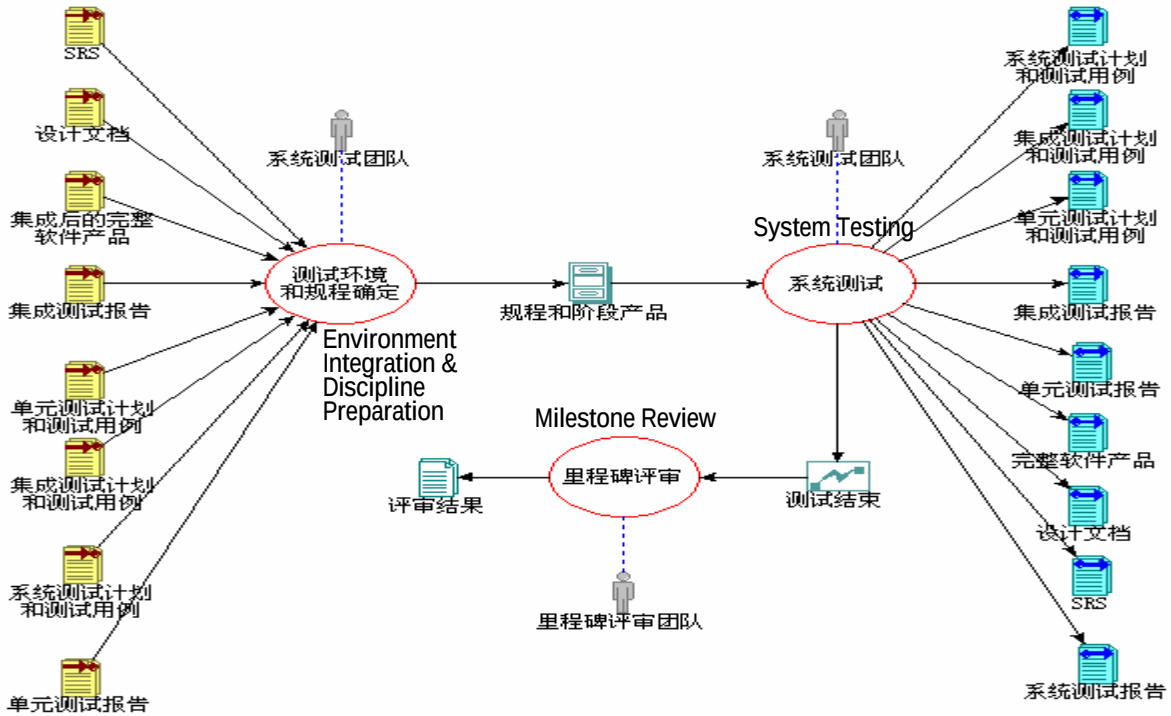
Integration Testing Phase

- Integration Testing Phase is composed of 3 simple activities: Environment Integration & Discipline Preparation, Integration & Testing, and Milestone Review.
- The input products and Output products for each activity are depicted in the diagram.



System Testing Phase

- System Testing Phase is composed of 3 simple activities: Environment Integration & Discipline Preparation, System Testing, and Milestone Review.
- The input products and Output products for each activity are depicted in the diagram.



III.2 Introduction to Simulation

- EPMS is a discrete type of simulation system. The whole simulation process is divided into 3 steps:
  - Non-reachable node can be found during instantiation check (diagram syntax check) and trial run.
  - Dynamic check is also to perform a trial run to detect whether there exist livelock and deadlock.
  - Optimization run is to adjust simulation parameters to ensure whether the model is optimized.
- As depicted on next 2 slides, red color of activity means that activity is running during simulation. We can use naked eyes to see whether the red color can reach the expected end. If not, then non-reachable node, or livelock, or deadlock are detected.

