How to determine the cost of Business Process-Aware Software Architecture Flexibility - The Travelsky Case

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Abstract

We build a model of business process-aware software architecture flexibility cost for business process variation and structural complexity. By using travelsky-airline-agent's e-commerce platform as an example, we conduct in the study by the investment decisions-making of the flexibility strategy and the regression formula of flexibility. The results demonstrate that the investment can improve the flexibility.

Keywords: Business process-aware, Software architecture, Flexibility cost, E-Commerce Platform

Introduction

Business Process-Aware Software Architecture (PASA) with a strong flexibility has been gradually applied to many areas of business administration, health care, civil aviation, tourism, stocks and securities, and financial and insurance (Dumas et al., 2012; Lenz and Reichert, 2007; Weber et al.,2007; Thom et al.,2009; Dumas et al.,2005). Cross-Organizational Business Process-Aware Software Architecture (CPASA) is based on PASA gradually developed (Chen and Liu, 2012). Organizations face CBP change the increasing need to reduce the problem of CPASA total lifecycle costs; however, organized by configuring CPASA meet CBP changes in demand, while reducing the cost due to the change process (Chen and Liu, 2012). However, in order to achieve with a flexibility change, organizations need in design time and run time, the flexibility paying the cost of the software architecture. Therefore, the correct grasp CPASA flexibility cost generating mechanism is a key capability organization should grasp, organizations need to use a flexibility cost mechanisms for the investment decision-making, thus avoiding the expensive costs and reduce errors decisions.

Scholars made certain achievements in research on the PASA flexibility costs, but these studies is neither system nor deep enough, there is no comprehensive and in-depth description of CPASA flexibility cost generation mechanism (Weber et al.,2008; Mutschler et al.,2006; Dreyfus and Wyner,2011; Schober and Gebauer,2011; Gebauer and Schober,2006; Gebauer and Lee,2008). For the lack of existing research, this study is

mainly based on the address the following key issues: which affect CPASA flexibility cost generated? How to measure variable? CPASA flexibility how to calculate the cost of flexibility CPASA cost and the CPASA total life cycle cost of relationships? These issues are one of the common challenges of the disciplines of modern information systems, software engineering, business administration, discipline, and even management engineering disciplines. Therefore, in the face the associated unresolved issues of this series, this article tries to research on the flexibility cost issues in CPASA depth. In Figure 1 shows the relationship between the main problems.
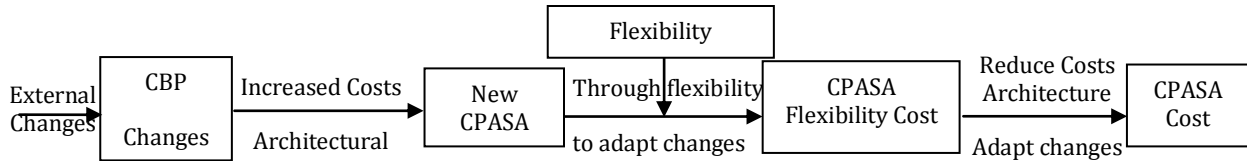

Figure 1 –A Study on the Cost of the CPASA Flexibility

Theoretical Foundations

Related research clear the importance of software architecture flexibility cost, but less software architecture flexibility costs related theory, software architecture flexibility cost to promote and reference the achievements mainly from (Gebauer and Schober, 2006; Mutschler et al., 2008; Gebauer and Lee , 2008; Dreyfus and Wyner, 2011; Schober and Gebauer, 2011; Liu and Chen, 2012), they analyzed the factors which affect the information systems, software architecture flexibility cost.

Business process change impacts the cost of information systems flexibility

The Schober and Gebauer (2011) pointed out that process uncertainty, process variability, time-criticality, load, information system life cycle and system stage can impact information systems flexibility costs, and these factors can be used as variables to calculate information systems flexibility costs. Schober and Gebauer (2011) pointed out that the model underestimate flexibility cost; and real data are difficult to obtain, because it is difficult to measure information system change cost in the run-time, so the model is used simulation data rather than real data. Liu and Chen (2012) uses the case study method of CPASA flexibility cost, but the model will underestimate flexibility cost problem cannot be an effective solution. Organized investment decisions based on the model may be inaccurate inadequacies of previous studies, this article will be optimized.

