Workforce Planning of Navigation Software Project Based on Competence Analysis

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***Abstract*—This paper introduces the quantitative research method for the personnel configuration of the software project by studying the effects of the overall competence of the developers in the vehicle navigation software project on the factors like project quality. The study shows the overall competence of the developers is related to the after-submission defect density, productivity and the average delay of software Version 0.99. Further, a quantitative formula of competence and competence is drawn on the basis of statistics; meanwhile, according to the research result an integer programming configuration method for the navigation software project personnel based on competence analysis is concluded.**

***Index Terms*—software project quality, competence analysis, defect density, integer programming, workforce planning**

I. INTRODUCTION

Vehicle navigation system, a kind of vehicle electronic device, not only can show electronic maps and locate the position of the vehicle, but also can search information and choose the optimal route through calculation to guide the drivers to the destination, thus the traffic efficiency will be improved. The fundamental functions of vehicle navigation system include human-computer interfaces, vehicle location, map display, route calculation, real-time guidance and information search [1, 2].

Any software development process is a strict logical thinking process, and the visibility and the controllability of the process is poor. The reliability and quality of the system depends on the developers' individual behavior features. The faults may be generated by software coding mode, development process and user's usage mode. The software coding mode includes code size, programming technology, algorithm, statement structure and so on. The longer software code size is the more complex software structure is. Development process includes the engineering technology, tools and developer's competency. Bailey indicates us the fault ratio in program and data and the result is shown as Table I [3, 4, 5].

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TABLE Ⅰ.
FAULT RATIO IN PROGRAM AND DATA BY DEVELOPER

Fault Type	Ratio
System Level Faults	10.0% - 25.0%
Data Writing Faults	10.0%
Transcription Faults	2.5%
Data Input Faults	0.5%

Since the logic structure of the vehicle navigation software is complicated and its development cycle is long, the competence of developers greatly influences the quality of the vehicle navigation software products. How to combine the competence of the developers and the quality target of projects to appropriately configure the personnel is the problem the software developing enterprises are considering.

The famous counterintuitive principle in software testing by Myers basically states that the more defects found during testing, the more that remained to be found later. The reason is that at the late stage of formal testing, error injection of the development process is basically determined. High testing defect rates indicate that the error injection is high; if no extra effort is exerted, more defects will escape to the field. Low defect density implies the high quality of the product [6]. Defect Density will be adopted here to describe the quality of the software system.

This paper concludes the linear programming configuration method for navigation software project personnel based on competence analysis by studying the effects of the overall competence of the developers in the vehicle navigation software project on the factors like project quality (after-submission defect density), productivity and the average delay of software Version 0.99 and the interrelation through a quantitative statistic research.

II. RESEARCH SCOPE AND METHODS

A. Research Scope and Data

This paper studies a project with the same business direction (vehicle navigation software system) and the

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similar team scale without taking the difficulty into account, and analyzes the correlation developer competence, after-submission defect density, Productivity, the average delay of software Version 0.99. The key factors that are closely related to the project performance are taken as the research object. Therefore, the method to forecast the overall competence of the developers on the basis of after-submission defect density(X1), Productivity(X2), the average delay of Ver0.99(X3).

According to the analysis of the project data last three years, twenty projects with the same business direction and similar personnel scale are selected as the specific research object. Detailed data are shown in Table I. Y is the total competence of the project personnel, X1 is the after-submission defect density, X2 is Productivity, and X3 is the average delay.

TABLE Ⅱ.
ANALYSIS DATA SHEET

Project	Y	X1	X2	X3
A	58	3	6	2
B	68	3	6	2
C	70	4	4	1
D	63	2	6	6
E	78	1	4	4
F	73	2	5	5
…	…	…	…	…

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B. Research Method and Procedure

Forecast the competence of the personnel according to QCD(after-submission defect density, Productivity, Ver0.99), and then conclude the correlation of Y, X1, X2 and X3 through regression analysis.

The research procedure is as follows:

1) Select the research samples: Twenty navigation software development project samples with stable business modes and similar scale are selected after screening the data.

2) Collect the project information: Collect the detailed information including project name, project number, starting and ending time, project scale, development time, product model number, the software model number, development module number, scale of per model(software model), % Reuse, demand total, after-submission defect number, Productivity, average delay of Ver0.99, etc.

