Performance Analysis of Distributed database during Preliminary Design stages using ER model

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ABSTRACT
Performance is an important non-functional attribute of the software system to be considered for producing quality software. Performance analysis by estimating development effort of the database application and workload estimation during preliminary design stages is an important consideration. In this paper It is propose a methodology for estimation of effort by considering Entity Relation model and combination of technical and environment factor(weak, strong) for performance analysis during preliminary design stages. Estimation of effort based on the complexity of ER by considering the entities set, attributes, relationship complexity, and structural constraints. The results are validated using multiple regression technique with case studies.

Keywords
ER model, Performance Engineering, Distributed Database.

1. INTRODUCTION
Cost estimation is one key aspect of project management based on which performance goals can be achieved. Performance problems may be so strict that they require extensive changes to the system architecture in design stages. If these changes are made late in the development process, they can increase development costs, delay deployment, or adversely affect other desirable qualities of a design. It is vital to maintain for early assessment of the performance characteristics of distributed database system since its functionality is decentralized. The need for automation for these systems is undeniable. Many processes, when automated become cost-effective by consuming less time and effort, and consequently, less money. The effort estimation depends on the complexity of software, ER diagram, data requirements. Data required for performance assessment are: performance goals, workload specifications, software execution structure, execution environment, resource usage and database. The data are gathered using performance walkthrough, by intuition, guesses and approximations. After gather the required data the effort also depends on the complexity of entities, attributes, relationship type and structural constraints. Predicting these factors reflect the level of complexity and predict in terms of number of lines of codes required for implement the business constraints [1] Performance is an important but often neglected aspect of software development methodologies. To construct performance models, analysts inspect, analyze and translate database part of software specifications into models, then solve these models under different workload factors in order to diagnose performance problems and recommend database design alternatives for performance improvement. In the early stages of design, performance analysis cycle, when done properly developer can choose a suitable database design that meets performance objective.

The rest of the paper is organized as follows: Review of the related literature is given in Section 2. Section 3 discusses the basic concepts involved in this paper. The proposed methodology is described with an algorithm in Section 4. The illustration of proposed technique with a case study is presented and the results are validated in section 5. The paper concludes with observations and the future work in section 6.

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2. RELATED WORK
Many researchers are made significant contribution in the field of software effort estimation using in the field of software development. Some author describes constructive cost model and the function point approach is the most popular tool for estimating software cost. It uses lines of code and function points to assess software size due to lack of performance details. ER model for the estimation of backend effort cost has been proposed [9][11][21][36]. In [1][4][5] estimation technique based on the function-oriented software development frame work. Research results on estimating efforts based on complexity of the development of database part of the software has narrowly been reported in the literature. In [37][38] use case point approach is widely used industry for estimation of software cost. Some authors in [39] used number of primary key and foreign key for effort estimation using the formula. Many techniques for estimating the cost of the relational database development based on ER model have been reported in the literature. However, these are actually execution details and difficult to estimate during the early stage of software development. The entity relationship (ER) model is well used in conceptual modeling for data-intensive systems. The path complexity metric is a complexity metric and used for effort estimation. This path complexity is computed from a graph derived from the ER diagram. So the process of creating a graph from an ER diagram and then calculating complexity from the graph is itself an additional effort in the process of estimation. Compared to the above, compute the information about total entities, total relationships, total constraint complexity and based on these information, the total complexity and then the effort can be estimated found in [1] . The MATLAB is used

for generating regression equation and Ms excel for computing R^2 and regression statistics, anova analysis, p-value and t-value and adopted different combination(weak, strong) of technical and environmental factor for computing the effort.

3. BASIC CONCEPTS

It is suggested an ER diagram and use case diagram to model and evaluate the effort estimation starting from the feasibility study. By considering the number of entities, number of relationships, number of attributes, number of descriptive attributes in a relationship set, Number of multivalve attributes in an entity or relationship set. Number of derived attributes in an entity. The entity complexity can be classified into simple complex based on their association with other entities and their weight measure is depicted in table 1. The weigh measure attributes type based on type of attributes and relationship sets based on number of attributes that relationship has depicted in table 2. The weigh measure of relationship set mentioned in table 3.

