Outsourcing versus in-house maintenance of medical devices: a longitudinal, empirical study

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ABSTRACT

Objective. *To determine what factors have a significant influence on the performance of medical device maintenance outsourcing, and to determine how the performance of external governance structures differs depending on whether a hospital is private or public.*

Methods. *This was a longitudinal study of 590 maintenance transactions at 20 hospitals in Bogotá, Colombia, involving 764 medical devices and 72 maintenance service providers. Maintenance performance data (i.e., turn-around time in hours; TAT) for the service providers (either in-house or outsourced) were primarily collected over a 20-month period, from December 2009–August 2011, by means of a monitoring procedure; then, a hazards model was run.*

Results. *The availability of specific repair parts, in-stock, in the city in which the medical devices were located, had a positive impact on the performance of both internal and external governance structures. Online service also had a positive impact on both, with a stronger positive impact on the performance of internal governance than on that of external governance. For transactions governed by external structures, better performance was seen in private hospitals than in public ones. In public health institutions, internal governance showed better performance than external governance. Both internal and external governance structures showed better performance in private healthcare institutions than in public ones.*

Conclusions. *In public health institutions, internal governance shows better performance than external governance; this suggests that healthcare managers should reconsider the trend to eliminate in-house maintenance service staff in public healthcare institutions.*

Keywords Equipment failure; contract services; quality control; outsourced services; preventive maintenance; Colombia.

Medical device maintenance increasingly demands larger sums from hospital budgets, is often outsourced, and its quality is pivotal to overall healthcare delivery. In 1996, service contracts generated approximately US$ 10 billion in revenues (1); by 2015, the global medical device outsourcing market is projected to reach US$ 42.6 billion (2), indicating continued growth (2). Yet extreme inefficiencies are generated by the anticompetitive nature of this market, both in terms of cost and quality, suggesting that although the industry is growing, maintenance service quality is not keeping pace with rising costs and sales volumes (3).

In a remarkable mapping review of the literature on maintenance outsourcing across a variety of industries, Miguel and Rios (4) found particular deficiencies (i.e., gaps) in the few studies on medical device maintenance outsourcing. Their study identified a cluster of papers that apply mathematical models to maintenance outsourcing problems, noting that while these models were proposed for specific industries, none were applied specifically to medical devices. Furthermore, weaknesses were identified in several papers that made critical assumptions that would fail to hold up in real-world applications, such as assuming that equipment does not become more likely to fail as it ages. In a second cluster of papers, identified as

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longitudinal-empirical studies of maintenance outsourcing problems, only five papers were found that were related to the performance measurement of medical device maintenance outsourcing (4). However, these papers did not mention any management theory to justify their findings, and discussion about the managerial implications of the findings is nonexistent, making it difficult to apply results in a meaningful way in terms of the make or buy decision paradigm. Additionally, no empirical proposal whose research was grounded in management or strategic management theory dealt in detail with the issues related to maintenance outsourcing, nor did any specifically deal with the outsourcing of medical device maintenance (5).

A study utilizing the theoretical approach, Transaction Cost Theory (TCT) (6, 7), was warranted. According to TCT, asset specificity, uncertainty, and frequency are the three main constructs along which transactions differ, with the governance structure that would prove most efficient being impacted (7, 8). More integrated governance structures should show performance advantages in transactions with high degrees of specific asset investments, in complex transactions where service provider performance is difficult to measure due to the interrelation of services, transactions with greater uncertainty (e.g., uncertainties in demand, technological changes, or supplier behavior), and transactions with high frequency (8–10). According to Williamson, asset specificity is represented as the most important transaction variable (7); as a result, it has been the most scrutinized and empirically tested of these variables in studies spanning several fields, including business and non-business areas (e.g., law and public policy, health economics and policy, agricultural economics policy) (8). Williamson defines asset specificity as "the degree to which the assets used to conduct an activity can be redeployed to alternative uses and by alternative users without sacrifice of productive value," (11) and notes that transactions involving highly specific assets are particularly ripe for opportunistic behavior on the part of either agent or principal. For example, if investments are made in non-substitutable, highly-specific assets by agents who are unable to easily find these elsewhere, there may be incentives for them to engage in opportunistic behavior with the power dynamics of the exchange relationship shifted in their favor.