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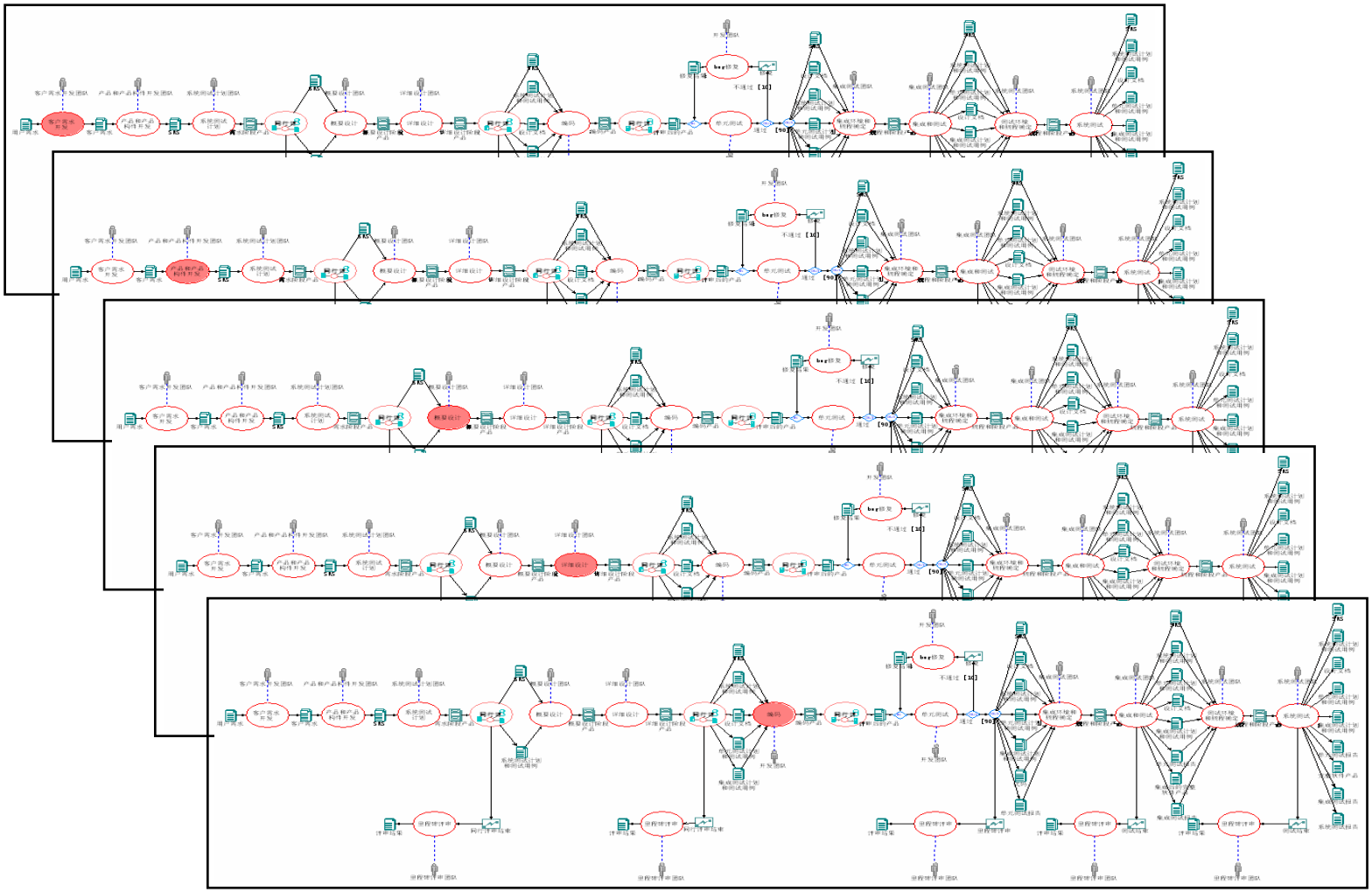
Lifecycle Simulation Running Chart - 1



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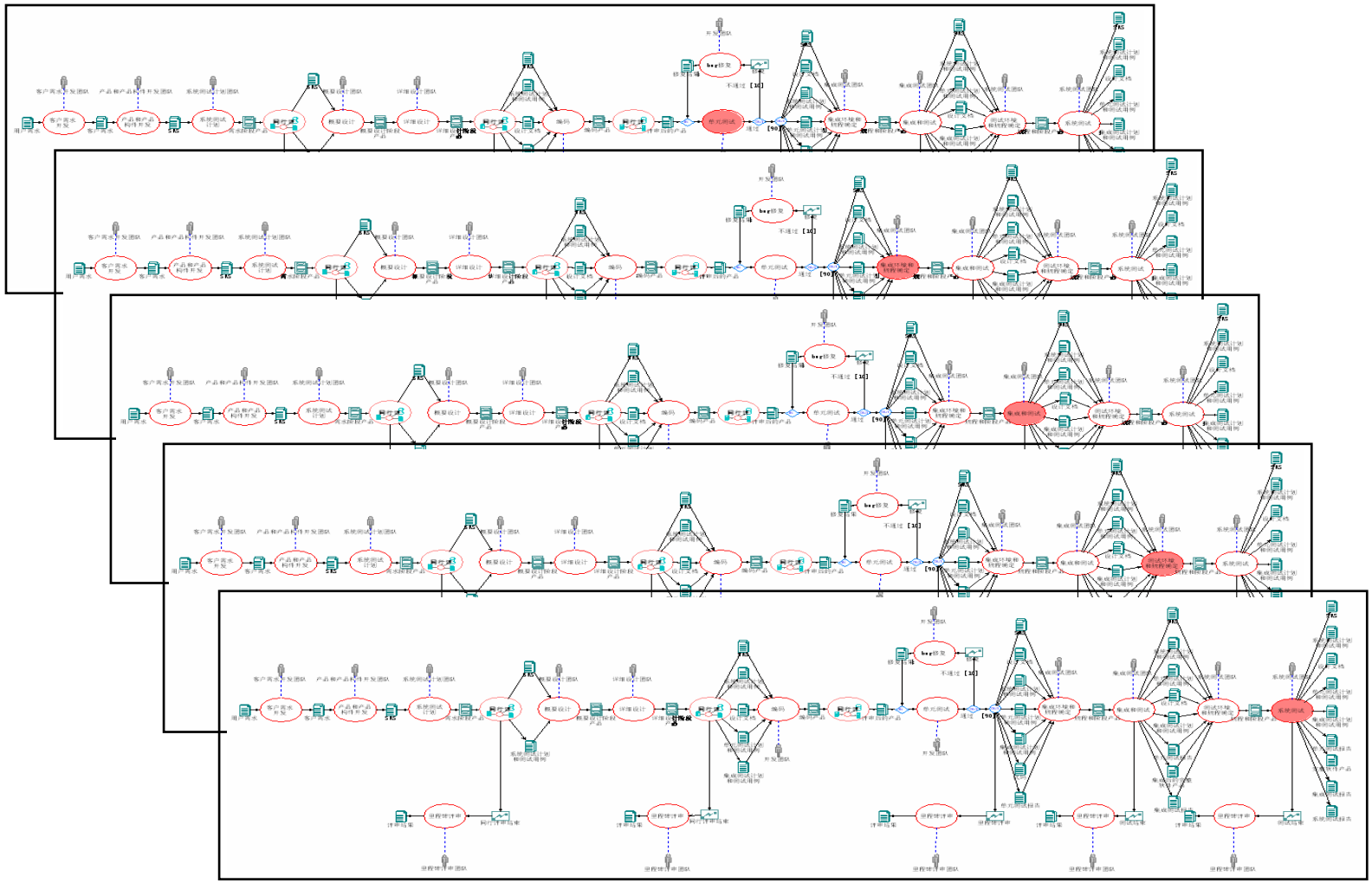
Lifecycle Simulation Running Chart - 2