Table 1. The weight measures of Entity Sets

Entity Sets	Entity Type	Weight Measure of Entities (WE)
Entity set participated with 1:1 relationship OR participated with M:1 relationship OR participated with unary 1:M relationship	Simple	1
Weak entity set	Complex	2

Table 2. The weight measure of Attribute sets

Attribute Category	Attribute Type	Weight Measure of Attributes (WA)
Multivalve attribute	Complex	2
Derived attributes	Average	1.5
Other Attributes (including descriptive attributes of relationship sets)	Simple	1

Table 3.The weight measure of Relationship set

Relationships Set	Relation Type	Weight Measure of relationship (WR)
M:N Relationship or Associative Entity Sets	Average	≥2
Relationship with Aggregation	Complex	3

4. PROPOSED METHODOLOGY AND ALGORITHM

4.1 Methodology

The procedure to estimate the effort calculation based on complexity

1. The key scenarios of the software system are identified.
2. The database part of the use case are identified.
3. Develop ER model which includes the ER diagram.
4. Compute EC: Entity Complexity by considering the weigh measure of entity sets(WE) and the weigh measure of attributes(WA)
$$EC = \sum_{i=1}^{i=NOA} (WA)i\,A)i + DIT + \sum_{j=1}^{j=NoAss} (WE)j$$
Where NoAss represents number of associations the entity set has with other entity set, NOA is the number of attributes; DIT represents the Depth of inheritance tree.
5. Compute total entity complexity (*TEC*) of ER diagram.
$$TEC = \sum_{j=1}^{j=NOE} (EC)j\ C)j$$
Where *NOE* represents the number of entity sets.
6. Compute Relationship complexity(RC) based on weigh measure of relationship sets(WR)
$$RC = \sum_{l=1}^{l=NOA} (WA)i + (WR)R)$$
7. Compute the total relationship complexity (*TRC*) of ER diagram.
$$TRC = \sum_{j=1}^{j=NOA} (RC)jC)j$$
8. Compute total Semantic constraint complexity $TSCC = \sum_{k=1}^{k=NOC} Ck\ C_k$

   Here *NOC* represents the number of constraints and Ck represents the semantic integrity constraints captured during requirements gathering and it has been assigned a weight measure of 1.5.
9. Compute total complexity of ER model i.e.
$$TC = TEC + TRC + TSCC$$
10. Compute Technical Complexity Factor (TCF) and Environment Factor (EF) using the formula:
$$TCF = 0.6 + (0.01 \times TFactor) \text{and}$$
$$EF = 1.4 + (-0.03 \times EFactor)$$ [2].
11. Compute adjusted ER Point (ERP) using the widely used formula $ERP = TC \times TCF \times EF$.
12. Compute estimated effort in person-hours
$$Effort = ERP\ x\ Person\ hours\ per\ ERP.$$

Person hours per ERP considered here is 1.00. It can be increased based on the complexity of SDLC phases.

13. Compute relative error and its mean.
14. Validate the results with actual effort and estimated effort by computing the relative error
15. Apply multiple regression technique in order to study the effectiveness of our model

4.2 Algorithm

The algorithm for the proposed methodology uses the procedure for calculating TEC, TRC, TSCC, TC, TCF, ERP and estimated effort.

Identify data centric part of scenario
Develop ER (extension of ER) diagram are used for modeling relational or object relational database system

{Compute the weight measure (WE) of entity, attributes}

If entity set participate with 1:1, or M: 1, or 1: M relationship

$WE \leftarrow Simple \leftarrow 1$

Else

$WE \leftarrow Complex \leftarrow 2$

End if

For j =1 to NoASS (number of associations)

$EC \leftarrow EC + (WE)j$

{Compute the weight measure of attributes}

If attribute category is multivaled

$WA \leftarrow Complex \leftarrow 2$

Else if attribute type is Derived

$WA \leftarrow Average \leftarrow 1.5$

Else

$WA \leftarrow simple \leftarrow 1$

End if

For i =1 to NoA (number of attributes)

$EC \leftarrow EC + (WA)\ i$

End for

{Find the depth of the inheritance tree (DIT)}

$DIT \leftarrow$ longest path.