Therefore, in an attempt to fill the gaps identified by Miguel and Rios (4), the goals of this study were to (a) determine which factors have a significant influence on the performance measurement of medical device maintenance outsourcing and (b) investigate how the performance of external governance structures differs depending on whether a hospital is private or public. The novelty of this approach lies both in its theoretical contribution and its examination of previously unexplored relationships between maintenance performance and governance selection; moreover, the model includes several control variables had been ignored by previous studies.

MATERIALS AND METHODS

This was a longitudinal study in which a primary data sample was used. Data were gathered from a primary data information source on maintenance transactions from 20 hospitals in Bogotá D.C., Colombia, from December 2009 – August 2011, resulting in a total sample of 590 observations, each representing a unique maintenance transaction. The authors determined that this sample size was sufficient, using as parameters an effect size of 0.2 and a statistical power of 0.9 ($P < 0.05$) (12). Due to the scarcity of previous empirical and longitudinal studies on maintenance performance, a low effect size was chosen in order to be conservative. The maintenance transactions were completed by 62 external maintenance service organizations and 10 in-house clinical engineering departments. By measuring the turn-around time (in hours; TAT) for each maintenance transaction according to governance structure, it was possible to measure the performance of both internal and external governance structures.

The 590 maintenance transactions (i.e., preventive or repair work orders) in the sample were characterized according to governance structure, the basic data of the equipment being serviced, the type of healthcare institution (HospType), and the TAT or "performance." To do so, a study was first conducted characterizing the 20 hospitals' inventories to identify equipment features, including the following: obsolescence level (Obsolesc), complexity level (TComplex), equipment acquisition cost over maintenance cost (COSR), acquisition date, and the maintenance service provider in charge of the equipment, either internal or external.

Once the equipment maintenance service provider and the governance structure type (GovStr) was identified, a survey was conducted via face-to-face interviews with the managers of the maintenance service firms and each hospital's clinical engineering department. The survey recorded only the main features and services offered by both internal and external maintenance providers: company name; contract service start and end dates; experience and qualifications of the company staff, in years and by degrees obtained (TechTLevel); contract duration, in years; whether the contract was guaranteed; whether it included replacements parts; total quantity of equipment covered; number of annual visits stipulated by the contract; total number of the company's engineers and technicians; number of engineers and technicians working on the contract; distance (km) from the service provider to the hospital; the company's years of experience in the industry (CompExp); whether online maintenance services were also offered (ServLine); whether replacement stocks existed in the locality in which maintenance services were being provided (RepParCity); equipment types covered by the maintenance contract; and lastly, whether training was being provided to users and operators. Finally, the primary data on hospital equipment maintenance incidents and the performance of maintenance service organizations (both internal and external) were collected for a 20-month period from December 2009 – August 2011 by means of a monitoring procedure. The variables, variable types (i.e., independent, dependent, or control), descriptions, and codifications are listed in Table 1.

Descriptive statistical analysis for all the variables was conducted. The data showed an abnormal distribution for both the dependent and independent variables. Therefore, both a Peto log rank and log rank tests on the Kaplan-Meier estimator of the independent variable groups and TAT, followed by a hazards model, were carried out. Some insight was first given by the Peto log rank and log rank tests as to whether the independent and control variable categories showed an impact on TAT. After

TABLE 1. Operationalization of the variables in a study of outsourcing versus in-house maintenance of medical devices, Colombia, 2011

Variable	Variable description	Variable operationalization
TAT[a]	Turn-around time of medical device repairs, in hours.	1 – ∞
GovStr[b]	Type of governance structure involved in the maintenance tasks.	Internal: 0 (in-house maintenance service) External: 1 (original equipment manufacturer, independent service provider, insurance company)
RepParCity[b]	Whether the maintenance service provider has replacement parts in the same location where the service is offered.	Yes=1 No=0
ServLine[b]	Whether online services are offered.	Yes=1 No=0
HospType[b]	Whether the maintenance service is provided to a private health care institution.	Public=0 Private=1
CompExp[b]	Experience of the company in the industry, in years.	Low=0 (0-10 years in the business) High=1 (>10 years in the business)
COSR[c]	Maintenance service costs relative to the original cost of acquisition, as a %	Low=0 High=1
TechTLevel[c]	Whether training is provided to technicians.	Low=0 Low complexity equipment, >2 years of experience personnel, maintenance tasks performed by artisans. High=1 High complexity equipment, >10 years of experience personnel, maintenance tasks performed by specialist and specialized engineers.
Obsolec[c]	Equipment level of obsolescence.	No=0 Yes=1
TComplex[c]	Technical complexity of equipment.	Low=0 High=1

[a] Dependent variable.
[b] Independent variables.
[c] Control variables.