Purpose and Assumptions

- Multiple objects optimization has not been solved in theory and practice. However, a lot of experiments could be performed to see whether the system is expected or not. Such as for system development, a special attention is paid on 3 aspects: cost, duration, and quality, which are chosen as optimized one depending on management's judgment.
- According to practice, review is a promise technology to optimize a system. The purpose of simulation is, when review effort is changed, to see what's the effect to efforts and duration of each system development phase.
- During modeling, there are some assumptions for simplicity:
  - The ratio of review effort of reqmts phase, design phase, and implementation phase to their total effort of that phase is respectively chosen as 0%, 10%, 20%, 30%, and 40%, which one should be chosen depending on simulation results.
  - At present, assume that one more defect found during reqmts (design, and implementation) phase will reduce 10 times defect removing effort during design (implementation, and testing) phase. Whether it is equal to 10 or some other value it is also needed to experiment.

Symbol Meanings - 1

- Duration computing
  - The total duration of whole lifecycle T = the sum of Reqmts phase duration Ta, Design phase duration Tb, Implementation phase duration Tc and Testing phase duration Td, i.e.:

    $$T = Ta+Tb+Tc+Td$$
- Effort computing
  - The total effort E of whole lifecycle = the sum of Reqmts phase effort Ea, Design phase effort Eb, Implementation phase effort Ec and Testing phase effort Ed, i.e.:

    $$E = Ea+Eb+Ec+Ed$$
  - Here Ea=Ea1+Ea2+Ea3, Eb=Eb1+Eb2+Eb3, Ec=Ec1+Ec2+Ec3, and Ed=Ed1+Ed2+Ed3, within which,
    - Ea1, Eb1, Ec1 and Ed1 are regular developments work efforts for each phase.
    - Ea2, Eb2, and Ec2 are peer review efforts conducted during requirements, design and implementation phases respectively. Ed2 =0, it means no testing review is taken.
    - Ea3, Eb3, Ec3 and Ed3 are efforts used to fix defects found in peer review.

Symbol Meanings - 2

- **Review and testing efficiency** is defined as the defects found per hour. Let Reqmts review efficiency is Pa, Design review efficiency Pb, Implementation review efficiency Pc, and Testing efficiency Pd respectively.
- **Defects removing efficiency** is defined as the defects removed per hour. Let Reqmts defects removing efficiency is Qa, Design defects removing efficiency Qb, Implementation defects removing efficiency Qc, and Testing defects removing efficiency Qd, respectively.

Symbol Meanings - 3

- Model state means the ratio of each review effort to the total effort of corresponding phase.
  - Assume that x, y and z represent the ratio of review effort for each phase respectively, which can be represented as follows:

    $x = (Ea2 + Ea3)/Ea,$

    $y = (Eb2 + Eb3)/Eb,$ and

    $z = (Ec2 + Ec3)/Ec.$
  - Then S{xyz} can be used to represent simulation state of model. If assume that A=0%, B=10%, C=20%, D=30% and E=40%, then x, y, and z can be represented as follows:

    $x \in \{A, B, C, D, E\},$

    $y \in \{A, B, C, D, E\},$ and

    $z \in \{A, B, C, D, E\}.$

Simulation Initialization - 1

- According to the results of case study, there are 5 projects of the similar project type, the following data are useful to lifecycle model simulation.
- Original effort data
  - Original state of the model is S{AAA}, i.e., the review effort ratios for Reqmts, Design, and Implementation phases are all equal to zero (0).
  - Total effort = the sum of Reqmts phase effort, Design phase effort, Implementation phase effort and Testing phase effort, according to the case study:

    E=Ea+Eb+Ec+Ed=1880 (Man-Hour),

    here Ea=300+0+0, Eb=240+0+0, Ec=890+0+0, and Ed=450, based on the average effort value of projects RMs.
- Review efficiency and testing efficency
  - Review efficiencies (Defects/Hour) are the average values of each project. For Reqmts review, Design review and Implementation review, they are:

    Pa=2.70, Pb=1.10, and Pc=1.30,(Defects/Hour), and Pd=1.0 is Testing efficiency (Defects/Hour).

Simulation Initialization - 2

- Defects removing efficiency
  - Based on case study, defects removing efficiencies of Reqmts phase, Design phase, Implementation phase, and Testing phase are as follows:

    Qa=2, Qb=2.5, Qc=6.0, and Qd=4.0, (Defects/Hour).
- Ratios between duration to effort
  - In principle, if effort and human number of each phase are known, and assume that communication efforts among humans do not consider yet, then:

    Duration = Effort/Human number.
  - The ratio Fi (i=a, b, c, d) from case study, between duration to effort for Reqmts, Design, Implementation, and Testing phases respectively are as follows:

    Fa=0.26, Fb=0.05, Fc=0.1, and Fd=0.08, (Man-Hour/Man).

Simulation Computing - 1

- Assume that the current state of model is S{uvw}, here:

  $u \in \{A, B, C, D, E\}$, $v \in \{A, B, C, D, E\}$, $w \in \{A, B, C, D, E\}$.

- If some review effort is changed, the successor state of model will become S{xyz}, there also exist that:

  $x \in \{A, B, C, D, E\}$, $y \in \{A, B, C, D, E\}$, $z \in \{A, B, C, D, E\}$.

