

Application of Multilinear Regression Model for Measuring the Impact of Maintenance Service Providers' Quality on Overall Healthcare Service Quality

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Abstract- This research was aimed at examining how transaction performance regarding medical equipment maintenance affected overall healthcare service quality, understood as healthcare input and/or process quality. A cross-sectional, retrospective, exploratory study was thus designed for examining 719 maintenance transactions. Such sample size guaranteed 0.8 statistical power, having 0.2 effect size at $\alpha=0.05$. Secondary source data were taken from databases kept at two hospitals in Bogotá, Colombia. A multivariate linear regression model was used for analysing the effect of turnaround time (TAT, the independent variable) in terms of hours on healthcare institution service quality (decreased overall quality, the dependent variable), controlling for the type of service provider carrying out the maintenance transaction (i.e. in-house or outsourcing) and the maintenance type concerned (i.e. preventive or corrective) in healthcare service quality. The results provided sufficient statistically significant support ($p<0.001$), good CI precision (+ 1.156, + 1.432) and low standard error (standard error=0.070), as healthcare service quality became negatively affected as TAT value increased due to low maintenance service provider quality or performance (i.e. $\beta_{TAT}=-1.473$).

Keywords- *Multivariate Linear Regression Model; Quality Management; Healthcare Service Operation Research; Maintenance; Medical Engineering; Clinical Engineering*

I. INTRODUCTION

A lot of research has concerned itself with discussing healthcare technology's positive impact on society [1]. It has been reported that the suitable use of healthcare technology may considerably reduce the time a disease lasts or the period a person remains disabled, thereby improving access to healthcare services (i.e. e-health, or home telehealth) or reducing healthcare institution operating costs [1] (i.e. by reducing hospitalisation time). However, such benefits are not so evident when medical technology is neither safe nor effective. Therefore, in hospitals, medical technology management processes are implemented to contribute towards healthcare technology functioning safely at a reasonable cost (i.e. medical device technology planning, procurement and management). One management-associated sub-process is related to maintenance service provider management and evaluation; this includes selecting external and internal maintenance providers and evaluating their performance. Regarding maintenance service provider performance evaluation, it has been reported that effective outsourcing of maintenance control leads to around 30% saving in internal equipment management costs compared to external manufacturer support, "primarily due to a 50% reduction in radiology maintenance costs." [1]. Another no less important aspect of such evaluation concerns measuring the impact of low maintenance service provider performance on healthcare service quality [2], this being the object of the current research.

Some reports have been related to studying and evaluating the impact of using biomedical technology management models on healthcare service quality [1, 3, 4]; positive experiences have been reported in which, "quality indicators show improvement across several key measures, both clinical process and clinical outcome-related" [1] in countries like Kenya, Tanzania, Senegal and Kyrgyzstan. However, such progress has been a lack of concern for specific evaluation of the impact produced by outsourced and in-house medical equipment maintenance activities on overall healthcare service quality. It was found that few works have dealt with this research topic after the pertinent literature was reviewed [5-8]; specifically dealing with the healthcare service medical device maintenance sector has shown that, "research into the outsourcing of medical device maintenance services in hospitals is still in its infancy."

Healthcare quality has been described as being the extent to which health services provided for users and patient populations improve desired health outcomes. It has also been stated that healthcare should be delivered in a way guaranteeing that it is effective, efficient, accessible, acceptable/patient-centred, equitable and safe [9]. A concept which is closely linked to healthcare service delivery quality concerns measuring the level of quality through assessing such healthcare service