TABLE 2. Correlation matrix for the covariates for the 72 maintenance service providers in a study of outsourcing versus in-house maintenance of medical devices (*n* = 590 maintenance transactions), Colombia, 2011

Covariable code	1	2	3	4	5	6	7	8	9	10
1. TAT	1.000									
2. RepParCity	–0.11[a]	1.00								
3. ServLine	–0.11[a]	–0.03	1.00							
4. HospType	–0.16[a]	+0.24[a]	–0.09[a]	1.000						
5. TComplex	+0.17	–0.19[a]	–0.51[a]	–0.09[a]	1.00					
6. Obsolesc	–0.01	+0.07[a]	–0.01	–0.12[a]	–0.17[a]	1.00				
7. COSR	+0.03	+0.10[a]	+0.12[a]	–0.34[a]	+0.24[a]	+0.37[a]	1.00			
8. CompExp	–0.20[a]	–0.05	–0.08[a]	+0.05[a]	–0.05[b]	–0.08[a]	–0.18[a]	1.00		
9. TechTLevel	–0.18[a]	–0.17[a]	–0.03	+0.07[a]	–0.08	–0.02	+0.37[a]	+0.38[a]	1.00	
10. GrvStr	+0.32	–0.21[a]	–0.16[a]	–0.647[a]	–0.30[a]	+0.07[a]	–0.06[a]	+0.75[a]	+0.43[a]	1.00

Note: 1. TAT = turn-around time, in hours; 2. RepParCity = local availability of replacement parts; 3. ServLine = online maintenance services; 4. HospType = type of healthcare institution; 5. TComplex = complexity level; 6. Obsolesc = equipment obsolescence level; 7. COSR = equipment acquisition cost over maintenance cost; 8. CompExp = the company's years of experience in the industry; 9. TechTLevel = experience and qualifications of the company staff, in years and by degrees held; 10. GovStr = governance structure type.
[a] $P < 0.01$ Significance level (2-tailed).
[b] $P < 0.05$ Significance level (2-tailed).

running this series of tests separately for each covariate and TAT, objective research was conducted by building five hazards models, allowing the overall influence of the independent and control variables on maintenance performance to be quantified. The inclusion and exclusion of the variables in the hazards models was conducted first by checking for multi-collinearity with a correlation matrix between covariates (Table 2); and second, by building the hazards models according to the 'stepwise' method described by Hosmer (13). Finally, the adequacy of the model was tested.

RESULTS

The descriptive statistics and correlation matrix presented in Table 2 are based on the 590 maintenance transactions obtained during the monitoring process explained above. Note that the correlation coefficient between cost of maintenance service over acquisition cost ratio (COSR) and TAT is near zero (r = +0.03) (see details in Table 2), indicating that TAT and COSR are fully independent; therefore, COSR could be used as dependent variable measuring financial performance in future research. Available upon request from the corresponding author (AMC) is an appendix containing descriptive statistics for all covariates, including the standard deviation (SD), standard error (SE), mean, and median TAT associated with each covariable category calculated by the Kaplan-Meier estimator, with their Log Rank and Peto Tests. Both the cumulative survival functions and log-log survival curves showed no intersection, confirming the appropriateness of the hazard models (13).