- If they have been known the effort and duration of model under state S{uvw}, the simulation is used to dynamically determine the effort and duration of model under state S{xyz}:

  S{uvw} => S{xyz}

Duration and Effort Descriptions of S{uvw}

- Duration Description of S{uvw}
  - Total duration T{uvw} is the Sum of Reqmts phase duration Ta{uvw}, Design phase duration Tb{uvw}, Implementation phase duration Tc{uvw}, and Testing phase duration Td{uvw}.

$$T\{uvw\} = Ta\{uvw\} + Tb\{uvw\} + Tc\{uvw\} + Td\{uvw\}$$

- Effort Description of S{uvw}
  - Total effort E{uvw} is the Sum of Reqmts phase effort Ea{uvw}, Design phase effort Eb{uvw}, Implementation phase effort Ec{uvw}, and Testing phase effort Ed{uvw}.

$$E\{uvw\} = Ea\{uvw\} + Eb\{uvw\} + Ec\{uvw\} + Ed\{uvw\}$$

Here:

$$Ea\{uvw\} = Ea1\{uvw\} + Ea2\{uvw\} + Ea3\{uvw\}$$

$$Eb\{uvw\} = Eb1\{uvw\} + Eb2\{uvw\} + Eb3\{uvw\}$$

$$Ec\{uvw\} = Ec1\{uvw\} + Ec2\{uvw\} + Ec3\{uvw\}$$

$$Ed\{uvw\} = Ed1\{uvw\} + Ed2\{uvw\} + Ed3\{uvw\}$$

Duration and Effort Descriptions of S{xyz}

- Duration Description of S{xyz}
  - Total duration T{xyz} is the Sum of Reqmts phase duration Ta{xyz}, Design phase duration Tb{xyz}, Implementation phase duration Tc{xyz}, and Testing phase duration Td{xyz}.

    T{xyz}＝Ta{xyz}＋Tb{xyz}＋Tc{xyz}＋Td{xyz}

- Effort Description of S{xyz}
  - Total effort E{xyz} is the Sum of Reqmts phase effort Ea{xyz}, Design phase effort Eb{xyz}, Implementation phase effort Ec{xyz}, and Testing phase effort Ed{xyz}.

    E{xyz}＝Ea{xyz}＋Eb{xyz}＋Ec{xyz}＋Ed{xyz}

    Here:

    Ea{xyz}＝Ea1{xyz}＋Ea2{xyz}＋Ea3{xyz}

    Eb{xyz}＝Eb1{xyz}＋Eb2{xyz}＋Eb3{xyz}

    Ec{xyz}＝Ec1{xyz}＋Ec2{xyz}＋Ec3{xyz}

    Ed{xyz}＝Ed1{xyz}＋Ed2{xyz}＋Ed3{xyz}

IV Transformation Formulas of Model

- Four sets of computing formulas of transforming Model S{uvw} to Model S{xyz} are as follows, the detail will be described on next several slides.
  - Efforts Computing when Reqmts Review Efforts are changed.
  - Efforts Computing when Design Review Efforts are changed.
  - Efforts Computing when Implementation Review Efforts are changed.
  - Efforts Computing when Testing Review Efforts are changed.

Efforts Computing when Reqmts Review Efforts are changed

- Efforts Computing is as follows, when Reqmts Review Efforts are changed:

$$Ea1\{xyz\} = Ea1\{uvw\} \qquad (E\text{-}a1)$$

$$Ea2\{xyz\} + Ea3\{xyz\} = x \times (Ea1\{xyz\} + Ea2\{xyz\} + Ea3\{xyz\})$$

$$Ea2\{xyz\} \times Pa/Qa = Ea3\{xyz\}$$

- From above we can get:

$$Ea2\{xyz\} = x \times Ea1\{uvw\} / ((1-x)(1+Pa/Qa)) \qquad (E\text{-}a2)$$

$$Ea3\{xyz\} = x \times Pa/Qa \times Ea1\{uvw\} / ((1-x)(1+Pa/Qa)) \qquad (E\text{-}a3)$$

$$Ea\{xyz\} = Ea1\{xyz\} + Ea2\{xyz\} + Ea3\{xyz\} \qquad (E\text{-}a)$$

- Note that Pa is Reqmts review efficiency and Qa is Defects removing efficiency of reqmts phase. From case study, there are:

$$Pa = 2.7,\ Qa = 2$$

Efforts Computing when Design Review Efforts are changed

- Efforts computing is as follows, when Design Review Efforts are changed:

$$Eb1\{xyz\} = Eb1\{uvw\} - (Ea2\{xyz\} - Ea2\{uvw\}) \times Pa/Qa \times 10 \qquad (E\text{-}b1)$$

$$Eb2\{xyz\} + Eb3\{xyz\} = y \times (Eb1\{xyz\} + Eb2\{xyz\} + Eb3\{xyz\})$$

$$Eb3\{xyz\} = Eb3\{uvw\} + (Eb2\{xyz\} - Eb2\{uvw\}) \times Pb/Qb$$

- From above we can get:

$$Eb2\{xyz\} = ((y/(1-y) \times (Eb1\{uvw\} - (Ea2\{xyz\} - Ea2\{uvw\} \times Pa/Qb \times 10 + Eb2\{uvw\} \times Pb/Qb - Eb3\{uvw\})/(1 + Pb/Qb) \qquad (E\text{-}b2)$$

$$Eb3\{xyz\} = Eb3\{uvw\} + (Eb2\{xyz\} - Eb2\{uvw\}) \times Pb/Qb \qquad (E\text{-}b3)$$

$$Eb\{xyz\} = Eb1\{xyz\} + Eb2\{xyz\} + Eb3\{xyz\} \qquad (E\text{-}b)$$

- Note that here $Pi(i=a,b)$ is Reqmts review and Design review efficiencies and $Qi(i=a,b)$ is Reqmts and Design review defects removing efficiency. Pa and Qa are already given, Pb=1.1 and Qb=2.5 respectively.