performance.¹ Healthcare service performance levels form part of so-called system performance measurements as “a method of gauging organisation performance that facilitates improvement by collecting data and information [about performance indicators] and disseminating process and/or outcome measurement.” [10] Traditionally, academics have made great efforts to measure hospital service quality; however, such efforts have concentrated on the area of hospital business and corporate strategy [11-13]. Empirical studies related to measuring healthcare service performance quality have been dealt with to a lesser extent because some authors have stated that measuring healthcare service quality as a measurement of performance is, “an elusive concept,” since, “it is difficult to measure,” and “some measures are merely noisy; others may introduce bias” [12]. Research into the quality of medical service operation is thus only beginning to emerge [14-16]. A review of the literature, which analysed over 900 papers; Macher & Richman [11], found less papers dealing with research involving transaction cost theory regarding this topic and that this field was unlikely to grow, thereby meriting greater attention. Nevertheless, consensus has stated that healthcare service quality may be measured by observing input quality, process quality and output quality² [15-17]. Even though outcome quality matters most to patients and healthcare users, input quality and process quality have been most used for measuring quality performance because they can be measured more objectively by counting specific input and services. Insufficient usable outcome quality data are thus available to health service researchers [1, 4, 12, 17], therefore, outcome quality as a healthcare service performance measurement has thus not been used in this study.

The present research has consequently been aimed at examining how medical device maintenance transaction performance quality affects overall healthcare service quality, quality being understood as healthcare input and/or process quality [12]. The two main maintenance service modes (i.e. in-house and outsourced), the maintenance type (i.e. corrective, preventive) are also scrutinised and medical device turnaround time (TAT) has been used for measuring maintenance transaction performance [18]. This research puts the following research questions:

1. Will maintenance transactions quality have an impact on healthcare service quality?
2. Does a given impact lead to a significant difference between maintenance transaction governance structure (i.e. external/outsourced compared to internal/in-house) performance and healthcare service quality?

II. METHODS

A. Experimental Design

1) Experimental Design Data Source and Sample Size

A cross-sectional, retrospective, exploratory study was used to answer the aforementioned research questions. Secondary source information was taken from a database in which scheduled (i.e. preventive) and unscheduled (i.e. corrective) maintenance transactions were recorded for 62 external maintenance services providers (i.e. outsourced maintenance) and 2 internal (i.e. in-house) maintenance service providers working with two hospitals in Bogotá Colombia. Maintenance transactions were carried out on 764 medical devices during 2007-2008.

A sample of 719 valid observations was obtained from the secondary data source, each representing a single maintenance transaction; it was determined that this sample size was sufficiently large to guarantee an empirical result having a high degree of statistical validity and reliability (effect size= 0.3, 3 independent variables statistical power=0.8 and $\alpha < 0.05$, $n = 267$ (see [19]: 852 for greater detail).

B. Operational Definitions for the Variables

1) Dependent Variable - Outcome

Decreased overall quality: A new dependent variable was created as a measurement of healthcare service quality related to the dimension of quality which dealt with healthcare service process quality [12, 17]. It was selected as it has been reported to have, “measured fairly objectively, through counts of specific inputs and services” [12]. This variable was constructed through the compound effect of adding the amount of all unwanted events which could have led to decreased medical service quality as a medical device was involved in a determined maintenance transaction. It would thus have been expected that increasing the time when a medical device was out of service due to a maintenance transaction would have also led to an increase in the dependent variable “decreased overall quality” (i.e. a reduction in healthcare service performance quality). Decreased overall quality could also result from following undesired events: (a) patient’s procedure or treatment being cancelled, (b) a patient not being admitted to a healthcare institution, (c) the time for a procedure is being prolonged, (d) delay in a patient being received, (e) delay in beginning a procedure, and (f) paying a third-party for treating a patient.

¹According to the business dictionary, performance is, “The accomplishment of a given task measured against preset known standards of accuracy, completeness, cost, and speed.” <http://www.businessdictionary.com/definition/performance.html#ixzz291D154E>.

²Input quality may be measured by observing staffing levels and experience/qualifications or state of equipment. Process quality may be measured by length of hospital stay, the numbers of tests and procedures, or the amount of prescriptions. Output quality may be measured by observing the mortality or morbidity rate.