$EC \leftarrow +EC + DIT$

{Compute total entity complexity (TEC)}

For j = 1 to **NOE** (number of entity)

$TEC \leftarrow TEC + (EC)j$

End for

{Compute Total relationship complexity TRC)

If relationship type is M: N

$WR \leftarrow Average \leftarrow \geq 2$

Else

If relationship with aggregation

$WR \leftarrow complex \leftarrow 3$

End if

For j = 1 to **NOA** (number of attributes)

{Compute relationship complexity RC}

$RC \leftarrow RC + (WA)j$

End for

$RC \leftarrow RC + (WR)$

For j = 1 to **NOR** (number of relationship)

{Compute total relationship complexity RC}

$TRC \leftarrow TRC + (RC)j$

End for

{Compute total semantic business constraints TSCC}

For k = 1 to **NOC** (number of constraints)

$\boldsymbol{TSCC} \leftarrow TSCC + Ck$

{Ck represents the semantic integrity constraints captured during requirements gathering and it has been assigned a weight measure of 1.5.}

End for

{Compute Total Complexity of ER Model}

$TC \leftarrow TEC + TRC + TSCC$

{Compute Adjusted ER Point}

$ERP \leftarrow TC \times TCF \times EF$

$Where\ TCF \leftarrow 0.6 + (0.01 \times TFactor)$

(from the table 4 and 5) and

$EF \leftarrow 1.4 + (-0.03 \times EFactor)$

{Compute the estimated effort in person-hours}

$Effort \leftarrow ERP \times PHperERP$

{Compute relative error and mean error}

Error = abs (estimated- actual)/actual

Mean error = error/ n {n be the number of projects}

Validate the results by applying multiple regression technique and PRED technique

Report the results and plot the graph

5. ILLUSTRATED THE PROBLEM MODEL WITH CASE STUDY

In this section it is proposed an approach of effort estimation to eight different projects having different number of constraints. It is considered ER having different number of entities, attributes, relationships, and constraints. For illustration it is propose the following E-R diagram in the figure 1 for the illustrative purpose for estimation of TEC, TRC, TSCC, TC .Tractor, Enactor, and Estimated effort**.**

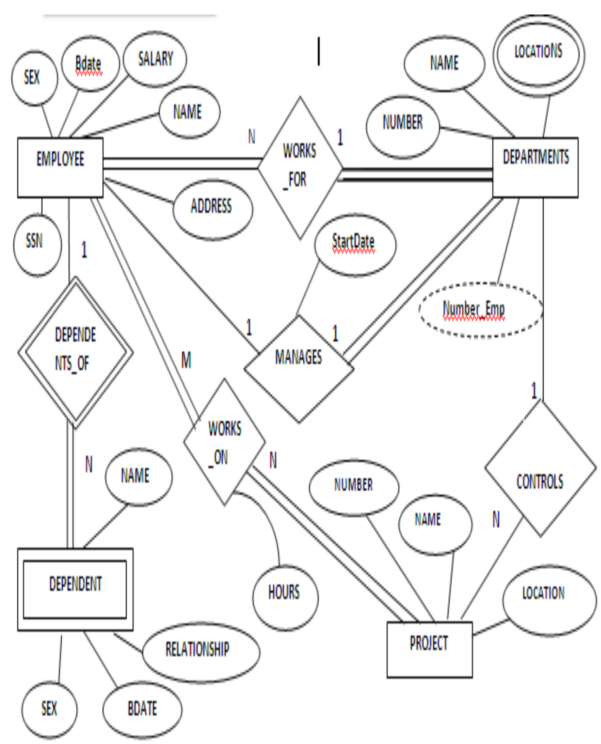

Figure 1: E-R diagram for Company Database System.