Structural complexity affects software architecture component flexibility cost factors

Dreyfus and Wyner (2011) from the angle of structural complexity to explore the relationship between the software architecture and software architecture flexibility cost, complexity can be divided into architectural complexity and components complexity. The component complexity constructs were operationalized as follows: structural, procedural, and data complexity. The architectural complexity constructs were operationalized as follows: coupling and cohesion. Coupling is operationalized through the network analysis measure closeness centrality (MacCormack et al., 2006; Dreyfus and Wyner, 2011). Dreyfus and Wyner (2011) did not explain the flexibility costs generated by the software architecture components, and model fitting result is unsatisfactory, is not suitable for the calculation of the cost of software architecture flexibility.

Methodology

Through theoretical research in CPASA and its flexibility cost, we create calculation model of flexibility cost-based of CPASA, and using travelsky-airline-agent's e-commerce platform as the sample, the dissertation researched how to establish relationship between CPASA and the changes in cross-organizational business processes by a flexibility cost.

Calculation model of the flexibility cost of software architecture for CBP variation
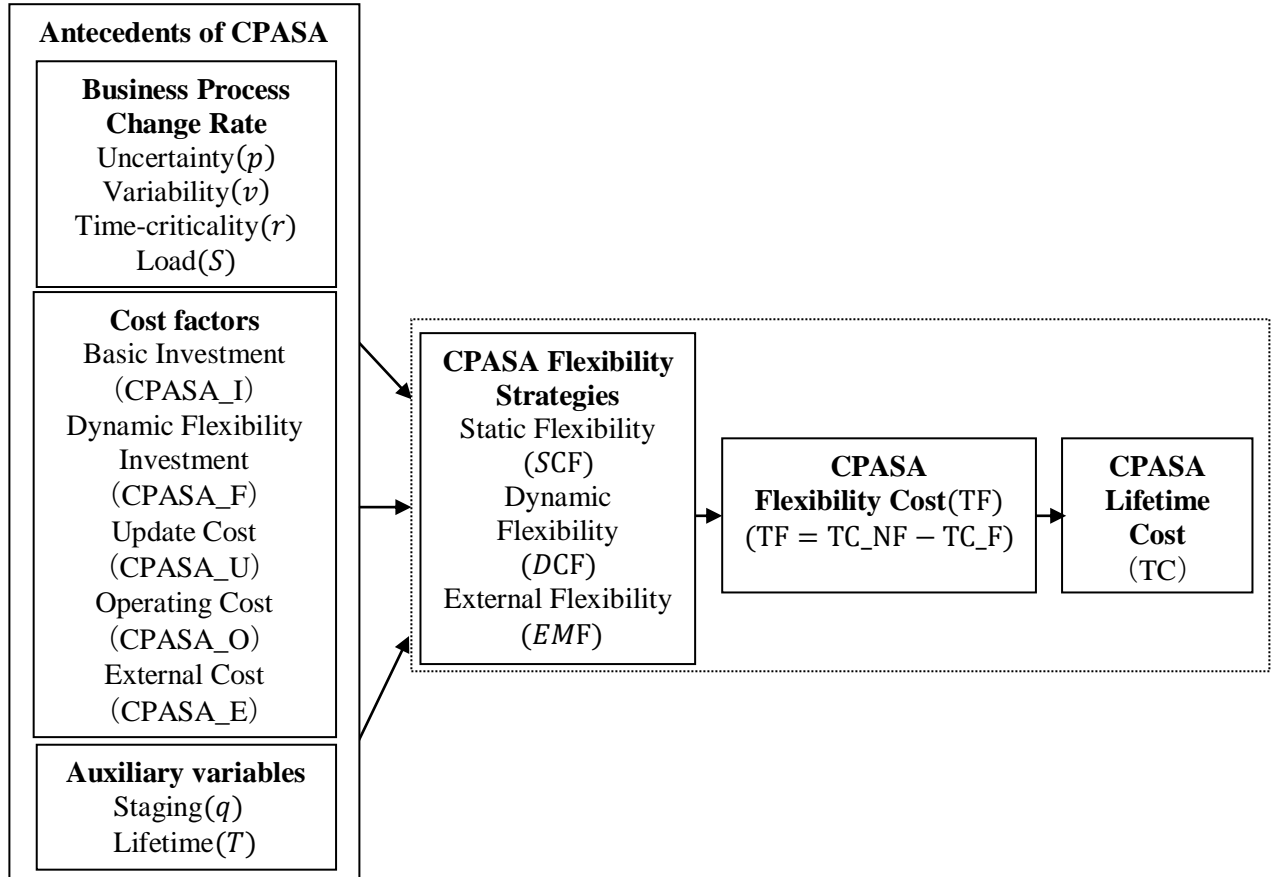