Then, the dependent variable was constructed as follows: the numbers of undesirable events in medical service due to a particular maintenance transaction were totalized i.e. decreased overall quality = $a+b+c+d+e+f$. It should be noted that a type (a) event could occur more than once due to a maintenance transaction concerning a medical device (e.g. cancelling 10 determined treatments for 10 different patients, and/or 5 patients not being admitted to a healthcare institution would give a total of 15 undesirable events for decreased overall quality, i.e. the higher the number of undesirable events in a given healthcare service the lower the quality). Such unwanted undesirable events were identified as follows. A list of outcomes was drawn up from the already standardised Joint Commission International Standards Manual [10, 20]. The most important ones were selected after holding several rounds of interviews with doctors and nurses working with the aforementioned medical services; they also had to be able to be recorded by existing information systems and healthcare institutions' quality-assurance systems.

2) Independent Variables

Turnaround time: Turnaround time (TAT, in hours) was selected as independent variable for this study [18]. TAT represented the total delay (in hours) experienced until a medical device became restored to its operational state after being involved in a maintenance transaction. As TAT was directly related to equipment availability, this was most appropriate for measuring maintenance provider performance. Small availability values (or, equivalently, high TAT values) would thus have affected healthcare service quality (i.e. decrease in the overall quality indicator). A continuous value was used for recording TAT values.

3) Control Variables

Type of maintenance provider (service provider type): It was thought that the way maintenance service providers performed (i.e. TAT values) would depend on the medical equipment they were maintaining; however, other factors depending on a particular firm or company also had to be considered, such as a firm's ability to provide their services and/or their resources' specificity [21-23]. It was thus thought that the type of maintenance service provider involved in a particular transaction would have some impact on TAT and consequently on decreased overall quality of healthcare service. Discrete values were used in this research for measuring the type of maintenance service provider involved in a maintenance transaction. Maintenance transactions carried out by external maintenance providers were coded "0", whilst internal maintenance service (i.e. in-house) maintenance transactions were coded "1".

Type of maintenance (maintenance type): Maintenance transactions could be catalogued as being scheduled or unscheduled. It could be said that scheduled maintenance transactions follow well-established procedures and that, as such, they must be standardised and would take less time than an unexpected maintenance transaction (i.e. it would be expected that average time taken involving maintenance transaction for devices having equivalent or similar complexity would take less time than that for an unscheduled maintenance transaction [24-26]. It was thus decided to include maintenance type as a control variable because it was thought that this would have some influence on TAT and on decreased overall quality (i.e. the dependent variable). A direct positive relationship would be expected between maintenance type and decreased overall quality (i.e. increased uncertainty (i.e. corrective maintenance) when carrying out a maintenance transaction would lead to decrease overall quality indicator value). The following dichotomous values were used for maintenance type: corrective or unscheduled maintenance was coded "1" and preventive or scheduled maintenance was coded "0".

The technological complexity of a medical device: It was not thought pertinent to incorporate equipment technological complexity as a control variable in the multivariate linear regression model. It would be expected (and has been previously reported) that technological complexity would be directly related to TAT (independent variable) [27], i.e. TAT increases as a device's technological complexity increases. This would be due to TAT affected by two time segments: maintenance service provider response time (RT) and service time (ST). ST would have the greatest increase with increased equipment complexity. Equipment/device technological complexity was thus excluded from this analysis to avoid collinearity between independent and control variables (i.e. maintenance type).

C. Statistical Analysis

Descriptive statistics (i.e. determining frequency, calculating the mean and standard deviation [SD]) were used for characterising the categories formed with maintenance service provider type (i.e. external, internal) and maintenance type (i.e. schedule/preventative, unscheduled/corrective). The results of the Kolmogorov-Smirnov (0.9965, $p < 0.457$) and Shapiro-Wilk tests (0.9842, $p < 0.561$) for decreased overall quality gave normal distribution; a multivariate linear regression model was thus chosen for responding to the research questions posed here. A one-way ANOVA test between each independent variable and the dependent variable was used for determining which of the three independent variables should enter the multivariate linear regression model (one independent and two controls), i.e. TAT *cf* decreased overall quality, service provider type *cf* decreased overall quality and maintenance type *cf* decreased overall quality. A $p < 0.05$ statistical significance cut-off point was considered for one-way ANOVA tests to enable including the variables in the multivariate linear regression model. The one-way ANOVA tests gave significant results; all the variables were thus included in the multivariate regression model. The data sample was then subjected to multi-collinearity diagnosis which revealed no multi-collinearity. The linear regression model was then constructed by first introducing TAT; the control variables' effect on the final model was then evaluated by introducing maintenance service provider type and maintenance type. The criteria used for evaluating whether control