Table 4. Environmental Factor

Factor	Description	Weight
E_1	Familiar with Rational Unified Process	1.5
E_2	Application experience	0.5
E_3	Object-oriented experience	1
E_4	Lead analyst capability	0.5
E_5	Motivation	1
E_6	Stable requirements	2
E_7	Part – time workers	-1
E_8	Difficult programming language	2
	Total	

Calculation of entity complexity:

Employee: 7
Departments: 6.5
Projects: 4
Dependents: 6
Total Entity Complexity= 7+6.5+4+6=23.5

Calculation of relationship complexity:

Works For: 0
Manages: 1
Controls: 0
Works on: 3
Dependent of: 0
Total Relationship Complexity (TRC): 0+1+0+3+0=4

Total Semantic Constraint Complexity:

Here the number of semantics integrity constraints identified during the early phase of database design=5, Therefore, $TSCC = 1.5 * 5 = 7.5$.
$TC = TEC + TRC + TSCC = 23.5 + 4 + 7.5 = 35$.
The TFACTOR calculated on the basis of the thirteen technical factors (Table 5) is: 28.
Therefore. $TCF = 0.6 + (0.01 * 28) = 0.88$
The EFACTOR calculated considering the eight environmental factors is 28.
Therefore, $EF = 1.4 + (-0.03 * 28) = 0.56$

$\boldsymbol{Estimated\ effort} = TC * TCF * EF = 35 * 0.88 * 0.56 = 17.248$. The estimated data are presented in the table 6 and table 7 in the second row. Consider technical and environment factor is 28 which presented in the section 5.1

5.1 Estimation of Benchmark value for the case Study

Since projects are distributed in nature, the rates for the technical and environmental factor are assumed as given in table 4 and table 5 respectively [3]

Table 5: Technical Factors

Factor	Description	Weight (*w*)	Rate (*r*)	Total
T_1	Distributed system	2	5	10
T_2	Response or throughput performance objectives	2	5	10
T_3	End-user efficiency	1	3	3
T_4	Complex internal processing	1	4	4
T_5	Reusable code	1	4	4
T_6	Easy to install	.5	3	1.5
T_7	Easy to use	.5	3	1.5
T_8	Portable	2	5	10
T_9	Easy to change	1	3	3
T_{10}	Concurrent	1	3	3
T_{11}	Includes security features	1	5	5
T_{12}	Provides access for third parties	1	1	1
T_{13}	Special user training facilities are required	1	3	3
	Total			58

Compute Technical Complexity Factor (TCF) and Environment Factor (EF) using the formula: $TCF = 0.06 + (0.01 \times TFactor)$ and $EF = 1.4 + (-0.03 \times EFactor)$ [1].

5.2 Estimation of Effort

After computing the technical and environment factor calculated the adjusted ER Point (ERP) using the formula $ERP = TC \times TCF \times EF$. The Estimated effort in person-hours calculated as $Effort = ERP \times PH - per - ERP$. The PH-per-ERP is stands for person-hour per ERP. The PH-per-ERP considered here is 1.00 and it can be increased to a higher value based on the complexity of SDLC phases, and testing of ER model. The details of all eight projects and their TEC, TRC, TSCC, TC, Technical complexity factor, Environment factor (EF), adjusted ERP, Estimated Effort in person hours, Actual effort in person hour's relative error as depicted in table 6, and 7. Consider technical complexity factor and environmental factor 0.56 for effort estimation. The details of eight projects and their effort depicted in table 6 and 7.

Table 6 Analysis of ER model with simulation results

PR NO	TEC	TRC	TSCC	TC	TFAC TOR	TCF	Efactor	EF	ERP	Estimated Effort	Actual effort
1	28	5	7.5	40.5	47	1.07	28	0.56	24.26	24.26	28
2	23.5	4	7.5	35	28	0.88	28	0.56	17.248	17.248	25
3	26	5	7.5	38.5	42	1.025	28	0.56	22.099	22.099	27
4	10	7	6	23	25	0.85	28	0.56	10.948	10.948	17
5	16.5	3	7.5	27	37.5	0.97	28	0.56	14.664	14.664	21
6	14	4	12	30	39	0.99	28	0.56	16.632	16.632	26
7	16.5	4	12	32.5	42	1.025	28	0.56	18.655	18.655	28
8	22	3	13.5	38.5	40	1	28	0.56	21.56	21.26	32