3) Collect the detailed competence information: Collect the detailed competence information of the project personnel, including more than sixty critical competence items in the project development process such as process capability (project planning, project monitoring, quantitative analysis, cause analysis, project conclusion, etc.), professional capability(fundamental knowledge, system architecture, C/C++ development and testing, vehicle bus, imbedded developing environment and tools, etc), and soft capability (communication capability, problem analysis and solving capability, learning capability, initiative responsibility, document writing capability, etc). The competence of each item of each sample is equal to the total sum of each member's scores of this item.

4) Find the critical competencies: Find the critical competencies influencing X1, X2, X3 through correlation analysis. Carry out the correlation calculation of the 66 capability items and X1, X2, X3 respectively. The capability items whose relative coefficient r>=0.3 is confirmed as critical items, and the score of each critical item in the samples are kept as the basis of the data for further study next stage.

5) Sum up the score: Sum up the score of each critical item obtained from 4) to get the overall personnel competence of each project Y. And a regression equation is concluded by regression analysis and check the equation.

After the research result verification, a peer review is required. The review result will be applied in the construction and programming of vehicle navigation software project next stage.

The research procedure is shown as Figure 1.

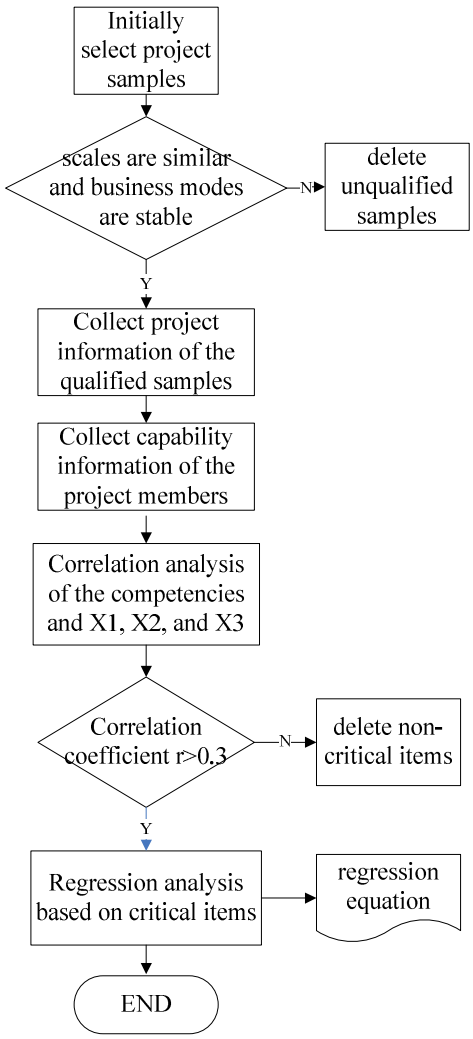

Figure 1. Quantitative analysis to the effect of critical competencies on project performance

III. RESEARCH SCOPE AND METHODS

A. The Critical Competencies Analysis of Project Personnel

Workforce Competency refers to a series of skills and process capability possessed and developed by a person who works on the specific job type in an organization [7]. A human resource capability can be explained in an abstract level such as requirements understanding ability, coding ability, unit testing, project planning ability and communicative ability, etc in the software development.

During the quantitative study of the influences of project personnel competence on vehicle navigation software QCD, the identification of critical competencies is an essential step. The critical competencies of different project personnel through Spearman analysis are shown in Table III:

TABLE III. MATRIX OF THE CRITICAL COMPETENCIES

Role	CM1	CM2	CM3	CM4	CM5
Software development	A	B	C	D	E
	F	G	H	I	-
Software testing	J	K	L	H	M
Testing management	N	O	L	H	I
Project management	P	N	O	H	I
Quality management	N	O	H	I	M
Process improvement	H	I	M	-	-
Business consultation	P	O	J	H	I

A: Requirements understanding
B: Outline design
C: Specific design
D: Coding
E: Unit testing
F: Integration testing
G: Embedded OS
H: Communicative ability
I: Documentation writing
J: Requirements understanding
K: System testing
L: Testing planning
M: Initiative responsibility
N: Quantitative management
O: Reason analysis
P: Project planning

According to the above analysis, the critical competencies of members of software development, software testing, testing management, project management in the project. In addition to the total competence calculation through regression, the critical competencies can be improved by training, tutoring, self-learning, conference, project practicing. The regression analysis shows that the more competent the members are, the higher the project product quality will be, and fewer defects will be.

B. The Regression Equation Based on the Critical Competencies

According to the critical competencies score of members of the project samples, we can obtain a regression equation including after-submission defect density, Productivity and the average delay of software Version 0.99. The regression equation is project competencies score=92.43.-1.528* after-submission defect density-3.345 *Productivity-0.338* the average delay of software Version 0.99.