Figure 2 –A model of the flexibility cost of software architecture for CBP variation

Earliest kind of options by Gebauer and Schober (2006) to study the information system flexibility cost, flexibility strategies involved in the study, according to the strategy to help organizations to do the flexibility cost investment decision-making. Mutschler et al. (2008) pointed out that the PAIS cost factors affect the organization contains fixed cost factors, dynamic cost factors. CPASA allows organizations to predefined business processes in the design period, the business processes needed in the run-time adaptive, and gradually support static evolution of business processes, the dynamic evolution, and dynamic refinement (Thom et. al.2009; Song et al., 2011; Reichert et al., 2003; Li, 2010). The calculated CBP variation CPASA flexibility cost model consists of antecedents of CPASA, the flexibility strategy of CPASA variables, CPASA flexibility cost the variables, CPASA cost variables. We further assume that there exist no dependencies between these model parameters, shown in Figure 2. The total cost of all stages in the

CPASA life cycle said TC, in order to be able to minimize the total cost of the investment in software architecture, it is necessary according to the decision variable The SCF, DCF and EMF, the primary decision variable x_1, x_2, y and z to be estimated to the above model, the corresponding cost model see equation (1), One of the characteristics of each relationship variable formula, see equation (2):

$$TC = CPASA\_I + CPASA\_F + CPASA\_O + CPASA\_U + CPASA\_E \qquad (1)$$

$$\begin{cases} CPASA\_I = \{a + bL(x_1)[q + (1-q)DC]\}z \\ CPASA\_F = cy \\ CPASA_O = Sd\{[q + (1-q)L^{-1}(0.6)]SCF + 0.4DCF\}TDC \\ CPASA\_U = eL(x_2)DC \\ CPASA\_E = Sf(1+rg)\{(1-q)[1 - L^{-1}(0.6)]SCF + 0.4DCF + EMF\}TDC \end{cases} \qquad (2)$$

The purpose of this model is the calculation of the minimum TC solution that solving the following programming model, see equation (3):

Min TC

$$\text{s.t} \begin{cases} y \geq x_2 \\ z \geq 0.5(x_1 + x_2) \\ x_1 + x_2 > 0, 则\ z = 1\ ;\ \text{else}\ z = 0 \\ y, z \in \{0,1\} \\ 0 \leq x_1, x_2 \leq 1 \end{cases} \qquad (3)$$

Above the proposed CPASA flexibility cost calculation formula in the model is nonlinear, $L(x)$ is the basis for the decision variables x_1 and x_2, this article selected modeling method for nonlinear programming decisions. According to a given value of y, decision variables in the model solved x_1、 x_2 and y、 z, flexibility optimal mixed strategy SCF, DCF and EMF will be calculated, which calculated CPASA flexibility cost TF (Total costs with software architecture flexibility provided, referred to TF). In not consider CPASA dynamic flexibility total cost (Total costs with no software architecture flexibility-to-change provided, TC_NF) and consider flexibility CPASA dynamic total cost (Total costs with software architecture flexibility-to-change provided, referred TC_F) the difference to calculate the cost of CPASA generated flexibility, wherein, TC_NF by assuming $x_2 = 0, c = 0$, arithmetic derived TC value.; while TC_F is $x_2 \neq 0, c = 0$, arithmetic derived by assuming the TC value, the need to satisfy order to guarantee CPASA flexibility cost meaningful TF> 0.