In Table 3, Models I, II, and III present the results of the tests that examined whether an online service, the availability of spare parts in the city in which the equipment was located, and maintenance tasks conducted in private healthcare institutions improve maintenance performance in transactions governed by both internal and external structures. To test the effect of these variables on maintenance performance, adjustments were made using a hierarchical model, presented in Models I, II, and III. Note that the β1 and β2 coefficients in Model III increased compared to Model II after the introduction of TechTLevel and CompExp control variables,

TABLE 3. Proportional hazard regression for the 72 maintenance service providers in a study of outsourcing versus in-house maintenance of medical devices (*n* = 590 maintenance transactions), Colombia, 2011

Independent variable (reference value)	Model I[a] β	Model II[a] β	Model III[a] β
RepParCity (Not, 0)	β_1= +0.387[b]	β_1= +0.252[b]	β_1= +1.192[c]
ServLine (Not, 0)	β_2=+0.779[b]	β_2=+0.535[b]	β_2=+0.763[a]
HospType (Public, 0)	β_3=+0.269[b]	β_3=+0.250[b]	β_3=+0.251[a]
Control variables			
TComplex (High, 1)		β_4=+0.569[b]	β_4=+0.575[b]
Obsolesc (Not, 0)		β_5=-0.107	β_5=-0.063
COSR (High, 1)		β_6=+0.199[d]	β_6=+0.079[d]
CompExp (Low, 0)			β_7=+0.401[a]
TechTLevel (Low, 0)			β_8=+0.597[b]
Chi-square	47.588	47.199	26.592
-2 LL_0 (Null model)	17657.624	17657.624	17657.624
-2 LL	17130.34	16532.23	15532.23
$R_{p,e}$	0.619	0.87	0.97
$R^2_{p,e}$	0.383	0.761	0.95
P	0.61	0.69	0.72
1/P	1.63	1.45	1.38
Alpha (α)	1.22	1.45	1.32

Note: Rpe^2= 1- EXP(2/m*(-2LLo-2LLp)); β: is the estimated coefficient for the covariable. No sign in the β coefficient is assumed to be positive (+); -2LLp: is the log of the partial likelihood for the fitted model with *P* covariates; -2 LL0 is the log of the partial likelihood for the fitted model of the Null model (no covariates).
[a] Likelihood ratio testing (LR). *P* value for the full conditional gap time frailty Model I, II, and Model III. *P* < 0.000.
[b] *P* < 0.01 Significance level.
[c] *P* < 0.05 Significance level.
[d] *P* < 0.10 Significance level.

indicating that as expected, the technician's level of training and the company's experience have effects on maintenance performance.

In Table 4, Models IV and V present the results of the tests that examined whether or not providing online services has a stronger positive performance effect on transactions under internal governance structures than those under external governance; the performance of external governance structures is higher in transactions conducted in private hospitals than in public hospitals; and finally, in public healthcare institutions, the performance in transactions of internal governance structures will be higher than for external governance structures. Again, to test the effect of these variables on maintenance performance, adjustments were made using hierarchical model presented in Model IV and V, i.e., interactions variables (ServLine) x (Gov Str) and (HospType) x (Gov Str); and (TComplex) x (Gov Str), (Obsolesc) x (Gov Str), (COSR) x (Gov Str), (CompExp) x (Gov Str), and (TechTLevel) x (Gov Str). Notice that no statistically significant results for the effects of equipment obsolescence on TAT were obtained, indicating that for this data sample, the age of equipment had no effect on the performance of the maintenance service providers.

An excellent empirical solution to the problem investigated in this study is provided in Models I – V, since the correlation coefficient (Rp,e) and the determination coefficient (R2p,e) were high, correctly classifying 95% and 46% in all of the observations in Models III and IV, respectively, with highly statistically significant *P*-values, providing support for each of the tests (see Table 5 for more details). An interpretation of the effects of asset specificity on the performance of the maintenance transactions by means of β coefficients and hazard ratios (HR) are summarized in Table 5, and in the results based on Tables 3 and 4.

DISCUSSION

The results show that the availability of in-city spare parts has a positive impact on the performance of both internal and external governance structures. While this may seem like an obvious relationship with clear implications, the reality is often more complicated. First, third-party maintenance providers often lack the ability to invest and stock these particular assets due to their high cost and the additional cost of storage. As a consequence, parts are ordered on an on-demand basis from an external supplier, such as the original equipment manufacturer (OEM), resulting in longer equipment downtime. Second, if the OEM does not have a formalized policy for supporting other maintenance companies, they may view other companies as competitors to their own equipment maintenance business and delay or block the sale of specific spare parts. Therefore, when selecting a governance structure for equipment maintenance, hospital managers should consider whether or not an external service provider has in-city stocks of spare parts; and contracts should include a clause addressing this issue. If external service providers do not possess in-city stocks of specific parts, and where negotiating clauses dealing with in-country spare parts fail, maintenance performance can be improved by choosing internal governance and by the hospital itself stocking spare parts. While this option may seem unfeasible because of the wide variety of spare parts and the high cost, some scholars have demonstrated choosing internal governance and keeping spare parts stocked is more efficient (14).