Table 7. Relative error with mean

Estimated Effort	Actual effort	Error	Mean Error
24.26	28	0.13357	0.289071
17.248	25	0.31008	
22.099	27	0.18152	
10.948	17	0.356	
14.664	21	0.30171	
16.632	26	0.36031	
18.655	28	0.33375	
21.26	32	0.33563	

The proposed model has been validated by computing the error of all the projects using following formula:

$$Error = \left|\frac{Effortestimated - Effort\ Actual}{Effort\ Actual}\right| \ and$$

$$Mean - relative - error = 1/n \sum_{i=0}^{i=n} (error)\ i.$$

From the table 7 the average relative error is 0.289071. The PRED (25) can be defined as the proportion of frequency that predicted effort fall within 25% of actual effort. This can be achieved by equation k/n where k denotes the number of projects with error less than 25%. From the table 6 PRED (25) = 0.625 i.e. 62 % project error less than or equal to 25%. The results are depicted in the form of graph.

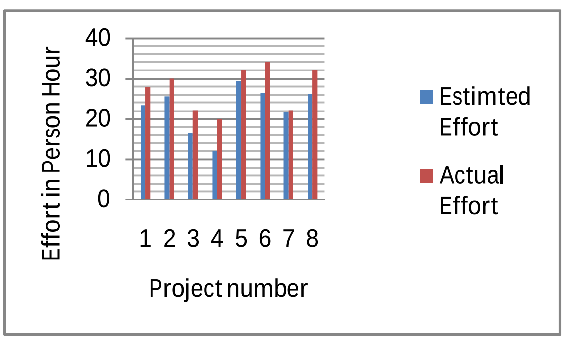

Figure 2: Estimated versus Actual Effort

It has been observed from the figure 2 that the estimated effort always slightly less than the actual effort.

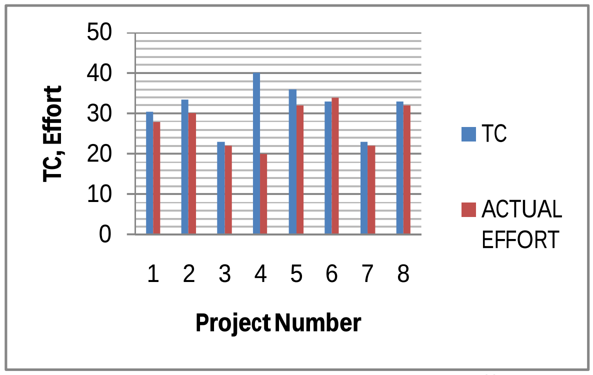

Figure. 3: Total complexity versus actual effort

Form the figure 3 it is observed that total complexity of ER diagram by considering the entity relationship, and semantic complexity in eight projects is same as actual effort. This indicates that the 87.5% of the projects with TC is exactly same as actual effort.

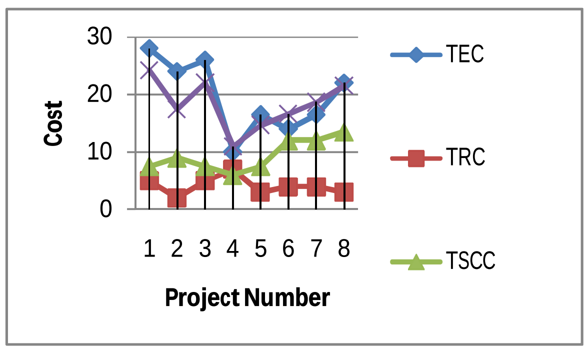

Figure 4: Estimated Effort with TEC, TRC and TSCC

From the figure 4 note that estimated effort of the database primarily depend on the total entity complexity. The effort takes less account when use total relationship complexity and total semantic complexity