Structural complexity affects software architecture component flexibility cost factors
Dreyfus and Wyner (2011) model fitting result is unsatisfactory. In order to solve the above problems: Increase the control variables, in order to reduce the Type I error and Type II error, and the control variables with CPASA flexibility related variables. Consider three forms of the centrality. Borgatti (2005) proposed centrality measure can be three forms; statistical analysis of the first by the Pearson product-moment correlation coefficient to measure the relationship between the three centrality, Pearson correlation coefficient suitable measure of the range [-1, +1] centrality; then Spearman's rank correlation coefficient measure the strength of the link between the three variables. The

n_i node for some i, $C(n_i)$ measure the center of the node i, three forms of the centrality CLO_C $\log(C(n_i))$; CLO_NC represented by 1; CLO_RC with $1/\log(C(n_i))$. The Calculation model of the flexibility cost of software architecture for structural complexity consists of antecedents of CPASA, CPASA component variables, CPASA cost variables, shown in Figure 3.
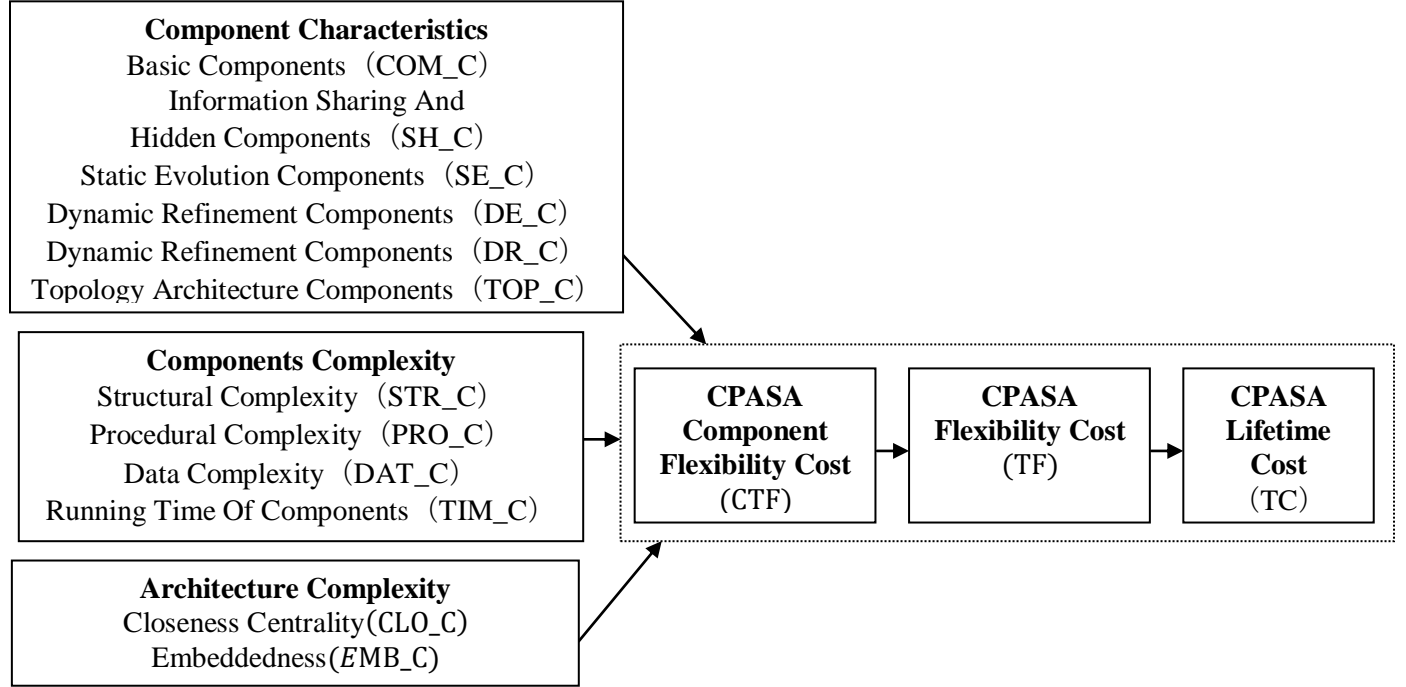

Component Characteristics Basic Components （COM_C） Information Sharing And Hidden Components （SH_C） Static Evolution Components （SE_C） Dynamic Refinement Components （DE_C） Dynamic Refinement Components （DR_C） Topology Architecture Components （TOP_C）			
Components Complexity Structural Complexity （STR_C） Procedural Complexity （PRO_C） Data Complexity （DAT_C） Running Time Of Components （TIM_C）	**CPASA Component Flexibility Cost (CTF)**	**CPASA Flexibility Cost (TF)**	**CPASA Lifetime Cost (TC)**
Architecture Complexity Closeness Centrality(CLO_C) Embeddedness(EMB_C)			

Figure 3 –A model of the flexibility cost of software architecture for structural complexity