The present study found that online diagnostic tools had a stronger positive effect on the performance of internal governance than it did on external governance. Part of this must be due to the fact that in-house maintenance departments are located on-site, and are therefore, able to respond quickly to problems as they arise. Additionally, the vast majority of contracts with external service providers that include online diagnostic services are between healthcare institutions and the OEM. Because the OEM frequently refuses other service providers access to online diagnostic tools, they face less competition, and as a result may face less performance pressure. Surprisingly, the findings that the performance of internal governance is higher than that of external governance in cases of high asset specificity goes against one of the most common assumptions in the medical device maintenance field. Through a

TABLE 4. Proportional hazard regression for 72 medical device maintenance service providers (*n* = 590 maintenance transactions) in a study of outsourcing versus in-house maintenance of medical devices, Colombia, 2011

Independent variable (reference value)	Model IV[a] β	Model V[a] β
Interactions - Independent variables		
(ServLine) x (Gov Str), (No=0, External=1)		
Service online and external	β_1=+0.239[b]	β_1=+0.439[b]
Service online and internal	β_2=+0.841[c]	β_2=+0.941[b]
(HospType) x (Gov Str), (Public=0, Internal=0)		
Public and external	β_3=-0.903[b]	β_3=-0.913[b]
Private and external	β_4=-0.603[b]	β_4=-0.623[b]
Private and internal	β_5=-0.853[b]	β_5=-0.858[b]
Control variables		
(TComplex) x (Gov Str), (Low=1, Internal=0)		
High technological complexity and internal		β_6=-0.204[b]
Low technological complexity and external		β_7=-0.555[b]
High Technological Complexity and External		β_8=-0.837[b]
(Obsolesc) x (Gov Str), (No=0, Internal=0)		
Obsolescence yes and internal		β_9=-0.03
Obsolescence no and external		β_{10}=-0.981
Obsolescence yes and external		β_{11}=-0.870
(COSR) x (Gov Str), (High=1, Internal=0)		
COSR high and external		β_{12}=-0.748[d]
COSR low and internal		β_{13}=+0.011[d]
COSR low and external		β_{14}=-0.830[d]
(CompExp) x (Gov Str) (Low=0, Internal=0)		
CompExp high and internal		β_{15}=-0.812[b]
CompExp high and external		β_{16}=+0.168[b]
(TechTLevel) x (Gov Str), (Low=0, Internal=0)		
TechTLevel low and external		β_{17}=-0.984[b]
TechTLevel high and internal		β_{18}=+0.132[b]
TechTLevel high and external		β_{19}=-0.697[b]
Chi-square	145.32	132.43
-2 LL_0 (Null model)	17657.624	17657.624
-2 LL	17530.34	17032.23
$R_{p,e}$	0.21	0.68
$R^2_{p,e}$	0.04	0.46
P	0.3	0.55
1/P	3.33	1.812
Alpha (α)	1.02	1.45

Note: Rpe^2= 1–EXP(2/m*(–2LLo–2LLp)), β: is the estimated coefficient for the covariable. No sign in the β coefficient is assumed to be positive (+); –2LL: is the log of the partial likelihood for the fitted model with covariates; –2 LL_0 is the log of the partial likelihood for the fitted model of the Null model (no covariates).
[a] Likelihood ratio testing (LR). *P* value for the full conditional gap time frailty Model I and II. *P* < 0.000.
[b] *P* < 0.01 Significance level.
[c] *P* < 0.05 Significance level.
[d] *P* < 0.10 Significance level.

focus group of clinical engineers and biomedical technicians, Blumberg (1) found that many "believed that managed care had caused, and that it would cause, many hospitals to eliminate their in-house service staffs." As shown by Cruz and colleagues (15), this may be especially true in developing countries. This represents a growing trend in the healthcare industry, as maintenance services are increasingly outsourced by hospitals. However, the results of this research give strong statistical support for the finding that in situations with high levels of physical asset specificity, better performance is shown by internal governance structures. This suggests that healthcare managers should reconsider the trend to eliminate in-house maintenance service staff in healthcare institutions.