Efforts Computing when Implementation Review Efforts are changed

- Efforts computing formulas are as follows, when Implementation Review Efforts are changed:

$$Ec1\{xyz\} = Ec1\{uvw\} - (Eb2\{xyz\} - Eb2\{uvw\}) \times Pb \times Qc \times 10 \qquad (E\text{-}c1)$$

$$Ec2\{xyz\} + Ec3\{xyz\} = z \times (Ec1\{xyz\} + Ec2\{xyz\} + Ec3\{xyz\})$$

$$Ec3\{xyz\} = Ec3\{uvw\} + (Ec2\{xyz\} - Ec2\{uvw\}) \times Pc/Qc$$

- From above we can get:

$$Ec2\{xyz\} = ((z/(1-z) \times (Ec1\{uvw\} - (Eb2\{xyz\} - Eb2\{uvw\} \times Pb/Qc \times 10 + Ec2\{uvw\} \times Pc/Qc - Ec3\{uvw\})/(1 + Pc/Qc) \qquad (E\text{-}c2)$$

$$Ec3\{xyz\} = Ec3\{uvw\} + (Ec2\{xyz\} - Ec2\{uvw\}) \times Pc/Qc \qquad (E\text{-}c3)$$

$$Ec\{xyz\} = Ec1\{xyz\} + Ec2\{xyz\} + Ec3\{xyz\} \qquad (E\text{-}c)$$

- Here the meanings of Pc=1.3 and Qc=6.0 are implementation review and implementation defects removing efficiencies, respectively.

Efforts Computing when Testing Review Efforts are changed

- Efforts computing formulas as follows, when Testing Review Efforts are changed:

$$Ed1\{xyz\} = Ed1\{uvw\} - (Ec2\{xyz\} - Ec2\{uvw\}) \times Pc/Qc \times 10 \quad (E\text{-}d1)$$

$$Ed2\{xyz\} = 0 \quad (E\text{-}d2)$$

$$Ed3\{xyz\} = Ed3\{uvw\} - ((Ec2\{xyz\} - Ec2\{uvw\}) \times Pc/Qc \times 10)) \times Pd/Qd \quad (E\text{-}d3)$$

$$Ed\{xyz\} = Ed1\{xyz\} + Ed2\{xyz\} + Ed3\{xyz\} \quad (E\text{-}d)$$

- Total effort of Testing phase can be computed out from (E-a4), (E-b4), (E-c4) and (E-d4):

$$E\{xyz\} = Ea\{xyz\} + Eb\{xyz\} + Ec\{xyz\} + Ed\{xyz\} \quad (E)$$

- Here the meanings of Pd=1.0 and Qd=4.0 are testing and testing defects removing efficiencies, respectively.

The Computing of Total Effort and Durations

- Computing of Phase duration and Total duration: according to the following formulas, Phase duration and Total duration can be computed out as follows:

$$Ta\{xyz\} = Ea\{xyz\} \times Fa \quad (T\text{-}a)$$

$$Tb\{xyz\} = Eb\{xyz\} \times Fb \quad (T\text{-}b)$$

$$Tc\{xyz\} = Ec\{xyz\} \times Fc \quad (T\text{-}c)$$

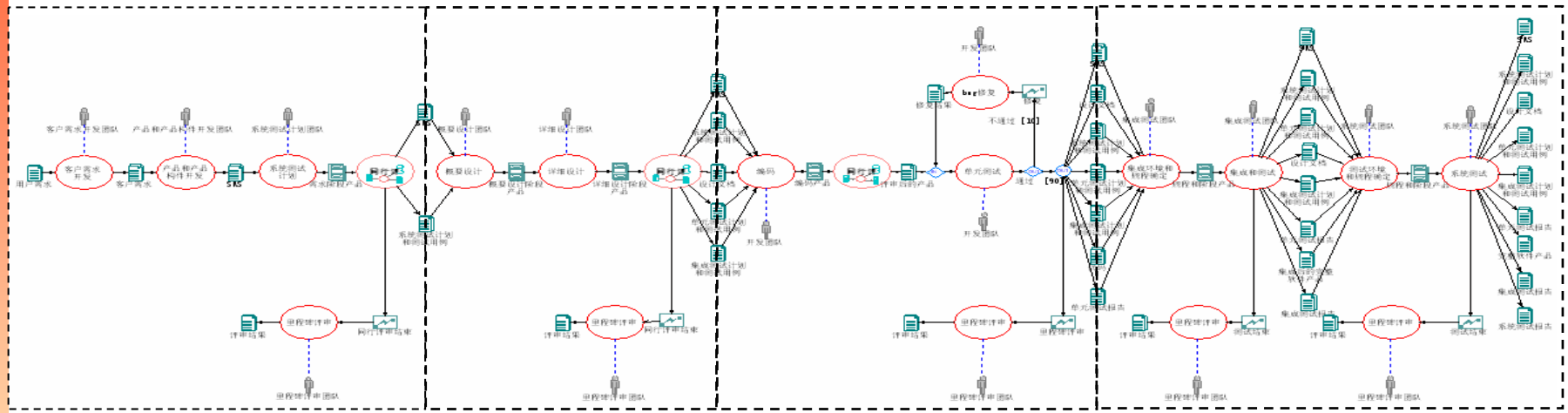
$$Td\{xyz\} = Ed\{xyz\} \times Fd \quad (T\text{-}d)$$

$$T\{xyz\} = Ta\{xyz\} + Tb\{xyz\} + Tc\{xyz\} + Td\{xyz\} \quad (T)$$

- The ratio Fi (i=a, b, c, d), from case study, between duration to effort for Reqmts, Design, Implementation, and Testing phases respectively are as follows:

  Fa=0.26, Fb=0.05, Fc=0.10, and Fd=0.08.

