Assessing the Effects of Information Technology on Firm Performance Using Canonical Correlation Analysis: A Survey in Iran Car Part Suppliers Sector

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***Abstract*—**In this paper we have analyzed the effects of IT usage on 112 Iranian car part suppliers. Canonical correlation analysis reveals a statistically significant relationship between one set of variables namely, the seven indexes of IT usage, and the other set of variables namely, three company performance indexes. Accordingly; the results show that correlation between company performance and the extend of using IT in the planning, administration and pecuniary affairs is stronger than the other aspects of IT usage.

***Keywords*—**Information technology, firm performance, canonical correlation analysis, survey, car part industry.

I. Introduction

THE relationship between the use of Information Technology (IT) and firm performance has widely researched over the recent years. The results have shown a significant and positive correlation between IT and firm performance (Alpar and Kim, 1990; Harris and Katz, 1991; Rai, et al, 1997; Newman and Kozar, 1994; Mukhopadhyay et al., 1995). Meanwhile the other researches have not been able to find such relationship (Brynjolfsson and Hitt, 1998; Davern and Kaffman, 2000). This is called productivity paradox in the literature of IT and productivity. Many Academic and industrial researchers and managers are now working on reasons of Productivity Paradox. These researchers spend efforts on applying improved methods for productivity measurment, improving data sets, and defining new measures to understand more about productivity pardox (Keramati, Albadvi; 2006).

Specifically, in this paper we have tested the relationship between IT usage and enhancing performance using a partially new method of data analysis in the literature of IT and performance. So, the aim of this paper is to empirically test whether the use of IT in companies leads to productivity improvement or not. In particular, it tries to answer the following questions:

1. Is there any positive and significant correlation between the use of IT and firm performance?
2. What is the effect of different aspects of IT usage on company performance?

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A careful scan of the literature shows that researchers in the similar studies generally apply statistical and mathematical models, such as regression analysis, correlation analysis, and data envelopment analysis (DEA)(Albadvi; Keramati, 2006). In this paper we apply Canonical Correlation Analysis (CCA) to study the relationship between IT usage and firm performance. Only Keramati and Albadvi (2006) were relevant CCA in a similar research to study the effects of integration of IT and total quality management (TQM) on organizational performance (and also Froza (1995) used this method to study productivity of information systems). Their study shows that integration of IT and TQM strongly and positively effects on firm performance. Investigating the application of CCA in the IT productivity problem is another purpose of this paper.

II. Literature Review

As Robert Solow claimed, "*You can see the computer age everywhere but in the productivity statistics*" (Belcher and Watson, 1993). He used term "productivity paradox" to show this fact. Brynjolfsson (1996) proposes four explanations for the productivity paradox including: Mis-measurement of inputs and outputs, Lags due to learning and adjustment, Mismanagement of information and technology, and Redistribution and dissipation of profits.

Brynjolfsson (1996) attributes the measurement error to the difficulty of developing accurate, quality-adjusted price deflators; He argues that improvements in product quality and the introduction of new products need to be properly accounted for the value of output. Lags as an explanation of the paradox suggest that the benefits associated with investments in IT may take several years before they show the bottom line. This is due to a period of learning associated with adjustment and possibly restructuring of the organization caused by new IT. The third proposition, mismanagement of information and technology, suggests that IT is not productive, and managers who choose to invest in IT are not acting in the best way for company's interests. Finally, redistribution as an explanation of the productivity paradox argues that IT rearranges the shares of the pie, in favor of some companies without making it bigger anymore.

There are some researches that tried to explain IT and

productivity paradox. Brynjolfsson and Hitt (1996) considered and empirically tested the possibility of the productivity paradox as an artifact of mis-measurement. They used the neoclassical production theory in order to determine the contribution of such inputs as computer capital and information systems staff labor to output. They measured output in inflation-adjusted dollar terms because, this partially accounts for changes in product quality and introduction of new products. They concluded that their results indicated that IT had made a substantial and statistically significant contribution to firm output, and that the productivity paradox disappeared by 1991, at least in their sample of firms. By focusing on one of the four possible explanations (mis-measurement) for the productivity paradox, Brynjolfsson and Hitt (1996) were able to show a significant relation between investment in information systems and firm output.

