INFORMATION TECHNOLOGY INVESTMENT AND FIRM PERFORMANCE: A PERSPECTIVE OF DATA QUALITY

(Research Paper)

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Abstract While firms are investing heavily in information technology (IT), the evidence of whether or not those investments are rewarded by the improved firm performance is mixed. Many studies have looked at the impact of IT investment on firm performance without considering the effectiveness and efficiency of the information system deployed. This could be very troublesome because different firms adopt, deploy and use information technology differently. Furthermore, more and more firms rely on computer data to conduct business operations and make more solid business decisions to improve firm performance; the quality of data flowing in the firms' information system has a substantial impact on the quality of services, products, operations, business decisions and the firm performance achieved later on. This paper proposes a study to see how data quality moderates the impact of IT investment on firm performance.

Key Words: Data Quality, Information Quality, Information Technology Investment, IT Investment, Firm Performance

INTRODUCTION

The relationship between information technology (IT) investment and firm productivity and performance has been an important topic in MIS research for years. However, contradictory results from research have not been helpful for IT managers in justifying IT spending. Recent studies of the relationships between investment in IT and organizational performance and productivity have reported positive and significant effects of such investment [4, 8, 15, 19, 20, 24], while others found no significant relationship [5, 16, 30, 31]. The contradictory results are partly due to inadequate data and flawed methodology [6, 29], but treating IT investment as a black box without looking further at what is going on inside the box could be an even bigger cause.

This research opens that black box and looks at the relationship between IT investment and firm performance one step further. Instead of treating IT investment as a black box, quality of the data which is the output of the information systems deployed in the firm, is proposed as a measure of the effectiveness and efficiency of the IT investment. How different effectiveness and efficiency of the IT investment, which generates different quality of the output data, would impact firm performance is researched here.

PRIOR RESEARCH

Different firms have different situations and therefore have different strategies in adopting, investing, deploying and using IT. For example, some have deployed expensive Enterprise Resources Planning (ERP) systems, some might focus on Customer Relationship Management (CRM) systems, and still others may have other different concentrations. But no matter what kind of IT systems a firm uses, the firm should pay attention to the efficiency and effectiveness of the deployed systems because they could contribute significantly to the variance of the firm's productivity and performance. Unfortunately, only a few of the studies, such as Shafer and Byrd [28], have addressed the relationship between IT investment and firm performance from the viewpoint of the effectiveness and efficiency of IT investment. Many studies explained the direct relationship between IT investment and firm performance, either significant or non-significant, outside of the box of the IT in which the firms had invested. For example, Morrison and Berndt [22] found that $1 worth of IT investment only delivered about $0.80 on margin. However, they did not explain further if that was due to the limitation of the IT systems in which the firms had invested, or if it was because the IT the firms had invested in did not get used effectively and efficiently in the firms.

In essence, IT is the technology for collecting, processing and presenting data information. One way to look at the effectiveness and efficiency of the deployed IT in a firm is to screen the quality of its direct output --- data. The quality of the data output from the information system has an important influence on the quality of the services, products, operations and business decisions.

In today's marketplace full of fierce competition, managers find themselves needing to make swift and high quality business decisions almost every day, and they need high quality data in their decision making process. How the data is collected, processed and presented holds a significant stake on the quality of the consequent operations and decisions. Firms could benefit greatly if the decisions lead the way to premium competitive advantage or strategic positioning. Otherwise, firms would not gain much if their investment could not deliver high quality data information which business managers rely on to make decisions, no matter how heavily they have invested in IT; what is even worse is that these firms could lose big if the inappropriate data lead to wrong decisions. If managers could not make quick, correct business decisions, it is unlikely that firms' performance could be improved, and their investment in IT could be justified thereafter. For example, CRM has the potential to provide a clear understanding of a firm's customers and therefore provide tailored products or services to them, but many CRM deployments are thwarted by faulty, inconsistent data which prevent firms from achieving their goal [18]. Today's net-enabled firms rely heavily on data to conduct business, to integrate operations, to understand customers, to develop new products and services, and to connect to suppliers, etc. The quality of the data is very critical to their business success. If an organization were to be a human body, then data is like the biological cells in the body. No one could survive if he or she did not have good body cells, nor a business could last if it did not have high quality of data.