variables should remain in the final model were as follows: if TAT β coefficient (i.e. regression) changed by at least 10% after the control variables had been introduced then this would have indicated that the control variables had affected TAT. It was thought that by doing this, the validity of the TAT coefficient result would have been prioritised without detriment to the model's precision, this being the criteria recommended by some authors when analysing the effect of control variables on the main independent variable [28]. The TAT β coefficient confidence intervals were analysed before and after introducing the control variables to guarantee a suitable precision level. It was considered that if introducing a control variable into the final model caused a variation in precision value lower than 10% in TAT β coefficient confidence interval, then it should be retained in the final model (see Eq. (1)).

$$\text{Decreased overall quality} = \beta_0 + \beta_1 * (TAT) + \beta_2 * (\text{service provider type}) + \beta_3 * (\text{maintenance type}) \quad (1)$$

III. RESULTS

A. Descriptive and Bivariate Statistics

Table 1 shows occurrence frequency (in %), the mean, the SD and confidence interval (CI) for each category regarding control variables. Table 1 also shows the one-way ANOVA test results for each category regarding the control and the dependent variable. It can be seen that most maintenance transactions (81.90%) were made by in-house service maintenance and that 63.50% of maintenance transactions were scheduled (i.e. preventive). It can be observed that values for the means of decreased overall quality were greater when maintenance transactions had not been scheduled (i.e. mean decreased overall quality (maintenance type=corrective)=0.769 undesired events > mean decreased overall quality (maintenance type=preventative)=0.013 undesired events) and when they had been carried out by an external maintenance provider (i.e. mean decreased overall quality (service provider type = external)=0.370 undesired events > mean decreased overall quality (service provider type = internal)=0.246 undesired events). Table 1 shows that one-way ANOVA tests gave significant results in all cases; all control variables were then considered for being included in the multivariate regression model.

The mean, SD and coefficients of correlation between all control, independent and dependent variables can be seen in Table 2. The values for the means led to corroborating the frequency values obtained in Table 1, i.e. maintenance transactions were mainly carried out in-house service (i.e. mean service provider type = 0.82), most types of maintenance were planned (mean maintenance type=0.36) and average TAT value was low (TAT=1.121). Excepting for TAT and Complexity variables³, the coefficients between each variable (r_{xy}) were lower than 0.75, indicating that the variables were completely independent.

TABLE 1 DESCRIPTIVE STATISTICS REGARDING DECREASED OVERALL QUALITY FOR ALL INDEPENDENT VARIABLE CATEGORIES

Independent variable	Independent and control variable category = value	Descriptive statistics regarding decreased overall quality for all independent variable categories				ANOVA tests
		%	Mean	SD	CI	
Service provider type	Internal = 1	81.90	0.246	0.747	0.186 - 0.307	187.547
	External = 0	17.60	0.370	0.732	0.241 - 0.498	0.000*
Maintenance type	Corrective = 1	36.00	0.719	0.094	0.585 - 0.852	377.986
	Preventive = 0	63.50	0.013	0.113	0.002 - 0.023	0.000*
Endnotes						
%: frequency, missing values represented 0.6% of the total sample size; n: 719 maintenance transactions; *p<0.001; SD: standard deviation; CI: confidence interval						

TABLE 2 CORRELATION MATRIX (CORRESPONDENCE ANALYSIS)

