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DECOMPOSING EFFICIENCY INTO ITS MANAGERIAL AND ITS REGULATORY COMPONENTS:
The case of European railways

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ABSTRACT

The purpose of this paper is to decompose traditional measures of productive efficiency into a management and a regulatory component. This procedure is applied to European railways. The policy implication of such a decomposition is obvious : management is responsible for just managerial inefficiency whereas governments are responsible for slacks in regulatory efficiency. Regulatory efficiency is based on indicators pertaining to managerial freedom in pricing, hiring and marketing decisions.

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1. Introduction

Technical efficiency is widely considered as one of the best yardsticks to evaluate the performance of production units, notably public and private, for-profit and non-profit firms. The technical efficiency approach rests on the construction of a production frontier, also called a 'best practice' frontier, which provides the input-output combinations that are accessible to the firm the operations of which are under scrutiny. The distance between that frontier and the actual level of production provides a measure of efficiency in the firm. This is wholly operational to the extent that this measure represents the proportion of the possible production that was actually obtained or per contra, it represents the loss of output from anything less than an efficient utilization of the resources employed by the firm.

It is tempting to attribute any efficiency slack so obtained to management. Yet, it may happen that some managers are required to operate within an environment that differs from the others and impinges on their operations. In this case, even assuming that all managers operate at 100% efficiency, they would not all get the top efficiency score. It thus seems important to control for variable environments when measuring the lack of efficiency truly attributable to management. The purpose of this paper is to address this issue. It will show that traditional inefficiency indicators can be decomposed in two parts: managerial inefficiency the responsibility of which falls exclusively on management and regulatory inefficiency which is attributable to the institutional, legal and administrative environment in which firms operate and the solution of which lies outside of and beyond the firm's management. To illustrate this decomposition we shall use a typical public enterprise: European railways which vary across countries both in the quality of their management and in the nature of their environment.

In this paper, we find that technical efficiency is affected by the nature and extent of government intervention and can be fostered by increasing the autonomy of the firm or by relaxing the institutional constraints to which it is subject. Is there a theory behind this hypothesis ? There exists much literature[2] explaining slack in technical

2 Yarrow (1986), Vickers and Yarrow (1988), Hart (1983).

efficiency (also called X-inefficiency or internal inefficiency) by lack of competition. This literature only applies partially to the activities studied here, railways, which have a quasi monopolistic position for the type of products they supply.

Even within a monopolistic structure, there can be competitive forces in the way that factors of production are purchased and in the attitude towards private substitutes (cars and trucks for railways). Those competitive forces can be induced by increased autonomy. More generally it seems obvious that a firm subject to constraints pertaining to pricing, choices of inputs, lines of products and productive techniques should find it more difficult to be close to the best practice frontier than a firm having full autonomy towards those matters.

Decomposing gross efficiency in managerial and regulatory efficiency can be objected to on the grounds that lack of freedom in making strategic and operational decisions is not the only aspect of the firm's environment which affects efficiency and on which management has no control. Among those uncontrollable variables, there are those which are totally uncontrollable (e.g. density, hilliness or unionization), those which can be controlled by management, but in the long run (e.g. electrification) and those which can be controlled by governments (e.g. managerial freedom in making decisions). In this paper, we focus on the latter and more specifically on managerial autonomy in commercial policy, pricing and purchase of inputs for which we have gathered some evidence. It is clear that were more evidence on the uncontrollable part of environment of the firm available a more refined decomposition could be conducted[3].

Before proceeding, two remarks are in order. First, one must admit that public services such as railways differ across countries not only as far as management and regulation are concerned but also in terms of scale, physical environment, input and output structure. However all those latter characteristics are expectedly taken into account when constructing the efficiency frontier. Second, the economic policy implication of this decomposition is obvious. Recent works aimed at comparing the performance of public and private firms have pointed to the fact that what really matters is not so much the ownership regime but rather differences in autonomy and competition[4].

The paper is organized as follows. In the next section, we show how the level of efficiency obtained from the parametric approach can be decomposed in a multiplicative way. Section 3 presents estimates of efficiency for European railways and section 4 shows how these indicators are changed when controlling the level of autonomy of each railway company.

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3 See Oum and Yu (1991) for a study including a wide number of factors non controlled by management.