IT Investment and Firm Performance

The results from the research of IT investment and firm performance are mixed. Tam [33] replicated the research conducted by Hitt and Brynjolfsson [12] on four newly industrializes economies --- Hong Kong, Singapore, Malaysia and Taiwan, over the period of 1983-1991. The results on ROE, ROA and ROS were mixed for different economies, but the impact of IT investment on shareholders' return in all four economies was not significant at all. Tam argued that IT investment in those four economies was much behind the United States and was in the category of transactional IT, while the market does not value non-innovative, transactional IT heavily. Regarding why the results of ROE, ROA and ROS were mixed for different economies, Tam commented that this was due to regional, cultural difference and policy differences, among them. More detailed and specific research is needed to filter those differences out to obtain a consistent result; just simply looking at the direct relationship between IT investment and firm performance is not sufficient to make conclusions.

Brynjolfsson and Hitt [8] did a study on 380 large firms between 1987 and 1991. They found that the return on investment for IT capital was over 50% per year and the return on spending on IS labor was also very high. In the service area, the return on investment was over 60% per year. Other research [12] studied the impact of IT investment on three different measures: productivity, business profitability and customer surplus by using the data of IT spending from 370 large firms over the period of 1988-1992. Their findings indicated that IT had increased productivity and created substantial value for consumers, but they were unable to detect increases in business profitability measured by ROE, ROA and Total Return. They then pointed out that the high standard errors of estimates in their research suggest that some firms were obtaining significant competitive advantages while others were not. However, the data was not sufficient to reliably distinguish characteristics of "winners" and "losers". This suggests that research needs to look into firms more specifically and in more detail about what their deployed IT is doing, and why some firms benefit from IT investment while others do not or even lose.

Some studies divide IT investment into three categories: transactional IT investment, strategic IT investment and informational IT investment [37, 41]. Weill [41] found that transactional IT investment is significantly and positively related to productivity over the time of 1982-1987, but there was no such evidence for strategic and informational IT investment.

A survey to managers conducted by Brynjolffson [7] and referred by Brynjolffson and Hitt [8] pointed out that the relative importance of investing in IT is customer service and cost saving, followed by timeliness and quality[1]. The IT used in customer service and cost saving usually falls in the category of transactional IT, especially in the rudimentary period of massive deployment of information system [33]. Compared to the rapid and more advanced development and improvement of information technology in the 1990s, the information systems before the 1990s were mainly transaction-oriented. It is reasonable to think that managers were focusing most on the transactional IT amongst those three kinds of IT at that period of time, even though the dollar amount of investment in the transactional IT was not the biggest in all three types of IT investment [41].

While transactional IT is targeted to improve internal efficiency and cost cutting, the objective of strategic IT investment is market expansion, such as exploring a new channel to customers, spawning new business, or restructuring an industry. By looking at the evolution of information systems, as illustrated in Figure 1, we know that, before the 1990s, MRP and MRP II were popular. MRP and MRP II were typically transaction-centric, those systems were designed to support routine transactional activities, but they did not mean to help continuous or strategic planning to drastically improve a firm's performance.

Certainly, there were some sorts of executive-support systems (ESS) or decision-support systems (DSS) available to help decision making before the 1990s; but compared to today's enterprise applications such as business intelligent systems, CRM, data mart, data warehousing, data mining tools, etc., the functionalities of the old generation of DSS or ESS were very limited. For instance, from the viewpoint of ERP systems, the real support for decision-making in corporate information systems, in terms of resources planning, did not happen until Supply Chain Management (SCM) was integrated into ERP in the 1990s, especially in the late 1990s. The added functionalities, which create the second generation of ERP, include not only decision support, but also CRM, e-Commerce, data warehousing and data mining; all of those are essential for a firm to achieve competitive advantage and better firm performance. Thus, because of the lack of real strategic information systems before the 1990s, the research done on IT investment and firm performance before the mid-1990s was actually the research of transactional IT investment and firm performance. The data reported by Weill [41] also indicates that firms were cautious and invested least on strategic IT, as compared to informational IT and transactional IT from 1982 to 1987. Therefore, it is not strange that Weill was only able to find the correlation between transactional IT investment and productivity, and he did not find the contributions to the firm performance from strategic information systems and informational systems. The non-profitability of strategic IT investment in Weill's data set was not a surprise because of limited functionalities and contributions of these strategic IT systems during that period of time.