The network diagrams used in this study and the COCOMO method to estimate the CTFvariables, the method can also estimate the variation of cross-organizational business processes software architecture flexibility cost calculation model of the relationship between characteristics of variable, Royce (2010) describe the specific use of the COCOMO method component level estimation step, the step of using a component-level estimate table corresponding cost of each component indicated with CTFrepresents units of the CTF is days, the model is shown in equation (4):

$$\text{CTF}_i = (\text{MM}_{\text{DEV}_i})(K_i \div \text{MM}_i) = \text{EAF}_i[\text{EDSI}_i \div (\text{EDSI}_i \div \text{MM}_i)_{\text{NOM}_i}] \qquad (4)$$

Wherein, $1 \leq i \leq N$, N for CPASA number of components.

When in estimates CPASA flexibility cost TF, person days and then multiplied by cost. According to the CBP business processes perception mode, the mapping between CPASA components estimation the CTF corresponding manpower needs mainly occurred in the entire life cycle of CPASA for the establishment of all human needs and pay CPASA dynamic flexibility of each component. In this paper the linear regression model based on Dreyfus and Wyner (2011) model, see equation (5):

$$\text{CTF}_i = \alpha + \beta_{cpasa}\text{X}_{\text{cpasa}_i} + \beta_{comp}\text{X}_{\text{comp}_i} + \beta_{const}\text{X}_{\text{const}_i} + \varepsilon_i \qquad (5)$$

Where: i = the component identifier.

CTF_i = CPASA components flexibility cost.

α= the mean of the probability distribution of CTF when all the Xs are 0; it is the CTF intercept of the regression line.

X_{comp_i} = the Kxl vector of independent variables containing the component complexity measures DAT_C, STR_C, and PRO_C.

β_{comp}= the lxK vector of coefficients of X_{comp_i} estimated by OLS.

X_{cpasa_i} = the Kxl vector of independent variables containing the architectural complexity measures CLO_C, CLO_NC, CLO_RC, EMB_C. Only one of the closeness variables is used in any single model.

β_{cpasa}= the lxK vector of coefficients of X_{cpasa_i} estimated by OLS.

X_{const_i} = the Kxl vector of control variables. Each component has been working time(TIM_C) as a control variable, expressed as the number of years ; Component characteristics as control variables, including basic components as COM_C ; information sharing and hidden components as SH_C ; static evolution components as SE_C ; dynamic evolution components as DE_C ; dynamic refinement components as DR_C ; and topology architecture components as TOP_C.

β_{const} = the lxK vector of coefficients of X_{const_i} estimated by OLS.

ε_i = the estimated error term or residual.

The Case Study

Travelsky-Airline-Agent's CPASA

With the civil aviation business development and the improvement of the level of information, as well as the aviation market competition intensifies, travelsky-airline-agent's business model changes, system integration for the development of the organization more and more important (Renyong, 2009). Travelsky use of OO patterns MDA model, SOA architecture, process preparation and process scheduling, organization information sharing and hidden business process model explicitly oriented, independent evolution of capacity and other business process-aware related technologies, the design of hybrid system topology structure CPASA, solve the obstacles to the development of information technology. Relationship between Travelsky - airlines - agent organizations formed by mixed-mode topology architecture shared costs, skills and mutual access to each other's information, most of the inter-organizational business processes have been standardized and inter-organizational business processes to meet the need to provide changing.

CPASA Flexibility Cost Calculation

Analysis component class diagram of the travelsky's e-commerce platform, analyzed with the software architecture consists of 69 components to form a network diagram, as shown in Figure 4. Study architecture meet CPASA characteristics to support the business process-aware mode, CBP change the characteristics required for most of the changes have been template, the code is modular, the program can be custom template, thus reducing the amount of repetitive coding labor, improving efficiency. Therefore predictable CPASA flexibility cost forecast data required component coupling and cohesion, the components of the file size, the type of components, the components of the corresponding database table, and through COCOMO method to estimate the cost data.
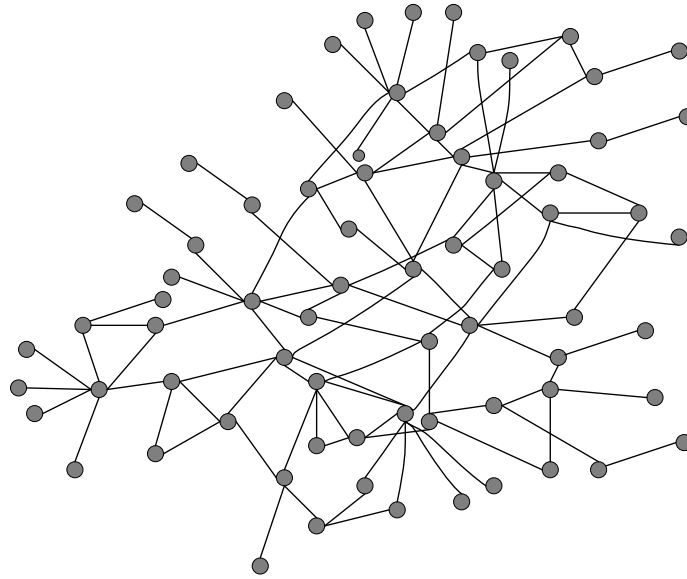
Figure 4 –Travelsky E-Commerce Platform Software architecture Component class diagram is converted into a network diagram