4 Vickers and Yarrow (1988), Pestieau and Tulkens (1992).

2. Managerial and environment inefficiency

There are two ways to proceed with the decomposition of inefficiency into managerial inefficiency (mi) and regulatory inefficiency (ri). One can first compute what we will call gross inefficiency (gi) and then control for variations in regulation or its contrary, autonomy. Alternatively, one can directly construct a best practice frontier and compute indicators which encompasses the variable regulation and which are then indicators of managerial efficiency. Under certain restrictive assumptions these two approaches lead to the same results. For the sake of clarity and to avoid cumbersome notation, we shall use a deterministic approach, that is, Greene's DOLS (*Displaced ordinary least squares)* measure. Our argument can however be easily extended to the stochastic approach which is used in the empirical part.

Direct approach

Let y, be the output, x, the single input, z, an index of the regulatory environment, e.g. autonomy[5], and v, a residual term. OLS estimation gives the following equation :

(1) $$\ln y_i = a + b \ln x_i + c\, z_i + v_i ,$$

where a, b and c are the *estimated* regression coefficients. The coefficient c is assumed to be positive reflecting the effect of an open and competitive environment on the level of output. If one posits $v^+ = \text{Max}\,[v_i]$, one obtains the frontier of managerial efficiency :

(2) $$\ln y_i^F = a + b \ln x_i + c\, z_i + v^+$$

which allows for measuring the level of managerial efficiency (me):

(3) $$me_i = y_i / y_i^F = \exp\,(v_i - v^+) \le 1 .$$

It is clear that y_i^F does not really represent the frontier of efficiency; it represents the maximum production for a level of autonomy equal to z_i. To obtain a global efficiency frontier, one should give each firm the maximum level of autonomy z^+. One writes this new frontier:

(4) $$\ln \hat{y}_i^F = a + b \ln x_i + c\, z^+ + v^+,$$

which provides an indicator of gross efficiency (ge):

[5] Both x and z could be vectors of inputs and characteristics of the institutional environment respectively.

(5) $$ge_i = y_i/\hat{y}_i^F = \exp [(v_i - v^+) + c(z_i - z^+)].$$

One can now derive the indicator of regulatory efficiency (re):

(6) $$re_i = y_i^F/\hat{y}_i^F = \exp [c(z_i - z^+)].$$

The expression $c(z_i - z^+)$ represents the production gain, in logarithmic terms, which would enable one to go from the observed level of efficiency to the level that maximum autonomy allows for. One observes right away that gross efficiency can be decomposed mutiplicatively and not additively. Namely :

(7) $$ge_i = me_i . re_i .$$

Gross inefficiency can also be decomposed additively but with a cross term :

(8) $$gi_i = 1 - ge_i = 1 - me_i . re_i$$
$$= 1 - (1 - mi_i)(1 - ri_i) = mi_i + ri_i - mi_i . ri_i .$$

Two stage approach

We now first estimate a production function without including the index of autonomy. That way, one derives a production frontier in which differences in the regulatory environment are not accounted for. Let this estimated production function be :

(9) $$\ln y_i = \alpha + \beta \ln x_i + \varepsilon_i,$$

where $\varepsilon_i \sim N(0, \sigma^2_\varepsilon)$. Traditionally, we express the measure of efficiency as being equal to: $\exp (\varepsilon_i - \varepsilon^+)$ with a unitary value for the firm the ε_i of which is ε^+. We are going to correct this residual by taking into account differences in autonomy; that is, we estimate the following equation:

(10) $$\varepsilon_i = \delta + \gamma z_i + \eta_i ,$$

which provides a ceiling value for the residual (η^+) and hence a production frontier including both types of efficiency:

(11) $$\ln \tilde{y}_i^F = \alpha + \beta \ln x_i + \delta + \gamma z^+ + \eta^+.$$