[1] The "quality" here means quality of product or service, not the quality of data studied in this paper

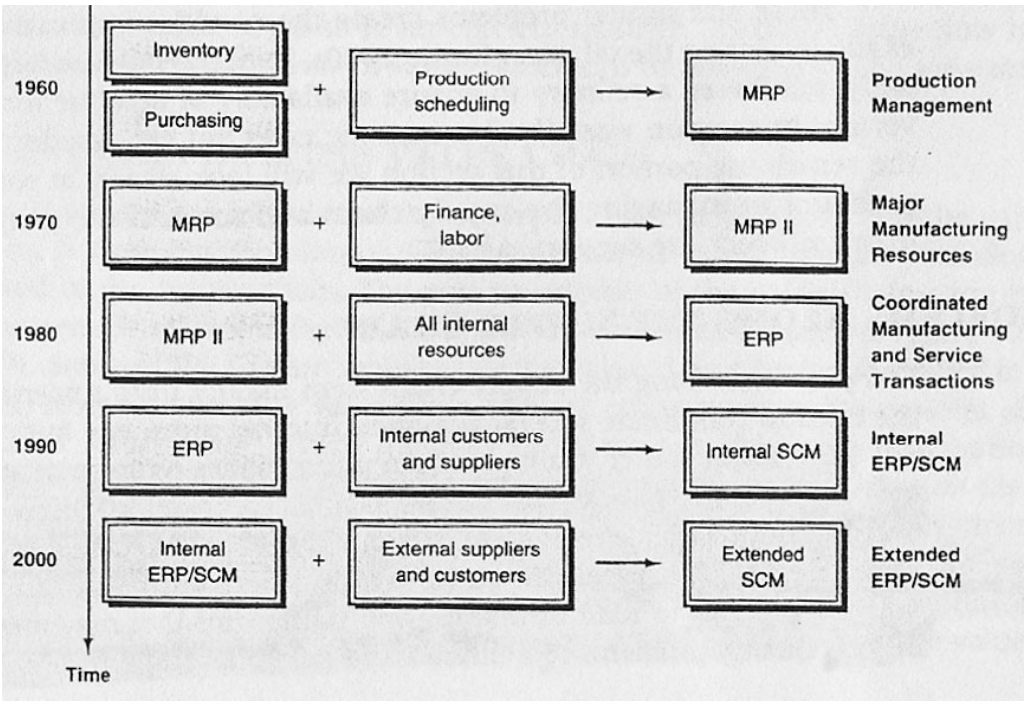

Figure 1 The evolution of integrated information system
Source: Turban et al., *Information Technology for Management*, John Wiley and Sons, 2000

This type of situation changed at the beginning of the 1990s after the introduction of the second generation of ERP, the wide use of the Internet and Internet-based B2B or B2C applications. The cost of collecting data has been lowered drastically because of the Internet and Intranet. Today, massive amounts of data are available to firms, and firms now have sufficient resources to do the analysis and then to conduct their business on more scientific, data-based style. The emergence of CRM is a good example. Teo et al. [35] found that firms had been increasingly investing in strategic IT since the mid-1990s. Because the use of strategic IT has become more popular than ever, and furthermore because the outcome of strategic IT systems is much more critical to the success of a business, how to let strategic IT systems generate high quality output is obviously a big concern for all IT and business managers. The low quality of data would apparently lead to poor business decisions which then harm a firm's performance. Therefore, we need to take more into consideration when we come to discuss the relationship between IT investment and firm performance. IT investment and firm performance are both high level variables, there are many aspects and details existing in-between, such as staff trainings, systems use, system-task fit, firm's characteristics, etc. But again, all of these aspects will influence the effectiveness and efficiency of the deployed IT systems, which is measured by data quality in the paper. Data quality could be the overall reflector of all positive and negative impacts from these aspects.