V Sketch Map and Explanation



Reqmts Phase
Formula (E-a1)
Formula (E-a2)
Formula (E-a3)
Formula (E-a)
{Pa, Qa, Fa}
{uvw, xyz}

Design Phase
Formula (E-b1)
Formula (E-b2)
Formula (E-b3)
Formula (E-b)
{Pb, Qb, Fb}
{uvw, xyz}

Implemt Phase
Formula (E-c1)
Formula (E-c2)
Formula (E-c3)
Formula (E-c)
{Pc, Qc, Fc}
(uvw, xyz}

Testing Phase
Formula (E-d1)
Formula (E-d2)
Formula (E-d3)
Formula (E-d)
{Pd, Qd, Fd}
{uvw, xyz}

- A set of parameters are transferred between different lifecycle phase.

Formulas are built in Activity

- The computing formulas are described in previous slides are:

  (E-ai, i=1, 2, 3) and (E-a),

  (E-bi, i=1, 2, 3) and (E-b),

  (E-ci, i=1, 2, 3) and (E-c),

  (E-di, i=1, 2, 3) and (E-d) and (E), and

  (T-i, i=a, b, c, d) and (T)

- All these formulas are built in Activity specification of EPMS and dynamically computed during simulation.
- The path of each execution is non-deterministic since there exist probabilistic distribution within each composite review activity at the output of Get Review Findings and Defects Fix activity, see next slide and see slides 25, 27, and 29 of this presentation.

Probability Execution Paths

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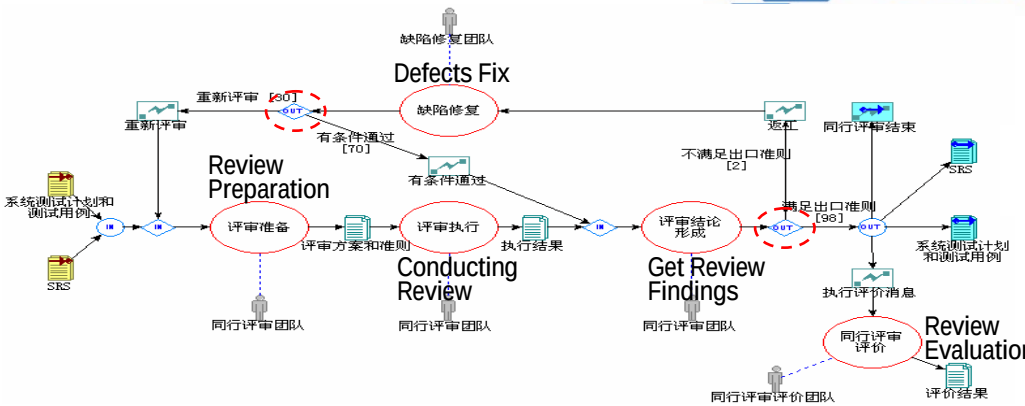
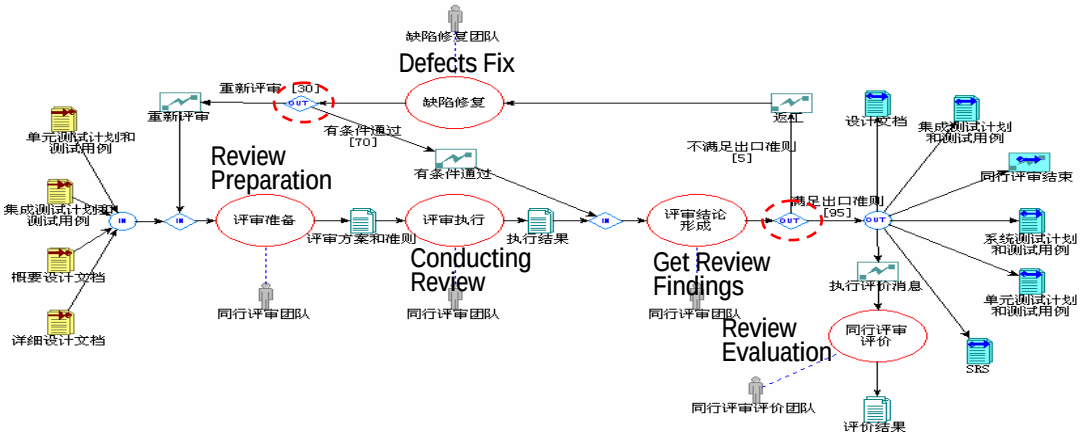
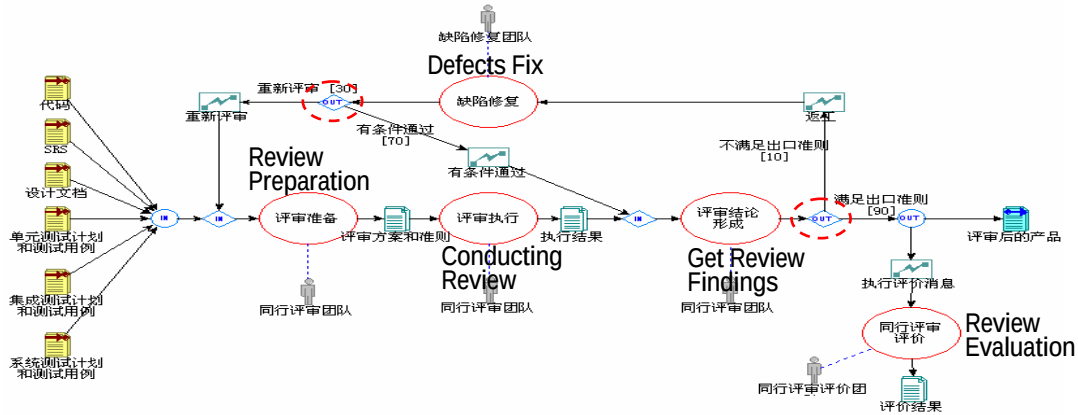