One observes that $\tilde{y}_i^F$ and $\hat{y}_i^F$ would be identical if $a = \alpha + \delta$, $c = \gamma$ and $b = \beta$, in which case $v_i = \eta_i$. Without making such restrictive assumptions, one can in this particular setting define the three alternative types of technical efficiency indicators:

$$(12) \qquad me_i = \exp(\eta_i - \eta^+)$$

$$(13) \qquad re_i = \exp[\gamma(z_i - z^+)]$$

$$(14) \qquad ge_i = \exp[(\eta_i - \eta^+) + \gamma(z_i - z^+)]$$

In this paper, we use the two-stage approach for reasons of convenience. Implicitly, we assume that the inputs, x, and the autonomy variable, z, are independent. Even though the one-stage approach is preferable when these assumptions are not verified[6], we have chosen to do so for two reaseons. First, the two-stage approach allows for explicitly trying alternative sets of variables pertaining to the institutional environment of the firms[7]. Second, in the particular case at hand, both y and x are panel data whereas z is given for just one year[8]. Note that with the stochastic approach either v_i or ε_i would have to be decomposed into two elements: a one-sided term representing efficiency and a symmetric random error term. In the two stage approach, only the efficiency term would be regressed against autonomy.

In this presentation, we have constructed an efficiency frontier for both managerial and gross efficiency. This implies that for those two types of efficiency, one has a maximum level of 100 %. Hence, the highest level of regulatory efficiency is likely to be higher than 100 % except if the same firm is the most efficient from both a managerial and an institutional viewpoint[9]. An alternative normalization which is used below gives a rate of 100 % to the firm with the highest regulatory efficiency. Consequently, the highest gross performance indicator is below 100 %.

Note that one finds a similar distinction in the works of Charnes, Cooper and Rhodes (1981) which study the efficiency of firms operating under different programs (or technologies). They distinguish 'management efficiency' which applies to managers operating under a common program and 'program efficiency' which deals with the efficiency gains that can be secured by moving firms from their actual program to the most performing one.

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6 Deprins (1989) discusses those two approaches and notes that the two-stage approach is easier than the one-stage approach but yields different estimates for β and γ unless x and z are statistically independent.

7 See Oum and Yu (1991).

8 An alternative approach used by Gathon and Perelman (1992) is a one-stage approach with the z variable constant over time used as reflecting the firms' fixed effect.

9 This come from the definition of $re_i \equiv ge_i / me_i$ If, say, $ge_k = 1$ and $me_k < 1$, then $re_k > 1$.

3. European railways efficiency comparison

In a number of countries, the performance of national railways is dealt with through comparisons with those of neighboring countries. It is hence quite natural to apply alternative techniques of productive efficiency measurement to a sample of railways as large as possible. In this paper, we present indicators based on the stochastic or composed error model (CEM)[10].

Our data set comes from the International Railway Statistics published yearly by the U.I.C. (International Union of Railways). It covers the period 1961-88 and includes 19 countries, all European. For each year and each company, the following input-output variables are available : two outputs, y_1 (gross hauled ton-kilometers by freight trains) and y_2 (gross hauled ton-kilometers by passengers trains); four inputs, x_1 (total number of engines and railcars used by the railway), x_2 (labor force: annual mean railway staff assigned to the rail operation), x_3 (length of *not electrified* rail lines operated at the end of the year), and x_4 (length of *electrified* rail lines operated at the end of the year). In the parametric approach which relies on the estimation of a production function, we use $\bar{y} = y_1 + y_2$ as the dependent variable for output and $\bar{x} = y_1/\bar{y}$ (the relative share of freight in total output) as an additional independent variable[11]. A time variable t is also used to reflect the possibility of technical progress[12].

In the estimation of the production function, we adopt the translog form which can be written as :

$$\ell n\, \bar{y}\,(s, t) = \alpha_0 + \alpha_t\, t + \frac{1}{2}\alpha_{tt}\, t^2 + \sum_{m}^{4} \alpha_m\, \ell n\, x_m\,(s, t) + \frac{1}{2}\sum_{m}^{4} \beta_{mt}\, t\, \ell n\, x_m\,(s, t)$$

$$(15) \qquad + \frac{1}{2}\sum_{m}^{4}\sum_{n}^{4} \beta_{nm}\, \ell n\, x_m\,(s, t)\, \ell n\, x_n\,(s, t) + \beta_0\, \ell n\, \bar{x}\,(s, t) + \varepsilon\,(s, t)$$

when (s, t) denotes company s and year t respectively, the α's and the β's are the coefficients of the associated independent variables. The error term $\varepsilon(s,t)$ is decomposed into two elements, each with a specific distribution: an one-sided term $u(s,t)$[13] representing efficiency and a symmetric random error term, $v(s,t)$ with zero mean. From the estimation of this model, one gets a set of efficiency values for each observation relative to the stochastic frontier as well as a measure $\lambda = \sigma_u / \sigma_v$, indicating when most of

10 We used the econometric package LIMDEP of W.H. Greene. For alternative measures using the same data set, see Gathon (1991). For an earlier study, see Perelman and Pestieau (1988).