Measures for IT Investment and Firm Performance

Finding the right measures for IT investment and firm performance is also difficult [6, 9]. Questions like what are the best proxies for IT investment and what should be used to measure productivity and firm performance are hard to answer. Different studies have used various measures on input (independent variables) and output (dependent variables). For example, some studies, such as Brynjolfsson and Hitt [8] and Hitt and Brynjolfsson [12], do not count software expenditures as a part of IT investment; some, such as Tam [33], do not even count IT labor in calculating IT investment. Inaccurate input measures could introduce significant bias to research. Sircar et al. [29] studied 624 firms over the years 1988-1993 and

proposed a framework for evaluating IT investment and firm performance. They proposed that the value of IS staff, IS staff training, other IS spending, computer capital, non-IS labor and non-computer capital should be used as independent variables; sales, market share, assets, equity and outstanding shares should be used as dependent variables in the research about the relationship between IT investment and firm performance. But still, there is no variable designed to measure the effectiveness and efficiency of the IT investment in their papers.

Brynjolfsson [6] suggests that one of the reasons for the productivity paradox could be the mismanagement of IT investment. For example, managers do not act in the best interest of the firm; the IT investment does not do what it is supposed to do, such as cutting cost, increasing productivity, or improving firm performance; instead, it might create slack or did not get used in the way it should be used due to the lack of understanding of what IT can do. Studies looking at how well firms use their information systems to generate valuable output are critical. Data quality certainly can be a measure of how well a firm uses its IT systems.

Researchers have done much work on finding the relationships between IT investment and firm productivity and performance, including finding the right measures of them. But overall, the IT investment is still treated as a "black box". A large quantity of research has focused on how much has been invested in IT, but research examining how effectively and efficiently the IT systems firms have invested in is generally unavailable. Brynjolfsson and Hitt [9] indicate that what goes on inside the black box of the firm has a substantial influence on the productivity. We really cannot say anything about whether or not IT investment helps firm performance unless this issue is addressed.

Data Quality

More and more companies are recognizing that data is a key organizational resource, and all kinds of business data are used increasingly in strategic information systems, such as executive- or decision-support systems. The emerging popularity of CRM and many other e-commerce initiatives are creating requirements for large, integrated data repositories and advanced analytical capabilities [42]. Consequently, the quality of data in those data repositories has become a greater concern for firms and their IT division. Watson and Haley [40] indicate that providing high-quality data to decision makers is the fundamental reason for building a data warehouse.

Data needs to be accurate in order to meet the quality requirements. But accuracy is not the only requirement for data quality. Data quality is synonymous with 'fitness for use', which means the data needs to be appropriate to a specific application or use, not just accurate. This implies that the concept of data quality is relative [34]. A set of data appropriate for one use may not be viewed as having sufficient quality for another use. Four dimensions of data quality were identified by Ballou and Pazer [2]: accuracy, completeness, consistency and timeliness. Wang et al. [39] believe that data consumers have a broader view of data quality than IT professionals. They then developed a conceptual framework of data quality from the perspective of the data consumer. The framework consists of 15 dimensions, grouped into 4 categories. The multiple dimensions of data quality from various research suggest that data quality is far more than being accurate, and it is a fairly complicated issue. As data travels from collectors to different databases, data marts and data warehouses, it may lose its meaning apparent in the initial context but not in the followings. A piece of five-year old stock price data may be appropriate for researchers doing a longitudinal study on that stock, but it is not fit for a stock day trader's use because it does not meet the requirement of "timely". A database satisfactorily used by one division might be regarded as a problematic database by the other division if the two divisions have incompatible data formats or one division has a lot of difficulties in accessing the database. Also, different persons see data differently. Although the value is accurate, it can be interpreted differently by different people.

Data stored in computer systems, especially transactional information systems, is usually hard data, which inherently is verifiable. But managers and executives also need their information systems to support soft data, such as the moving trend of the market, competitor's intentions, and so on, which are

not inherently verifiable. Today, management uses soft data more often than hard data in strategic thinking, and the requirements for data quality have been raised to a much higher level.

The high quality of data cannot be simply achieved via investing in IT alone. Instead, there needs to be a formal, official mechanism in place within the organization to ensure it. Like Total Quality Management (TQM) in physical product manufacturing or services, there are many factors affecting the quality of data or information product, such as top management commitment, continuous improvement, etc; different studies look at this issue from different perspectives. Besides the research in defining data quality, measurement, analysis and improvement, several other studies regarding how to develop tools, methods and processes to manage and improve data quality and how data quality affect job satisfaction, etc. have been done [3, 13, 14, 23, 25, 38]. For example, by adapting the Deming cycle of Plan, Do, Check and Act in physical product manufacturing [11], Wang [38] developed the TDQM cycle: Define, Measure, Analyze, and Improve. Redman [26] discussed the impact of data quality in firms on different levels, e.g., the operational level. But, nothing has been done empirically about how data quality would impact a firm's performance. This research addresses this issue.