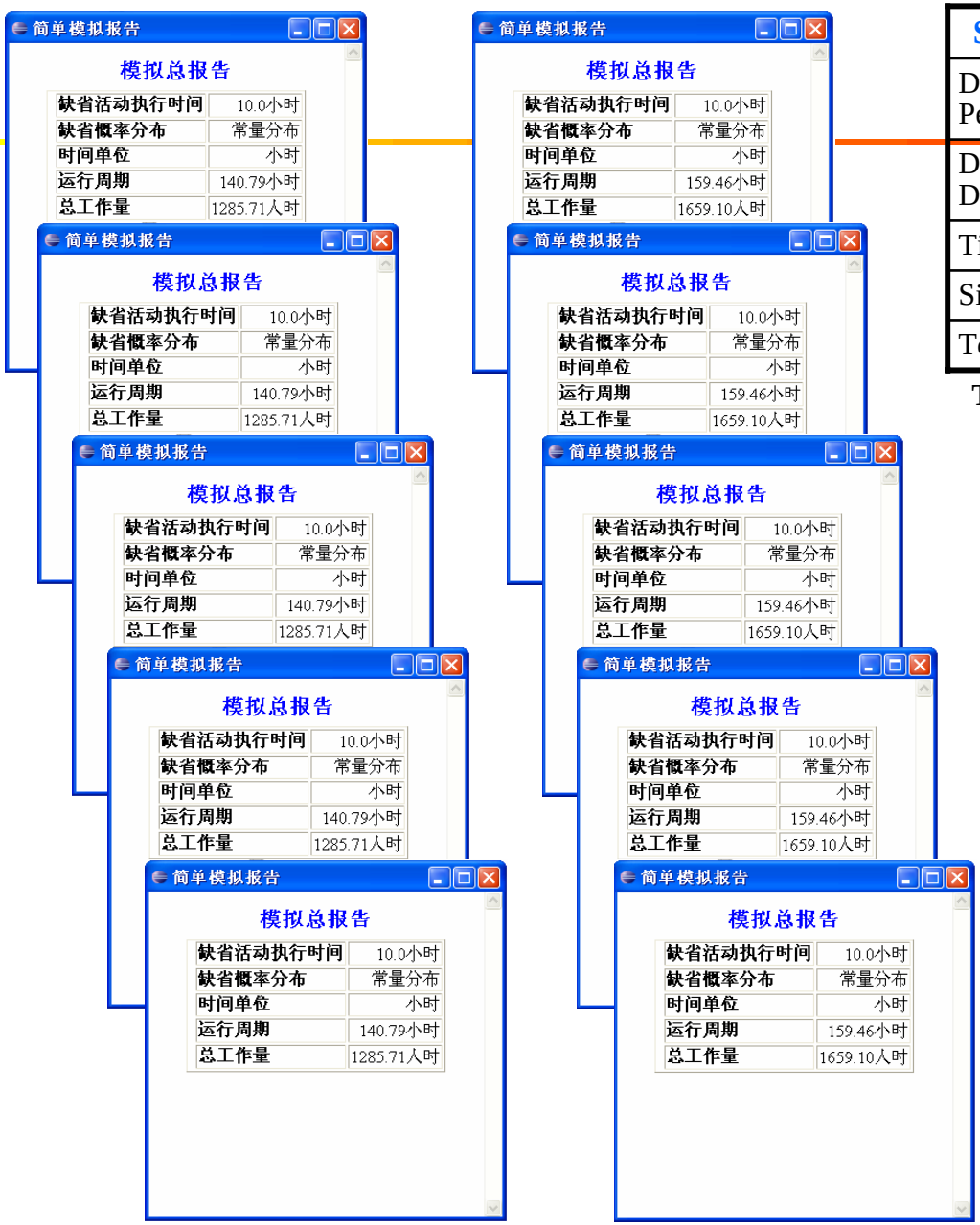


Simulation Results Report 1

Simulation Results Report	
Default Performing Time	Hour
Default Probability Distribution	Constant distribution
Time unit	Hour
Simulation Time	Hour
Total Effort	Man-Hour

Translation of Record Titles

Simulation Results Report - 2



Simulation Results Report	
Default Performing Time	Hour
Default Probability Distribution	Constant distribution
Time unit	Hour
Simulation Time	Hour
Total Effort	Man-Hour