Stratopoulos and Dehning (2000) research considers the possibility that a portion of the productivity paradox is attributable to mismanagement. Empirical findings of Strassmann (1990), also, indicate that the lack of any significant correlation between the investment in IT and performance, points to possible irrational behavior of the management. Furthermore, Chaos (1995) reported that 80 percent of IT projects cannt meet their budjet and/or time goals because of the mismanagement of projects. These evidences emphesis on the role of mismanagement in IT productivity paradox introduced by Brynjolfsson (1996).

Shafer and Byard (2000) developed a framework for exploring each of the four possible explanations of productivity paradox by DEA on two-digit code industries data set.

Productivity paradox is still a research area on IT and productivity. One of the most important ways to explain productivity paradox is the application of new methods of data analysis. Osei-Bryson and Ko (2003) applied regression spline analysis, Scott and Byrd (2000), Desheng Wu (2006) used data envelopment analysis (DEA) to solve IT productivity problem. As mentioned before, Keramati and Albadvi and also Froza (1995) used CCA in the similar research.

III. Research Model

Because of the great potential of IT, such as flexibility, location independency, low cost of communications and collaboration in work to business performance improvement, we expect a significant improvement in firm performance after using IT (Turban, 2002). Fig. 1 shows a conceptual framework of the effects of IT usage on firm performance.

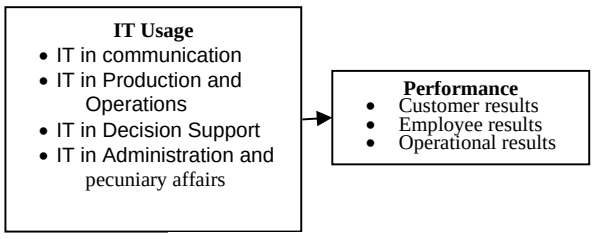

Fig. 1 Research model

This research model is similar to research models used by researchers in the field of IT and performance prior to this study. For example Ang et al. (2000) applied a similar model to study the effects of IT on improvement of quality management system. Froza (1995) applied similar model to investigate the effects of IT on information quality and quality of management information systems. In the other study, Martinez-Lorente et al. (2003) used a similar model in their work to show the relationship between IT use, total quality management and firm performance. Results of these researches show a positive significant correlation between IT usage and firm performance.

IV. Method

A. Instrument Development

Our approach in this study was a survey and the instrument for data collection was a questionnaire. Data were collected from 200 firms in the automotive part suppliers in Iran.

A set of items, based on the research model, were developed, and aggregated into four scales for measuring the use of IT in company, and also three scales for measuring the company performance.

In this section we will operationally define the research variables and then introduce their measuring instruments. It is important to note that reuse of instrument from previous studies ensures content validity of the current study. When necessary, we have defined some first time used instruments that are validated at the end.

1) The extent of IT Usage (ITU)

A list of information technology used in companies based on literatures by Boyer et al. (1997); Kotha (1998); Swamidass (2003); Martines-Lorente et al. (2003) is drawn out. Since variables are directly immeasurable, their measurement requires scale definition. Therefore, 35 measures have been defined to evaluate IT in organisations (appendix 1). Then, they have been classified into four criteria in terms of their application objectives consisting of IT in communications, IT in decision-making support, IT in production and operation, and IT in administration. In IT and performance literature, measuring IT in organisations using subjective criteria is mainly carried out by researchers like Grover et al. (1998); Pinnesealt (1998); Martinez-Lorenze (2003). In these researches reliability and validity of such criteria are shown.

IT in communications

IT in communications refers to those directly involved in transaction of information. This criterion includes the following applications: e-mail, fax, cell phone, Internet access, local access networks (LAN) for technical data within the company, LAN for companies, internal networks of the company, company's website for advertisement, intranet, data interaction with suppliers and customers. Measures of IT in communication are drawn from works of

Grover et al. (1998); Pinnesealt (1997); Martinez-Lorenze (2003). Accordingly, following scales representing respondent's perception of the degree of IT application in communication in their company were developed. A seven-point Likert scale was used to measure each of the dimensions identified. They were anchored at the ends with 'not at all' and 'strongly'.