The issue of online diagnostic tools, however, presents a more complicated problem for healthcare managers. In some cases in the study, where an in-house clinical engineering department had access to online diagnostic tools, the results showed that internal governance performed better than external structures. Yet, because a monopoly is frequently maintained by the OEM over such tools in order to retain market power for its own equipment maintenance business, it is often nearly impossible for hospitals to gain access to online diagnostics while using internal governance for maintenance tasks. While it is an important finding that online diagnostic services have a stronger positive impact on internal governance performance than on external governance, the problem of access to these tools is not likely to be resolved soon.

Furthermore, the results obtained in this research lend support to the assertion that hospital type influences the performance of the selected governance structure in maintenance transactions. The findings in this research show that: (a) for transactions conducted under external governance structures, performance is higher in private hospitals than in public ones; (b) internal governance structures show performance advantages over external governance structures for public hospitals; and (c) regardless of the selection of the governance structure, maintenance performance is higher in transactions conducted in private healthcare institutions than in public ones. There may be various explanations for these results. First, from a theoretical point of view the finding that external maintenance service providers have lower performance levels in public healthcare institutions corroborates the findings of Coles and Hesterly (9–10), which showed that public institutions are subject to more lenient efficiency standards because the government subsidies they receive allow them to operate even if unprofitable. Therefore, they may have different incentives (i.e., political) than private organizations operating in the same market. This could also be due to a low propensity to control and monitor the maintenance performance of service providers contracted by the public sector, which is a common scenario in develop-

TABLE 5. Model interpretation in a study of outsourcing versus in-house maintenance of medical devices (*n* = 590 maintenance transactions), Colombia, 2011

Statistical significance	Interpretation
$P < 0.05$	Model III: β_1=+1.192 ⇔ HR[a] = e $^{(\beta 1)}$ = 3.293 The presence of in-city stocks of highly-specific repair parts has a positive impact on the performance of both internal and external governance structures. Specifically, the risk of higher TAT[b] values decreased by 3.293 times when in-city repair part stocks were available.
$P < 0.001$	Model III: β_2=+0.763 ⇔ HR = e $^{(\beta 2)}$ = 2.144 Online service has a positive impact on the performance of both internal and external governance structures. Specifically, the risk of higher TAT values in maintenance tasks decreased by 2.144 times in relation to transactions for which these services were unavailable.
$P < 0.001$	Model V: β_2- β_1=+0.502 ⇔ HR = e $^{(\beta 2 - \beta 1)}$ = 1.652 Online service has a stronger positive impact on the performance of internal governance than external governance. Specifically, for transactions where online service tools were available, the risk of higher TAT values for external governance was 65.2% (i.e. 1.652 – 1.00) greater than for internal governance.
$P < 0.001$	Model V: $\beta^4 - \beta^5$=+1 481⇔ HR= e $^{(\beta 4 - \beta 5)}$ = 4.3973[3] For transactions governed by external structures, external governance shows better performance in private hospitals than in public hospitals. Specifically, the risk of higher TAT values decreases by 4.3973 times for external governance structures in private hospitals when compared to public hospitals.
$P < 0.001$	Model V: β_3=-0.903 ⇔ HR= e $^{(\beta 1)}$ = 0.405 In public health institutions, internal governance shows better performance than external governance. Specifically, the risk of higher TAT values increases by 59.5% (i.e., 1 – 0.405) for external governance structures in public hospitals, when compared to internal governance.
$P < 0.001$	Model III: β_3=+0.251 ⇔ HR = e $^{(\beta 3)}$ =1.285 Both internal and external governance structures show better performance in private healthcare institutions than in public institutions. Specifically, the risk of higher TAT values is 28.5% (1.285 – 1.00) lower for private hospitals than for public hospitals.

[a] Hazard rates.
[b] Turn-around time of maintenance repair.

ing countries, such as the one in which the research was conducted. Second, the authors of the present study verified that (a) the time it takes public hospitals to pay service providers can be extremely long (e.g., in some cases up to 90 days), owing in part to internal inefficiency and a lack of operating funds to cover maintenance activities; (b) as a result, some external service providers demand advance payment of between 50%–75% of the contract total, which in turn creates an environment ripe for opportunistic behavior; and (c) after reviewing the maintenance contracts between hospitals and external providers, it was observed that many contracts were incomplete, lacking safeguards or penalties in cases where the service provider failed to honor the terms of the contract.