Calculation model of the flexibility cost of software architecture for structural complexity
The first year of the Travelsky e-commerce platform is the design period, the second year is the running period, and estimates of 3, 4, 5-year data. A measure of the degree of cohesion and coupling uses the most popular social network analysis software UCINET (Borgatti, 2005). The other components run time, expressed as the number of years, indicated by 1 is less than 1 year, more than one year but less than 4 years with 2, said more than 4 years 3 shows a. Flexibility calculation of the cost of the software architecture for structural complexity model variable statistics, such as shown in Table 1.

Table 1 –Summary statistics for software architecture variables

Variable	Description	N[a]	Range	Mean	Var.
CTF	Compound component flexibility measure	69	2.10-6.22	3.70	1.18
STR_C	Structural complexity	69	-1.21-2.29	0.00	0.92
PRO_C	Procedural complexity	69	-1.02-1.22	0.00	0.94
DAT_C	Data complexity	69	0-5.59	2.33	4.85
CLO_C	Closeness centrality. Arc value = $\log(C(n_i))$	69	0-9.96	2.85	10.10
CLO_NC	Closeness centrality. Arc value=1	69	0-33.96	16.52	136.52
CLO_RC	Closeness centrality. Arc value=$1/\log(C(n_i))$	69	0-362	141.91	1214.47
EMB_C	Embeddedness	69	0-0.52	0.18	0.06
TIM_C	Respondent's Time with component	69	1-3	1.19	0.40

Pearson correlation coefficient to measure the relationship between the three centrality variable, then the Spearman rank correlation coefficient measure CLO_C, the strength of the link between CLO_NC CLO_RC three centrality variable shown in Table 2, derived by analyzing three variables on the flexibility cost calculation model of the software architecture of the structural complexity of some significance, they need to be incorporated into the model regression, but only in one model close to the centrality variables to be used.

Table 2 –Pearson and Spearman rank correlations among closeness centrality variables[a,b]

Name	1	2	3
1.CLO_C	1.00 1.00		
2.CLO_NC	0.78 0.92	1.00 1.00	
3. CLO_RC	0.69 0.68	0.89 0.82	1.00 1.00

[a] Top number is Pearson correlation; bottom number is Spearman rank correlation.
[b] $p<0.01$ for all correlations. N=69

Table 3 –OLS results for dependent variable CTF

CTF	Model 1	Model 2	Model 3
TIM_C	0.59^{**}	0.42^{**}	0.29^{*}
COM_C	-0.04	-0.05	-0.06
SH_C	-0.45^{*}	-0.52^{*}	-0.47^{*}
SE_C	-0.30^{*}	-0.41^{*}	-0.39^{*}
DE_C	-0.20^{**}	-0.07^{*}	-0.04^{*}
DR_C	-0.03	-0.04	0.05
TOP_C	-0.10	-0.35	-0.49
STR_C	0.32^{**}	0.11^{*}	0.09^{*}
PRO_C	0.32^{**}	0.06	0.02
DAT_C	0.46^{***}	0.22^{*}	0.24^{*}
CLO_C	0.15^{***}		
CLO_NC		0.01	
CLO_RC			0.00
EMB_C	0.62^{*}	0.42^{*}	0.67^{*}
Constant	3.45^{**}	3.06^{**}	3.42^{**}
F-test	5.96^{***}	4.94^{***}	5.01^{***}
R-squared	0.85	0.63	0.74
Adjusted R^2	0.72	0.51	0.43