IT in decision-making

The decision-making support criterion indicates the application of IT in management supporting of processes. So, it includes IT applications such as Decision and prognostic software. Measures of IT in decision-making are drawn from works of Grover et al. (1998); Pinnesealt (1997), Swamidass & Kotha (1998), Boyer et al. (1997), Albadvi and Keramati (2006) and Martinez-Lorenze (2003). Respondents were asked to indicate the application rate of the decision-making support technologies on a Likert scale from 1 (Not used) to 7 (Very frequently used).

IT in manufacturing and operation

This criterion works as an umbrella to delineate the range of computer-assisted technologies for direct or indirect support, control, detecting and monitoring of manufacturing activities. Measures of IT in manufacturing and operation are drawn from works of Turban et al. (2002); Boyer et al. (1997); Froza (1995), Albadvi and Keramati (2006). Based on work of Albadvi and Keramati (2006), measures of IT in manufacturing and operation are calssified in following three categories. Respondents were asked to indicate the rate of the use of IT in manufacturing and operation on a Likert scale from 1 (Not used) to 7 (Very frequently used).

IT in administrative or office work

This criterion refers to the use of IT to help administrative or office work like organizing documents, organizing and storing data etc. Measures of IT in administrative or office work are drawn from works of Turban et al. (2002); Martinez-Lorenze (2003) and Albadvi and Keramati (2006). Based on work of Albadvi and Keramati (2006), measures of IT in administrative or office work are calssified in two following categories. Respondents were asked to indicate the extent of the use of IT in administrative or office work on a Likert scale from 1 (Not used) to 7 (Very frequently used).

2) Performance Measurement (PER)

In this study we used four separate performance scales from different sources. First question consist of two questions relating to customer satisfaction and relation taken from Froza (1995) and EFQM (1999) excellence model. The average of two questions is named 'customer results'. The second performance scale consists of two questions relating to satisfaction and performance of staff taken from EFQM (1999) excellence model. The average of two questions is named 'empolyee results'. The third performance scale consists of four questions relating to achieving sustainable competitiveness through quality, flexibility, defectives, delivery and cycle time are drawn from Swamidasd (1998) and Froza (1995). The average of these five questions is named 'operation results'. The last criterion consists of two questions, which evaluate the growth of the company in sales and return of investment (ROI). These eleven questions ask respondents to rate their plant's position with respect to competitors on a seven point Likert scale ranging from 1 = No Competitive to 7 = Highly Competitive with reference to Boyer et al. (1997) and Dewhurst (2003).

B. Quality of Instrument

To improve the validity and reliability of the survey data, the measurement instrument was evaluated by pre-testing the questionnaire prior to its administration (Cooper, 2003). Personal interviews were conducted with 6 participants in order to see if the items are understandable, length of the questionnaire and the sequence of questions, sensitivity of the items, and the time needed to complete it. The participants were academic with practical experts in the fields of IT. The instrument was modified regarding to the comments of participants. After pre-testing, the questionnaire was sent to a group of twelve respondents in positions similar to those of final respondents. They were asked to answer the questions and suggest any modifying views concerning our questions. We then applied slight modifications and prepared the final draft.

In order to assess the reliability of instrument, we have calculated Cronbach's alpha for criteria of research variables. The reliability coefficients (Cronbach's alpha) of all scales of the IT usage and company performance were above 0.70, except for the "IT in administration" and "IT in pecuniary affairs, which was 0.63 and 0.69, respectivly (Table I). These reliability coefficients are well above acceptable criterion of 0.70 (Nunnally, 1967), and indicate the reliability of scales. According to Nunnly (1987) an alpha of below 0.7 and over 0.6 for new instruments is acceptable. Construct validity of the questionnaire was assessed by means of principle component factor analyses of each scale separately. As Table I shows, each scale loaded on a single individual factor, because all of the eigenvalues were considerably more than the accepted criterion of 1.0 (from 1.596 for the customer results to 3.203 for the Operational performance indicators). Extracted single factors indicate the proper construct validity, because the single individual factors accounted for about 41 - 88% of the total variance of each respective scale (Nunnally, 1967).

Finally, non-response biasness was tested. To test the non-response bias, time-dated groups were compared with variables. No T-tests were statistically significant at the .05 level. These results show that findings can be generalized to the sample.