MODEL AND PROPOSITIONS DEVELOPMENT

Figure 2 illustrates the model for this research; it posits a relationship between IT investment and firm performance, moderated by quality of data in the firm's information system.

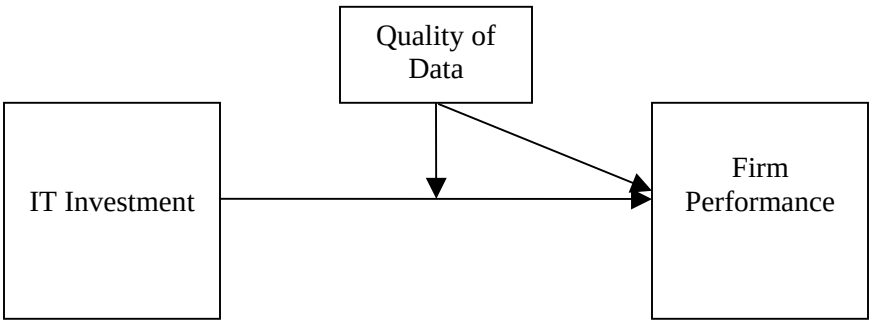

Figure 2 Research Model for the relationship between IT Investment and Firm Performance

Firms invest in IT to achieve better competitive advantages through reducing costs or improving differentiation or focus. Industry structure and the rules of competition have changed since the drastic application of IT. Organizations have outperformed their competitors by using IT, and furthermore IT helps create new business. While, the results from various empirical research on IT investment and organizational performance and productivity were mixed. Some believe that the greatest benefits of IT appear to be realized by organizations when IT investment is coupled with other complementary investments such as business process reengineering [9]. Most of these studies used data before the mid-1990s when the IT applications in firms were pretty much transaction-oriented, and the strategic IT had not yet helped a lot before the mid-1990s. The integration of SCM and ERP and the emergence of all kinds of business intelligence software after the mid-1990s indeed make the process of making business decisions more timely, accurate and easy. Advanced data analysis tools allow managers to see their industry, their customers and their competitors much clearer and better. By and large, this helps a lot in the strategic positioning of the firm and insures its movement on the marketplace to achieve better performance. The support from information systems has become a competitive necessity nowadays. U.S. businesses allocated 47% of all capital investment funds in the year 2000, or $664 billion, to IT; that

percentage is twice what it was in 1991 according to the US federal government [32]. Many organizations have turned to information technology for solutions for competition.

Proposition A: The magnitude of IT investment of a firm is positively related to the firm's performance.

The data flowing in a firm's information systems is used to conduct business, such as processing transactions, servicing customers, and help make business decisions. For example, the data in ERP/SCM systems is used to plan enterprise resources to better fulfill production or service. The data in CRM is mainly used for customer service and to analyze customers' consuming patterns or preferences; the results can guide customer-oriented product design, conduct more specific marketing campaigns, etc [17]. The data in an executive support system is often used to analyze the overall industry environment, a firm's and its competitors' strength and weakness, economic situations, market movement, and so on. In general, the use of data is seen everywhere inside an organization now. The purpose of implementing information systems is to gather data, process it and then generate high quality information from the data. Its ultimate goal is to "improve operation and decision making at the back end and marketing and service at the real-time front end for increased revenues and a competitive advantage in the new, global, wired economy" [1].

Poor information quality impacts a typical firm in many ways on the operational, tactical and strategic level. These impacts include customer dissatisfaction, increased operational costs, less effective or wrong decision-making, and a reduced ability to make and execute strategies. Furthermore, poor information quality reduces the employees' trust in the data, the employees' enthusiasm to use the data, and makes it more difficult to align the firm [26]. Poor information quality and its underlying causes are potent contributors to an "information ecology" inappropriate for the Information Age [10]. Redman further pointed out that although it was very difficult to estimate the total cost of poor data quality, three proprietary studies that he knew of yielded an estimate in the 8% -12% of revenue range. More informally, 40% - 60% of a service organization's expenses may be consumed as a result of poor data. A system displaying high data quality and system quality can lead to net benefits for various stakeholders, including individuals, groups of individuals and organizations [27]. Proposition *B* is based on the assumption that better data quality leads to better business operations and strategic positioning, which then lead to better firm performance.