Absolute value of t statistics in parentheses * $p<0.05$ ** $p<0.01$ *** $p<0.001$

Dependent variable OLS the following results, shown in Table 3: According to the goodness of fit of the model 1 adjustment and F-test, with respect to the model 2, the model results can Description CPASA assembly features; there is a relationship between the component complexity, the complexity of the software architecture and software architecture flexibility cost component complexity, the complexity of the software architecture. DAT_C, STR_C, PRO_C, EMB_C, centrality CLO_C, TIM_C significant positive impact on software architecture flexibility cost. SH_C, SE_C, DE_C significant negative impact of software architecture flexibility cost. COM_C, DR_C, TOP_C affect the software architecture flexibility cost. Predicted by the formula (4) 3, 4 and 5 years of software architecture components flexibility cost, get flexibility software architecture components costs CTF person days cumulative first and second years of flexibility software architecture components and then multiplied by the cost per average human cost person days come CPASA flexibility cost 980 yuan TF = 59.42 million. Therefore, the Travelsky e-commerce platform CPASA flexibility cost 594,200.

Calculation model of the flexibility cost of software architecture for CBP variation
This paper points out that in CPASA, S = 1.2 years in the identification and prediction first,3,4,5 all processes that need to be run in the software architecture based on the calculating step estimates the estimates are based on the equation (4) of the parameters a, b, c, d, E, where in the average human cost of 980 yuan per person per day. The model calculates the TC smallest solution equation, see (1), the following results, as shown in Table 4: First set $x_2 = 0, c = 0$, obtained TC_NF corresponding to $y = 0$. The model suggests that 76% of business processes by the CPASA static flexibility support 23% by CPASA external flexibility processing. CPASA dynamic flexibility and did not consider. $x_2 = 0, y = 0, w_2 = 0$ as the optimal solution. Do not limit $x_2 = 0$, allows flexibility CPASA dynamic investment, get TC_F. The model suggests that 77% of business processes will be CPASA static flexibility supported 11% by CPASA dynamic flexibility processing, and 12% by CPASA external flexibility processing. TF = TC_NF − TC_F = 1546.514 − 1491.056 = 55.458 , therefore the Travelsky flexibility e-commerce platform CPASA cost is 55.458 wanyuan.

Table 4 –Calculation model for solving   unit: wan yuan

a=125.67, b=367.58, c=63.75, d=175.45, e=324.56, f=467.24			
$p = 0.8, v = 0.6, r = 0.1, S = 1, q$=0.4, T=5, i=0.035			
SCF	DCF	EMF	TC
0.77%	0.11%	0.12%	(TC) 1554.806
0.76%	0%	0.23%	(TC_NF) 1546.514
0.77%	0.11%	0.12%	(TC_F) 1491.056

The result can be shown that: TF> 0, meaningful prove uncertainty model. 59.42 > 55.458, the model values are so close. Flexibility cost calculation complexity-oriented structure of the software architecture is superior oriented inter-organizational business processes flexibility costs of the software architecture of the variation calculation results. The presence of the model underestimated flexibility cost problem does not exist. If you do not consider the inclusion of dynamic flexibility, external flexibility processing increases 11%. Actually take flexibility strategy combinations and model calculations are consistent. In the context of the gradual opening up of competition in the domestic civil aviation market, epitomized Travelsky - airlines - agent three parties to the framework agreement as the main implementation of inter-organizational business processes, as well as the tripartite the mutual surplus beneficial cooperation model.

Conclusions and Future Research Agenda
In this paper, the model calculates the flexibility cost of CPASA through application research of travelsky's e-commerce platform; we draw complex structure-oriented software architecture flexibility cost calculation results superior to the calculation of the model by case analysis of travelsky's e-commerce platform result, the calculated results are close, the organization through a flexibility strategy make investment decisions. Organization by establishing regression formula of flexibility cost of CPASA, can eventually improve the software architecture flexibility. The results of this research is to expand and deepen the research in the field of CPASA and its flexibility cost, meanwhile empirical research, case studies and experience can provide a good reference for the

development organization, it has a certain significance to them. Overall, the main limitations and problems need to be solved include the following aspects: A longitudinal study of the variation of inter-organizational business processes-oriented software architecture flexibility cost calculation model, it is assumed that further refinement; Sub-industry, multi-case study, the study concluded applicability.

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