C. Sampling

Questionnaires were sent out to *car part suppliers* in Iran. In Iran 560 companies are involved in car part and component manufacturing. We have selected the top 200

suppliers with respect to their yearly turnover. Because yearly turnover of these companies is as significant as those firms which can be invested on IT applications. Among them 112 companies participated in survey. Therefore, the response rate came out to be 56%,which is a feasible rate for such researches (Ang et. al., 2001).

V. Findings

The findings of this study are demonstrated in terms bivariate analysis in the form of correlation between variables and, finally, multivariate analysis in the form of canonical correlation analysis.

A. Bivariate Correlation Analysis

This section shows the results of testing the correlation between two research variables including amounts of use of IT (ITU) and company performance (PER (Table II). Altogether, all of the bivariate correlations in Table II are

TABLE I
VALIDITY INDEX AND FACTOR ANALYSIS FOR ITU AND PER VARIABLES

Variable	Measurement criterion		# of measures	# of eliminated measures	N	Mean	Std. Deviation	Alpha	Eigenvalue	% from total variance
Information Technology Use (ITU)	IT in communications ITCO		6	2	96	4.37	1.32	0.7673	2.945	49.086
	IT in production and operation: ITPO	IT in planning	9	4	97	4.43	1.40	0.7521	2.314	57.853
		IT in operation			96	3.92	1.63	0.7106	1.929	64.306
		IT in quality control			97	5.89	1.48	0.8621	1.760	88.001
	IT in decision making and support: ITDS		3	1	97	3.05	1.51	0.7749	2.102	70.067
	IT in administration: ITAD	IT in administration	8	2	97	4.52	1.02	0.6364*	2.089	41.775
		IT in pecuniary affairs			97	5.98	1.04	0.6936*	1.961	65.354
Total ITU					97	4.59	0.85			
Performance: (PER)	Customer results: PECO		2	0	97	6.14	0.92	0.7417	1.596	79.784
	Employee results: PEEM		2	0	97	5.46	0.93	0.7756	1.638	81.877
	Organisational performance results: PEOP		5	1	97	5.97	0.81	0.8587	3.203	64.063
	Company's growth rate: PEGR		2	0	97	5.40	1.08	0.6810*	1.558	77.876
Total PER					97	5.81	0.76			
Total PER* (PEGR eliminated)					97	5.90	0.78			

*An alpha of below 0.7 and over 0.6 for new instruments is acceptable (Nunnly, 1987)
An alpha of below 0.6 is not acceptable

TABLE II
BIVARIATE CORRELATIONS BETWEEN IT USAGE AND COMPANY PERFORMANCE

Criterion			Customer results (PECU)	Employee results (PEEM)	Performance (PEOP)	Growth rate (PEGR)	Total PER* (PEGR eliminated)
IT in communications: ITCO		r	0.302**	0.269**	0.318**	0.144	0.335**
		p	0.003	0.008	0.002	0.162	0.001
		N	96	96	96	96	96
IT in production and operation: ITPO	IT in Planning: ITPOI	r	0.424**	0.428**	0.449**	0.103	0.482**
		p	0.000	0.000	0.000	0.314	0.000
		N	97	97	97	97	97
	IT in Operation: ITPOII	r	0.202*	0.377**	0.345**	0.164	0.354**
		p	0.049	0.000	0.001	0.111	0.000
		N	96	96	96	96	96
	IT in Quality control: ITPOIII	r	0.263**	0.299**	0.272**	0.096	0.293**
		p	0.009	0.003	0.007	0.352	0.004
		N	97	97	97	97	97
IT in decision support: ITDS		r	0.246*	0.336**	0.290**	0.104	0.321**
		p	0.015	0.001	0.004	0.312	0.001
		N	97	97	97	97	97
IT in administration: ITAD	IT in Administrative affair: ITADI	r	0.428**	0.375**	0.460**	0.223*	0.476**
		p	0.000	0.000	0.000	0.028	0.000
		N	97	97	97	97	97
	IT in pecuniary affair: ITADII	r	0.351**	0.281**	0.427**	0.214*	0.416**
		p	0.000	0.005	0.000	0.035	0.000
		N	97	97	97	97	97
Total IT usage: ITU		r	0.481**	0.535**	0.562**	0.228*	0.590**
		p	0.000	0.000	0.000	0.024	0.000
		N	97	97	97	97	97

positive and statistically significant except the correlation between "growth rate (PEGR)" and "IT in communication (ITCO)" as well as "IT in production and operation (ITPO)". Consequently, "growth rate (PEGR)" scale has been deleted from the later analysis, because bivariate is statistically significant correlation and essential for the canonical correlation analysis in this paper. Table II shows the values of the bivariate Pearson's correlation coefficients (*r*) and respective statistical significant levels (*p*). Following these results, it appears logical to pursue canonical correlation analysis.