Proposition B: Quality of data of a firm is positively related to the firm's performance.

The impact of IT investment on a firm's performance could be different due to the different quality of the data in the firm's information system. A firm certainly could not benefit much from inappropriate and lagged output. The appropriate and timely output could lead to correct and quick business decisions, superior product design, better customer services, faster and more successful marketing campaigns, and so on; all of those will drive a firm's performance higher. For firms with high data quality, their information systems produce what they are supposed to produce. This implies that the managers of these firms have superior skills to choose, manage and use the information systems. According to Mata et al. [21], managerial IT skills are the source for achieving competitive advanatege, as compared to capital requirement, proprietary technology and technical IT skills. So for these firms, their information systems would generate more value than the firms that do not have high data quality. Proposition *C* looks at the moderator effect of data quality on firm performance.

Proposition C: The impact of the magnitude of IT investment on a firm's performance is larger for the firm that has a higher quality of data than the firm that does not.

DISCUSSION AND IMPLICATIONS

This paper calls attention to what is going on behind the IT investment. The contribution of this paper is to open the "black box" of IT investment by looking at the quality of the output of the IT systems a firm has invested in. This helps to justify the relationship between IT investment and firm performance on a deeper level. An interesting thing in the existing literatures is that almost all the research about this topic has made an assumption upfront, which is that the IT systems a firm has adopted work as expected, but actually it is not always true. Data quality can tell us how well the IT systems are functioning. The quality of IT is important if we want to study its impact toward a firm's performance.

This paper also suggests why IT systems need to be carefully managed. The data quality of a well-managed IT system could be greatly different from the data quality of mismanaged IT systems. The different data quality could influence the quality of services, products, business operations and decisions of a firm, and each of them could later impact the firm's performance. Mata et al. [21] did a resource-based analysis on information technology and sustained competitive advantage and they concluded that the managerial IT skill, as compared to capital requirement, proprietary technology and technical IT skills, is the only one that can provide sustained competitive advantages. Superior firm performance cannot be achieved by just simply investing in technology alone. Instead, firms should manage and organize their information systems to produce high quality data output to improve business activities. The information technology should be evaluated in light of the business model and strategy prior to the adoption and deployment, and then managed to achieve its pre-determined goals after deployment. The management skills here do not only mean the skills for understanding and managing business, but also the skills of understanding and managing information technology. While the information system itself can be easily replicated by competitors, the managerial skills of and the understanding to information technology are not replicable; this is where firm gains sustained competitive advantages through IT.

This paper could also help explain the high standard errors of estimates reported in Hitt and Brynjolfsson [12]. They found that some firms were obtaining significant competitive advantages while others were not. The reason for firms that did not obtain competitive advantages could be because their information systems did not work effectively and efficiently to produce high quality output to help their business operations. In other words, their information systems were not as well managed and utilized as they should be, or maybe their expensive information systems were processing and producing the data with high rates of errors so that there was not much useful output from which the firm could benefit.

The relationship between IT investment and firm performance is a very complicated issue. It could be influenced by many factors, such as the characteristics of the IT systems, the managerial skills, the degree of diffusion and assimilation of the IT systems in a firm, the organizational culture, and so on. There might be many moderating factors and mediating factors as well. Although many of them can be reflected in the quality of the data output from the systems, to find what they are and how to manipulate them are worthy doing because it will provide firms a list of practical aspects which they can work on to improve the contributions of their IT investment toward their firm's performance.

The data quality issue is gaining attention in corporations. Corporations are getting more and more data every day. How to manage this data and utilize this data could be a key contributor to the firm performance, either financial or managerial. This paper only looks at how the data quality could impact a firm's financial performance, but the data quality could have its impact everywhere within a firm. For example, Joshi and Rai [13] empirically studied the impact of quality of information products on information system users' job satisfaction. They found that the quality of the information product has a positive correlation with job satisfaction of the users of the information systems, and the correlation is fully mediated by role conflict and role ambiguity. So, research related to where and how data quality impacts a firm's performance on all aspects is needed very much and is very valuable in today's information era.

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