	Mean	SD	1	2	3	4	5
1. Decreased overall quality	0.268	0.074	1.000				
2. Turnaround time (TAT)	1.121	0.326	+0.645*	1.000			
3. Service provider type	0.82	0.382	-0.063**	-0.208*	1.000		
4. Maintenance type	0.36	0.326	+0.455*	+0.431*	-0.152*	1.000	
5. Complexity	0.6	0.11	+0.023	+0.85	-0.120	+0.36	1.000
Endnotes							
*p<0.001 one-tail test; ** p<0.05 one-tail test; SD: standard deviation							

³A value of the r_{xy} higher than 0.75 indicated a strong correlations amongns variable. Since, TAT and Complexity variables are colineall, complexity was excluded from the multilineal regression analisys (see Table 2 for more details).

B. Multivariate Regression Model

Table 3 shows the result of the multivariate regression model in responding to the research questions posed in this study. This table shows a 17.9% change in TAT β coefficient when introducing maintenance service provider type and maintenance type carried out, meaning that the control variables stayed in model 2 since they caused a higher than 10% change in TAT β value. It should be noted that such change in TAT β coefficient had no considerable effect on precision (just 2% variation between model 1 and model 2). Confidence interval variation (Δ CI) in model 1 for the β_{TAT} coefficient was 0.256 (i.e. Δ CI = $|+1.345 - 1.601| = +0.256$) and 0.276 in model 2 (i.e. Δ CI = $|+1.156 - 1.432| = +0.276$), leading to Δ CI_{model 2-model 1} = $0.276 - 0.256 = 0.020 = 2.0\%$. It was thought that model 2 provided an excellent empirical model for responding to the research questions posed here since the coefficient of correlation ($R=0.680$) and determination ($R^2=0.426$) were high, i.e. model 2 correctly explained 42.60% of the dependent variable in all observations of independent and control variables, whilst β_{TAT} coefficient precision only affected 2% in the final model. Model 2 was thus chosen for explaining the results. It can be observed that the β_{TAT} coefficient in model 2 was positive and its value equalled +1.473 units, indicating a statistically strong, direct relationship between TAT and decreased overall quality; i.e. when TAT value changed (increased) regarding a unit, decreased overall quality value also became increased. In other words, when more unwanted events occurred, they had a negative effect on healthcare service quality as TAT value increased. A $p<0.000$ value gave sufficient statistical support to state that an increase in TAT value had a significant negative impact on healthcare service quality. It can also be observed in model 2 that the $\beta_{\text{service provider type}}$ coefficient was positive and equal to +0.174 units, indicating a direct (though not so strong) relationship between service provider type and decreased overall quality; i.e. when service provider type value changed an unit i.e. from external = "0" to internal = "1" then decreased overall quality value became increased. This meant that more unwanted cases occur which negatively affected healthcare service quality when a maintenance transaction was carried out by an in-house service. A $p<0.002$ value provided sufficient statistical support to state that an increase in service provider type unit had a negative impact on healthcare service quality. It can be observed in model 2 that the $\beta_{\text{maintenance type}}$ coefficients were equally positive, having a value of +0.349 units, indicating a direct, stronger relationship between maintenance type and decreased overall quality. When maintenance type value changed in a scheduled maintenance unit = "0" to unscheduled maintenance = "1" then decreased overall quality value also became increased. This meant that more unwanted events occur negatively affecting healthcare service quality when a maintenance transaction was corrective/ unscheduled. A $p<0.000$ value provided sufficient statistical support to state that an increase in a maintenance type unit would have a negative impact on healthcare service quality.