Study limitations

In the context of medical device maintenance outsourcing, the authors of this paper see five specific improvement opportunities for future studies. First, new variables that affect the performance of maintenance service providers should be included in future studies. For example, the type of maintenance tasks (i.e., corrective versus preventive); the type and features of contractual relationships (i.e., contract duration, whether the contract is guaranteed, the total quantity of equipment included in the contract, and whether replacements parts are included in the contract); and the capacity of the firm to deliver the services (e.g., the number of engineers and technicians working on the contract and the total number of contracts managed by the company). Second, other types of maintenance performance transactions should be considered, such as Market (Classical Contracting), Trilateral Governance (Neoclassical Contracting), Bilateral or Unified Governance Structures (11). Third, future research might focus on which capabilities and characteristics of medical device maintenance providers affect the vertical integration or "make or buy" decisions made by the managers of healthcare institutions. More specifically, according to TCT, how asset specificity, uncertainty, and transaction frequency are affected by the decision-making processes as healthcare managers decide whether or not to outsource a maintenance service and which external provider to choose. Fourth, and most importantly, more research is needed to examine how the performance of maintenance service providers affects the quality or performance of medical services in terms of input quality (staffing or equipment), process quality (length of stay of patients, numbers of tests and procedures performed), and output quality (patient mortality/morbidity). Finally, the finding that COSR is independent of TAT presents an opportunity to complement this study by investigating the effects of asset specificity, and the impact of uncertainty and transaction frequency on financial performance, all of which are measured by COSR.

Conclusions

In conclusion, the most important findings of this study are: first, the external governance structures show lower performance levels in public healthcare institutions, and suggest public hospitals should use internal governance where possible; second, two of the most important selection criteria for choosing a maintenance service provider are the ability to solve problems online via remote diagnostic tools and the availability of spare parts in the same city where the equipment is located; and third, the online diagnostic tools have stronger positive performance implications for internal governance structures than for external ones.

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Mantenimiento de los dispositivos médicos, interno o mediante contratación externa: un estudio longitudinal y empírico

ABSTRACT

Objetivo. Establecer los factores que influyen significativamente en el desempeño del mantenimiento de los dispositivos médicos mediante contratación externa, y determinar cómo difiere el desempeño de las estructuras externas de gobernanza según un hospital sea privado o público.

Métodos. Se realizó un estudio longitudinal de 590 transacciones de mantenimiento en 20 hospitales de Bogotá (Colombia), que incluyeron 764 dispositivos médicos y 72 proveedores de servicio de mantenimiento. Por medio de un procedimiento de vigilancia, se recopilaron principalmente datos de desempeño del mantenimiento (es decir, el plazo de entrega en horas) por parte de los proveedores del servicio (ya fuera este interno o externalizado) durante un período de 20 meses, desde diciembre del 2009 a agosto del 2011; a continuación, se aplicó un modelo de riesgos.

Resultados. La disponibilidad de piezas de repuesto específicas en existencia en la misma ciudad en que se ubicaban los dispositivos médicos tuvo una repercusión positiva sobre el desempeño de ambas estructuras de gobernanza, la interna y la externa. El servicio en línea también tuvo una repercusión positiva en el desempeño de ambas estructuras; pero esta repercusión fue más intensa en el desempeño de la gobernanza interna que en el de la externa. En cuanto a las transacciones regidas por estructuras externas, se observó un mejor desempeño en los hospitales privados que en los públicos. En las instituciones de salud pública, la gobernanza interna mostró un mejor desempeño que la externa. Ambas estructuras de gobernanza mostraron un mejor desempeño en las instituciones de atención de salud privadas que en las públicas.

Conclusiones. En las instituciones de salud pública, la gobernanza interna muestra un mejor desempeño que la externa; ello indica que los gerentes de atención de salud deben reconsiderar la tendencia a eliminar al personal de los servicios de mantenimiento interno de las instituciones públicas de atención de salud.

Key words Falla de equipo; servicios contratados; control de calidad; servicios externos; mantenimiento preventivo; Colombia.