A. Canonical Correlation Analysis: Multivariate Analysis

To demonstrate the application of canonical correlation, we use all of the scales as input data. Seven variables of the use of IT in companies are designed as the set of multiple independent variables or the predictor variables. Three measures of company performance are specified as the set of multiple dependent variables or the criterion variables. The statistical problem involves identifying any latent relationships between extent of use of IT in companies and the level of company performance.

The canonical correlation analysis was restricted to drive three canonical functions, since the dependent variable set (company performance) contained three variables. To determine the number of canonical functions included in the interpretation stage, our analysis focused on the level of statistical significance, and the redundancy indices for each variate.To do statistical significance test, multivariate tests of three functions are performed simultaneously. The test statistics employed are Wilk's lambda and Chi-Square tests. Table III shows the multivariate test statistics, which both indicate that the first canonical function is statistically significant at .001 levels. In addition to statistical significance, the canonical correlation of first function is (0.639) which is partially significant.

TABLE III
MULTI VARIATE TEST OF SIGNIFICANCE

Canonical Function	Canonical Correlation	Wilk's	Chi-SQ	DF	Sig.
1	.639	.513**	59.026**	21.000	.000
2	.429	.867	12.663	12.000	.394
3	.292	.962	3.429	5.000	.634

The next step is to perform redundancy analysis on canonical functions. Table IV A shows that redundancy index for the dependent variate is 0.15. Table IV B indicates that the redundancy index for independent variates is 0.323. These redundancy indices belong to the first canonical function. The variates for the second and third

functions are too low to be of practical importance (Tables IV A and IV B). These numbers indicate the amount of variance of one variate, explained by the other. Explaining more than 25% of the variance in an organizational level of study can be fairly significant, considering all other factors that can contribute to performance measures (Byrd; Turner, 2001). This, together with the results presented in Table III, justifies the exclusion of the second and third functions.

With the canonical relationship, deemed statistically significant and the magnitude of the canonical root and acceptable redundancy index, the analysis proceeds to make substantive interpretations of results. In general, the researcher faces the choice of interpretation of the functions using canonical weights (standardised coefficients), canonical loadings (structure correlations) or, canonical cross loadings. Given a choice, it is suggested that cross loadings are superior to loadings, which are in turn superior to weights (Hair et al., 1998). Hence, the interpretation presented here is based on cross loadings.

TABLE IV A
REDUNDANCY ANALYSIS OF DEPENDENT VARIATES FOR THREE FUNCTIONS

Canonical Function	Variance explained by own variables		Variance explained by opposite variables	
	Percent	Cumulative percent	Percent	Cumulative percent
1	37.1	37.1	15.1	15.1
2	10.7	47.8	1.1	16.2
3	10.5	58.3	00.4	16.6

TABLE IV B
REDUNDANCY ANALYSIS OF INDEPENDENT VARIATES FOR THREE FUNCTIONS

Canonical Function	Variance explained by own variables		Variance explained by opposite variables	
	Percent	Cumulative percent	Percent	Cumulative percent
1	79.3	79.3	32.3	32.3
2	13.2	92.5	1.3	33.6
3	7.5	1.00	3	33.9

Table V includes the cross-loadings for the three canonical functions. Considering the first function, canonical cross-loadings for the independent variate range from 0.300 to 0.481. The canonical cross loadings for the dependent variate are more than 0.523 for the first function. Both of the canonical cross-loadings for the dependent and independent variates are acceptable for interpretation. All cross-loadings are positive. This gives one more indication of a valid relationship between two variates.The results for the dependent variables indicate that the strongest correlations in descending order of importance, are associated with the extent to which IT is used in the planning, administration affaires, pecuniary affaires, production and operations, communication, decision support and quality control. The overall correlation between dependent and independent variables indicates that high ratings on the dependent variables are associated with higher levels of company performance.