Translation of Record Titles

Effort Distribution of Simulation Results

State No.	Effort	Reqmts Review Effort %	Design Review Effort %	Code Review Effort %	Reqmts Phase Effort (Man-hour)	Design Phase Effort (Man-hour)	Implemt Phase Effort (Man-hour)	Testing Phase Effort (Man-hour)	Total Effort (Man-hour)
1	S{A, A, A}	0%	0%	0%	300.00	240.00	890.00	450.00	1880.00
2	S{A, A, B}	0%	0%	10%	300.00	240.00	978.99	94.55	1613.54
3	S{A, A, C}	0%	0%	20%	300.00	240.00	1068.01	0.00	1608.01
4	S{A, A, D}	0%	0%	30%	300.00	240.00	1157.00	0.00	1697.00
5	S{A, A, E}	0%	0%	40%	300.00	240.00	1245.99	0.00	1785.99
6	S{A, B, A}	0%	10%	0%	300.00	321.26	797.40	450.00	1868.66
7	S{A, B, B}	0%	10%	10%	300.00	321.26	836.93	450.00	1908.19
8	S{A, B, C}	0%	10%	20%	300.00	321.26	876.46	450.00	1947.72
9	S{A, B, D}	0%	10%	30%	300.00	321.26	915.98	450.00	1987.24
10	S{A, B, E}	0%	10%	40%	300.00	321.26	955.51	450.00	2026.77
11	S{A, C, A}	0%	20%	0%	300.00	402.51	704.80	450.00	1857.31
12	S{A, C, B}	0%	20%	10%	300.00	402.51	730.40	450.00	1882.91
13	S{A, C, C}	0%	20%	20%	300.00	402.51	756.01	450.00	1908.52
14	S{A, C, D}	0%	20%	30%	300.00	402.51	781.61	450.00	1934.12
15	S{A, C, E}	0%	20%	40%	300.00	402.51	807.21	450.00	1959.72
16	S{A, D, A}	0%	30%	0%	300.00	483.76	612.22	450.00	1845.98
17	S{A, D, B}	0%	30%	10%	300.00	483.76	623.90	450.00	1857.66
18	S{A, D, C}	0%	30%	20%	300.00	483.76	635.58	450.00	1869.34
19	S{A, D, D}	0%	30%	30%	300.00	483.76	647.26	450.00	1881.02
20	S{A, D, E}	0%	30%	40%	300.00	483.76	658.94	450.00	1892.70
21	S{A, E, A}	0%	40%	0%	300.00	565.02	556.97	450.00	1871.99
22	S{A, E, B}	0%	40%	10%	300.00	565.02	556.97	450.00	1871.99
23	S{A, E, C}	0%	40%	20%	300.00	565.02	556.97	450.00	1871.99
24	S{A, E, D}	0%	40%	30%	300.00	565.02	556.97	450.00	1871.99
25	S{A, E, E}	0%	40%	40%	300.00	565.02	556.97	450.00	1871.99

Duration Distribution of Simulation Results

State No.	Simulation State	Reqmts Review Effort %	Design Review Effort %	Code Review Effort %	Duration of Reqmts Phase (Hour)	Duration of Design Phase (Hour)	Duration of Implemt Phase (Hour)	Duration of Testing Phase (Hour)	Total Duration (Hour)
1	S{A, A, A}	0%	0%	0%	78.00	12.00	89.00	36.00	215.00
2	S{A, A, B}	0%	0%	10%	78.00	12.00	97.90	7.56	195.46
3	S{A, A, C}	0%	0%	20%	78.00	12.00	106.80	0.00	196.80
4	S{A, A, D}	0%	0%	30%	78.00	12.00	115.70	0.00	205.70
5	S{A, A, E}	0%	0%	40%	78.00	12.00	124.60	0.00	214.60
6	S{A, B, A}	0%	10%	0%	78.00	16.06	79.74	36.00	209.80
7	S{A, B, B}	0%	10%	10%	78.00	16.06	83.69	36.00	213.75
8	S{A, B, C}	0%	10%	20%	78.00	16.06	87.65	36.00	217.71
9	S{A, B, D}	0%	10%	30%	78.00	16.06	91.60	36.00	221.66
10	S{A, B, E}	0%	10%	40%	78.00	16.06	95.55	36.00	225.61
11	S{A, C, A}	0%	20%	0%	78.00	20.13	70.48	36.00	204.61
12	S{A, C, B}	0%	20%	10%	78.00	20.13	73.04	36.00	207.17
13	S{A, C, C}	0%	20%	20%	78.00	20.13	75.60	36.00	209.73
14	S{A, C, D}	0%	20%	30%	78.00	20.13	78.16	36.00	212.29
15	S{A, C, E}	0%	20%	40%	78.00	20.13	80.72	36.00	214.85
16	S{A, D, A}	0%	30%	0%	78.00	24.19	61.22	36.00	199.41
17	S{A, D, B}	0%	30%	10%	78.00	24.19	62.39	36.00	200.58
18	S{A, D, C}	0%	30%	20%	78.00	24.19	63.56	36.00	201.75
19	S{A, D, D}	0%	30%	30%	78.00	24.19	64.73	36.00	202.92
20	S{A, D, E}	0%	30%	40%	78.00	24.19	65.89	36.00	204.08
21	S{A, E, A}	0%	40%	0%	78.00	28.25	55.70	36.00	197.95
22	S{A, E, B}	0%	40%	10%	78.00	28.25	55.70	36.00	197.95
23	S{A, E, C}	0%	40%	20%	78.00	28.25	55.70	36.00	197.95
24	S{A, E, D}	0%	40%	30%	78.00	28.25	55.70	36.00	197.95
25	S{A, E, E}	0%	40%	40%	78.00	28.25	55.70	36.00	197.95

VI Remarks

- The case study is still in processing and improvement. However, several remarks have obviously concluded:
  - Process Simulation Modeling technology (PSIM), supported by Resource Model Building and Analyzing (RMBA) technology, can be used on process improvement and optimization, especially a optimized development lifecycle can be provided.
  - A holistic view should be chosen to see the corresponding supporting environment to CMMI-based process improvement, which should include 5 systems: Cost management system, Schedule management system, Quality management system, Process modeling system, and Process optimization system .
  - PSIM and RMBA are a good twins, which is enabler of helping an organization in process improvement and optimization through building computing formulas into activity of the environment.
  - However, a lot of coefficients Pi(i=a,b,c,d), Qi(i=a,b,c,d), Fi(i=a,b,c,d), Probability distribution value within each review, and the computing formaulas for effort computing, etc. should be determined through a lot of experiments.

Thanks!