TABLE 3 MULTILINEAR REGRESSION MODEL

	Model 1				Model 2			
	β	SE	Stat. sig.	CI	β	SE	Stat. sig.	CI
Constant	-1.383	0.073	0.000	(-1.532, -1.233)	-1.452	0.095	0.000	-1.639 to -1.264
Turnaround time (TAT)	+1.473	0.065	0.000	(+1.345, +1.601)	+1.294	0.070	0.000	+1.156 to +1.432
Service provider type					+0.174	0.055	0.002	+ 0.066 to + 0.282
Maintenance type					+0.349	0.047	0.000	+ 0.256 to + 0.442
Overall statistical model	ANOVA test: (F = 204.619; p<0.000) R = 0.645, R ² = 0.416 (41.60%) df: 1				ANOVA test: (F= 204.619; p<0.000) R= 0.680, R ² = 0.426 (42.60%), ΔR ² = 0.01 (1%) df: 3			
End notes								
Dependent variable: decreased overall quality;df: degree of freedom;n: 719 maintenance transaction;β: model coefficient;SE: standard error ;Stat Sig: statistical significance (p value); CI: confidence interval								

IV. DISCUSSION

The present research has tried to determine whether maintenance service provider performance had any sort of impact on overall healthcare service quality, using TAT to measure this.

It was found that an increase in TAT value had a negative impact on overall healthcare service quality, i.e. the greater the TAT value, the more cases of unwanted events negatively affecting overall healthcare service quality; it was also found that healthcare service quality could be affected by service provider type (i.e. maintenance governance structure type) and maintenance type. Even though it might be thought that this would have been an obvious conclusion, it was thought that the results highlighted certain aspects which should not be ignored when selecting how maintenance service provider governance should be structured in the healthcare sector and that for medical devices. This can be stated because there is sufficient empirical evidence in other industries which has demonstrated that how service provider type or the type of governance relationship between a service provider and a client is chosen does affect such relationship's performance [11,29]; it can thus be stated that these results could be applied to the field involving the medical device maintenance industry. An attempt has thus

been made to use transaction cost (TCT) ([21-23]) and resource-based view (RBV) [30, 31] theory to explain the meaning of this study's results.

For example, Table 2 shows that r_{xy} partial correlation coefficient is negative and statistically significant between TAT and service provider type (i.e. $r_{xy} = -0.208$, $p < 0.001$). This implied that maintenance transactions in which external maintenance providers were involved performed better (i.e. $TAT_{\text{service provider type=external}} < TAT_{\text{service provider type=internal}}$) than internal or in-house service provider maintenance transactions. A possible explanation depending on RBV theory would state that external service providers have certain competitiveness over internal service providers, allowing them to have better performance levels (i.e. lower TAT values). External maintenance providers' competitive advantages regarding medical equipment maintenance could be related to two basic points. They can synchronise the purchase of idiosyncratic spare-parts and locate them better, as well as having better economies of scale when carrying out routine maintenance tasks thereby ensuring lower maintenance service costs and TAT values. They also have access to highly specialised assets in the medical device maintenance field, such as online ancillary support service (i.e. maintenance diagnosis software tools or online maintenance service) when carrying out maintenance tasks.

Regarding the first point, repairing highly complex medical devices requires specific spare-parts for medical device maintenance, these being costly to acquire and store, whilst devices requiring such specific spare-parts are limited and there is significant uncertainty regarding when (or if) a given spare-part will be needed. As a result, acquiring and storing replacement parts for complex equipment represents significant asset investment by a particular service provider. It is essential that spare-parts and maintenance materials are available for medical equipment because medical devices cannot be maintained or repaired without them, even when problems can be fixed easily [32, 33]. Consequently, if spare-parts are not readily available, then medical equipment cannot be adequately maintained thus breakdown frequency increases, thereby provoking long periods of equipment TAT. This is particularly important in developing countries where spare-parts must often be ordered from abroad. Procuring such spare-parts from abroad is a lengthy and tedious process because a significant amount of time is taken up in obtaining price quotes and shipping goods [34-38]. For example, [39] found that the response time for bringing critical spare-parts to a maintenance site represented 80% of overall TAT involved in corrective maintenance tasks. External service governance maintenance structures (mainly concerning original equipment manufacturers) thus have a competitive advantage over in-house ones because they can synchronise idiosyncratic spare-part purchase and locate them better and they have better economies of scales when performing maintenance tasks, thereby resulting in lower maintenance service costs (i.e. better financial performance) [40] and lower TAT values.