TABLE V
CANONICAL CROSS-LOADINGS OF THE THREE FUNCTIONS

	Function 1	Function 2	Function 3
Independent variate			
IT in planning	0.481	0.065	-.060
IT in administration affaires	0.480	-.041	-.014
IT in pecuniary affaires	0.422	-.118	0.089
IT in production and operations	0.341	0.176	0.098
IT in communication	0.338	0.008	-.025
IT in decision support	0.314	0.131	-.035
IT in Quality control	0.300	0.079	-.068
Dependent variate			
Customer results	0.558	-.083	-.080
Staff results	0.523	0.180	-.009
Operation results	0.621	-.006	0.046

VI. CONCLUSION

Table I shows that, total use of IT exceeded from moderate level (4.59) and the highest amount of IT usage is in the “IT in pecuniary affairs”(5.98) closely followed by “IT in quality control”(5.89). IT applications in pecuniary affairs are one of the oldest applications of IT (Turban, 2002) and numerous software applications are developed and used in companies, inexpensively. Also, implementing a quality management system (such as ISO9000, QS9000) is one of the requirements of car part suppliers in Iran. These companies use IT applications for gathering and analyzing quality data. Table I indicated that only “IT in decision support systems” is used less than moderate level (3.05). Decision support systems are more advanced and more expensive than the other type of IT applications in Table I.

In this study we asked respondents to rate their plant's position with respect to competitors on a seven point Likert scale. Table I, also, shows that most of the respondents recognized themselves high competitive. They recognized the most competitive improvement in “Customer results” (6.14), in descending order, followed by “organizational performance results”(5.97), “employee results”(5.46) and “Company's growth rate” (5.40) (Table I). Consequently, the results indicate that four variables, are considerably exceeded moderate level in the sample companies of this study.

Bivariate correlation analysis reveals that there are significant correlations between three company performance variables including “customer results”, “employee results” and “operational performance results” and the seven scales of the IT usage including IT in communication, decision support, planning, operation, quality control, administration and pecuniary affairs. Previous works on effects of IT usage on performance show consistent results on the IT in communication (Grover et al. (1998); Pinnesealt (1997); Martinez-Lorenze (2003)), IT in operation, (Boyer et al. (1997); Froza (1995)), IT in decision-making (Swamidass & Kotha (1998); Boyer et al.

(1997)) and IT in administration (Martinez-Lorenze). However, the effects of IT in quality control, IT in planning and IT in pecuniary affairs on firm performance have not been reported in the literature.

The benefit of the canonical correlation analysis, in contrast to the univariate analysis of scales is that it takes into account the simultaneous interaction between all scales. The results of the analysis indicate a statistically significant relationship between company performance and IT usage and are consistent with the results of previous research applied to other sectors. Furthermore this study strongly showed positive significant associations between three out of seven scales of IT usage (IT in planning, IT in administration, IT in pecuniary affaires) and the company performance indicators. This shows the importance of use of IT in planning, administration and pecuniary affaires to realize the potential of IT. According to canonical correlation findings (Table V), the effect of IT usage on operational results is more than the effects of IT usage on the two other company performance measures.

Accordingly, results of this study, bivariate correlation analysis (Table II) together with results of canonical correlation analysis (Tables III, IV and V), show a positive significant association between the use of IT and firm performance. Specifically, this research has indicated that use of IT in planning, administration and pcunairy affairs are associated with more improvements in the company performance indicators.

VII. Limitations

The study's sample size is 112 plants. This size is considered small for our statistical analysis. On the other hand, this size is generally used at individual respondent level of analysis, where measures' instability is fairly high (Froza, 1995; Hofstede et al., 1990). In the present study, each measure used, has high internal consistency, in other words, the answers are highly correlated, and this consistency increases the stability of measure (See Table 1). Hofstede et al. (1990) states that a lower sample size is acceptable when this kind of stable data with high internal consistency is used.

VIII. Future research directions

Stronger role of use of IT in planning, administration and pecuniary affairs to enhance firm performance is found in this study. To explore the relationships between extent of use of IT in the above-mentioned scales and the firm performance highlighted here, needs deeper study. Case study research could throw more light on the mechanisms of this relationship.

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