We can know the higher project competencies score is the lower after-submission defect density is, and the project quality is better according to the regression equation.

C. The Methods of Workforce Planning based on the Integer Programming and Competencies Analysis

According to the above result of the regression analysis we find the quantitative relationship between the software project quality and the project members' competencies level, and based on the relationship and the regression equation the method of workforce planning in the navigation software project can be studied further.

In this part two ways of workforce planning in the navigation software project can be discussed. The first one is the way of workforce planning with the least project member number to ensure the project's quality, and the second one is the way of workforce planning with the least project cost to ensure the project's quality. More methods of the workforce planning can be designed in this way and they can be applied to all kinds of project situations.

1) The method of workforce planning with the least project member number:

Precondition : The goals of after-submission defect density, productivity and the average delay of software Version 0.99 have been figured out, and the project competencies score N has been computed based on the regression equation in part 2.2.

Assumption:

The number of the project management is X1 and the persons' competencies average we can choose is V1.

The number of Quality management is X2 and the persons' competencies average we can choose is V2.

The number of Testing management is X3 and the persons' competencies average we can choose is V3.

The number of Software development is X4 and the persons' competencies average we can choose is V4.

The number of Software testing is X5 and the persons' competencies average we can choose is V5.

The upper limit of the project number is n.

In a common project X1=1, X2=1, X3=1

The IP equation is:

$$\text{Min } Z=X1+X2+X3+X4+X5 \quad (1)$$
$$\text{s.t. } X1*V1+ X2*V2+ X3*V3+X4*V4+X5*V5 \geqslant N \quad (2)$$
$$X1+X2+X3+X4+X5 \leqslant n \quad (3)$$
$$X1=1 \quad (4)$$
$$X2=1 \quad (5)$$
$$X3=1 \quad (6)$$
$$X4, X5 \geqslant 1 \text{ (Must be a integer)} \quad (7)$$

2) The method of workforce planning with the least project cost

Precondition : The goals of after-submission defect density, Productivity and the average delay of software Version 0.99 have been clear, and the project competencies score N has been computed based on the regression equation in part 2.2.

Assumption:

The number of the project management is X1 and the persons' competencies average we can choose is V1. The persons' salary average we can choose is S1.

The number of Quality management is X2 and the persons' competencies average we can choose is V2. The persons' salary average we can choose is S2.

The number of Testing management is X3 and the persons' competencies average we can choose is V3. The persons' salary average we can choose is S3.

The number of Software development is X4 and the persons' competencies average we can choose is V4. The persons' salary average we can choose is S4.

The number of Software testing is X5 and the persons' competencies average we can choose is V5. The persons' salary average we can choose is S5.

The upper limit of the project number is n.

In a common project X1=1, X2=1, X3=1

The IP equation is:

$$\text{Min } Z=X1*S1+X2*S2+X3*S3+X4*S4+X5*S5 \quad (8)$$
$$\text{s.t. } X1*V1+ X2*V2+ X3*V3+X4*V4+X5*V5 \geqslant N \quad (9)$$
$$X1+X2+X3+X4+X5 \leqslant n \quad (10)$$
$$X1=1 \quad (11)$$
$$X2=1 \quad (12)$$
$$X3=1 \quad (13)$$
$$X4, X5 \geqslant 1 \text{ (Must be a integer)} \quad (14)$$

Many other ways can be studied further except above ways. For example, we can discuss the way when the number of software development or software testing is limited, and the method is similar.

F. RESULT AND APPLICATION

After-submission defect density = (92.434-project competencies score-3.345*Productivity-0.338* the average delay of software Version 0.99)/1.528 (15)

In the project planning phase we can use the regression equation in part 2.2 and data including productivity, project competencies score and the average delay of software Version 0.99 to predict the project quality (after-submission defect density). If the project quality level prediction does not reach the goal, the project member can be adjusted and more experienced persons can join the project to make the project competencies score higher to increase the project quality.

The matrix of the critical competencies can be used in employee competency development, all kinds of development activities can planed to improve the project member's competency level. At last the competency development can increase the performance of the project member to make the whole project QCD better.

The method of workforce planning in the navigation software project based on the integer programming and competencies analysis enhances the capability and accuracy of the current ways of the software project planning. It can be used in the practical software development, and we can find the appropriate ways to make a workforce planning based on competencies in a specifically project in the same idea.

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