The second case shows clearly that there is a high demand for ancillary support services such as remote diagnosis and online parts management among medical technology users, particularly for highly complex equipment. Such technologies increase service provider value chain performance [41] and create new competitive advantages for maintenance providers by anticipating equipment failure and diagnosing failures when they occur, isolating a particular problem and identifying the spare parts needed for making a repair, even before a maintenance technician is dispatched. This therefore decreases medical devices' out-of-service downtime. When hospitals purchase highly-complex equipment and the original equipment manufacturer refuses to allow other maintenance organisations access to products such as online diagnosis programmes, hospitals become locked into maintenance contracts with the original equipment manufacturers to gain access to such services, thereby driving costs above what they would have been in a competitive environment. This has led to significant controversy in the field of medical device maintenance as noted by some scholars, "In some cases, it is almost impossible to service the equipment without this software, a situation that obviously has the potential to seriously hamper in-house or third-party service." [36]. Therefore, when only external service provider hospitals (mainly being supplied by original equipment manufacturers) have access to online diagnostic tools, they are able to make use of their natural advantages, such as site and organisational specificity thereby allowing them to service equipment faster than other service providers. It would thus seem that online diagnostic services may cause higher external maintenance service provider performance levels compared to those of in-house or internal service providers.

The only risk here is that transactions involving highly specific assets are particularly open to opportunistic behaviour by either an agent or principal. For example, if a maintenance service provider invests in non-substitutable, highly-specific assets which cannot easily be found elsewhere, then there may be incentives for such maintenance service provider to engage in opportunistic behaviour, as the power dynamics of the exchange relationship have shifted in his favour. Likewise, if a maintenance service provider makes highly specific asset investments in providing a good or service for which the number of alternative buyers is limited then the healthcare institution holds significant power in the exchange relationship. A TCT approach is thus advisable in such cases to internalise services, i.e. more integrated governance structures should show performance advantages regarding transactions involving high degrees of specific asset investment [11, 29, 42].

It would seem that external maintenance service providers' opportunist attitude has not been shown in our data source because their performance was better than that of internal service maintenance providers. There was a lower negative impact on decreased overall quality. From the management decision-making point of view regarding the form of governance to be selected when carrying out maintenance activities, it could thus be recommended that governance relationships should be hybrid-type involving both in-house and external maintenance services so as not to completely lose control over the business. Such experience has already been reported, providing excellent results when comparing extreme forms of governance (i.e.

hierarchies or market-based ones) [43]. Such recommendation would seem to be feasible as decision-making regarding outsourcing services in general (but specifically concerning the maintenance area) is an issue which is still under debate by academics. For example, according to a survey by Deloitte Consulting, 44% of respondents indicated that they saw no cost saving in their outsourced activities, while only 34% of respondents were satisfied with the suppliers' service quality [44]. It was also found that, in some cases, outsourced maintenance service provider performance was very poor in the medical device maintenance field [39], maintenance TAT having average values of 9.79 days. Higher TAT values have a direct impact on medical equipment availability, in turn lowering healthcare quality by increasing patient waiting time due to equipment downtime.

The fact that lower healthcare service quality levels were obtained when the equipment had corrective maintenance (i.e. high uncertainty level) could have been perfectly explained by theoretical TCT statements. TCT states that uncertainty relates to either unforeseeable disturbances or an inability to measure outcomes efficiently [22].

V. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This research posed two research questions. The first question concerned whether maintenance service transaction performance had an impact on healthcare service quality. Our evidence indicated that decreased maintenance service performance (i.e. higher TAT values) led to a decrease in healthcare service quality (i.e. more patients being transferred to another acute care hospital on day of arrival) [17].

The second question concerned whether governance structure transaction maintenance performance (i.e. external cf internal) affected overall healthcare service quality. A tendency was found that external maintenance service providers caused a lower negative impact on healthcare service quality than internal ones. Such findings would seem to provide strong and consistent support for maintenance service providers' performance having a direct impact on overall healthcare service quality.

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