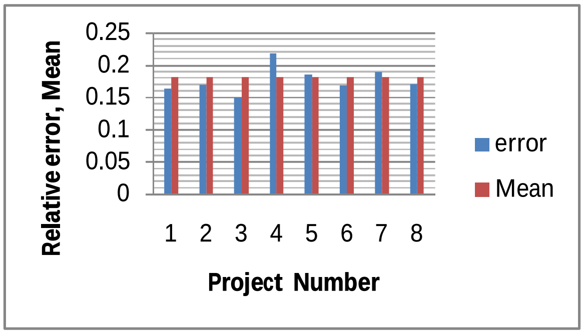

Figure 5: Relative error with mean value of error

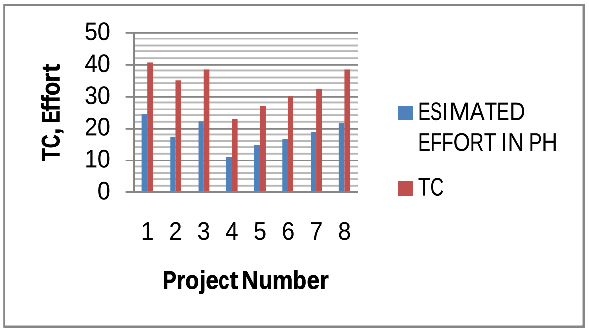

Figure 6: Estimated efforts with Total complexity of ER diagram

In the figure 6 the total complexity of ER diagram is slightly more than the estimated effort of the database. In the figure 3, 85% of the projects TC and Actual effort are same. Hence TC is exactly map with actual effort.

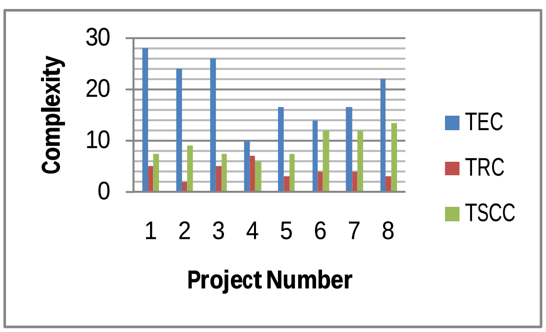

Figure 7. Total entity complexity, total relationship complexity, total structural semantic complexities chart

From the figure 7 it is observed that the effort estimation mainly depend on the total entity complexity. Some projects the TRC and TSCC slightly less than the TEC

5.3 Regression Technique

The multiple regression technique adopted in order to study the correlation among data. The resultant equation is obtain using the MATLAB applications as:

$$Effort = 0.0764 + 0.5547 * TEC + 0.4600 * TRC + 1.3379 * TSCC$$

The multiple regression statistics obtained and the results are depicted in table 8. The results from the table indicate that there is strong correlation among data of TEC, TRC, and TSCC and with actual effort. The multiple R value is 0.99524. The multiple coefficients ($R^{2)}$ are 0.9905 and the adjacent R square is 0.9810 which is close to 1. Hence the results indicating better strength. The anova analysis p-value and t-value presented in the table 9 and table 10 respectively.

Table 8 Multiple Regression Statistics

	TC with respect to Estimated effort	TC with respect to Actual effort
Multiple R	0.997586637	0.997322899
R Square	0.995179099	0.994652965
Adjusted R Square	0.991563423	0.990642688
Standard Error	0.469787067	0.63273949
Observations	8	8

Table 9 ANOVAs Analysis

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	87.14	87.14	95.19	0.00
Residual	5.00	4.58	0.92	A	
Total	6.00	91.71			

Table10: P-value and T value of Regression Analysis

	Coefficients	Standard Error	t Stat	*P value*	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	2.79	2.04	1.37	*0.23*	-2.46	8.05	-2.46	8.05
28.0	0.78	0.08	9.76	*0.00*	0.58	0.99	0.58	0.99

6. CONCLUSION

It is proposed a methodology for estimation effort using ER model for performance analysis. The data gathered during feasibility study, are technical and environmental factors, and ER-diagram. It is estimated the effort and the results are validated by computing the relative error. The multiple regression technique is adopted and R^2 is computed for data analysis and it is obtained nearer to 1. The model may be used to estimate effort of the database part of the industry applications. The paper can be further extent by consider the communication cost of backend with front end distributed real time applications and convert effort into performance prediction in distributed database system.

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