11 A similar approach is used by Klein (1953). The duality of outputs has led some analysts to rather use a non parametric technique such as DEA. See, e.g., Gathon (1991) and Oum and Yu (1991).

12 As examples of technical progress in the railways industry, one can mention the substitution of fuel and electricity to coal traction, the automation of signalling, switching, level crossing...

13 We assume that u(s,t) is half-normally distributed.

the variance from the frontier is due to randomness or to inefficiency.

To give an idea of the scale variations[14], the average value of both outputs are given in Table 1. We estimated equation (1) through Maximum Likelihood and then, we measured the level of stochastic efficiency for each year and each company. The estimates of equation (1) are presented in Table 2. In Table 2 one finds the value of λ equal to 2, which indicates that greatest part of the variance is due to inefficiency. We also derived the yearly rate of technical progress from the coefficients associated with the trend variables. Those figures are summarized in Table 1. The current level of efficiency is given in terms of an average over the last three years (1986-88) of the period considered. This gives an efficiency index ranging from 0.947 (Netherlands) to 0.742 (Norway).

We are not only interested in the current standing of each company but also by where they come from. Thus, we provide the change in efficiency, that is the relative difference between efficiency averaged over the last three years (1986-1988) and the efficiency averaged over the first three years (1962-64). One clearly sees a wide range of patterns : the Netherlands and Norway which have been steadily first and last respectively; British Railways which is now among the most efficient but has come a long way and Denmark which has declined over the years to now be among the least efficient. Note however that overall there is a positive correlation (0.40) between the level and the change in efficiency. This means that on the average a good (bad) score in 1986-88 results from some improvement over the 1961-86 period.

In introducing technical progress, we account for the possibility of a displacement over time of the production function. This displacement varies across countries in view of the cross-effects between time and inputs in the translog function. As can be seen from Table 1, technical progress is consistently positive and in a number of cases, it is not only higher than efficiency change but outweighs it when the latter is negative. Finally, by adding efficiency changes and technical progress, we get an approximation of what is known to be the variation in total factor productivity. We thus underscore the old idea recently developed by Nishimizu and Page (1982) that productivity gains are to be divided into these two components, the determinants of which are supposedly different. Efficiency would be linked to the quality of management and to the institutional setting of railways operations; technical progress would be linked to R & D.

14 Scale variation over time is much lower than that across countries. Across countries scale variation (in terms of ton-km) is 1 to100 as it appears; over time scale variation is at most 1 to 2.

Table 1
Efficiency measures of the European railways

Railways	Country	AVERAGE OUTPUT 1961-1988 Ton-km Passenger (10^6)	Freight (10^6)	PARAMETRIC FRONTIER (CEM) Efficiency 1986-88	Effic.change 1961-88	Techn.progress 1961-88	TFP change 1961-88
BLS	Switzerland	4.9	1.1	0.9222	0.2349	0.3999	0.6348
BR	United-Kingdom	343.6	104.2	0.9261	0.3527	0.5743	0.9270
CFF	Switzerland	64.1	28.0	0.9324	- 0.0097	0.5651	0.5554
CFL	Luxembourg	2.9	1.5	0.7719	- 0.1799	0.6333	0.4534
CH	Greece	12.8	3.2	0.7847	- 0.0945	1.6460	1.5515
CIE	Ireland	7.6	4.3	0.9098	0.2971	1.4432	1.7403
CP	Portugal	24.5	6.2	0.9035	0.1975	0.7380	0.9355
DB	Germany	384.7	196.3	0.8472	- 0.0393	0.6097	0.5704
DSB	Denmark	35.7	8.3	0.7315	- 0.2259	0.6767	0.4508
FS	Italy	210.3	60.3	0.8760	0.0133	0.6015	0.6148
NS	Netherlands	82.6	15.3	0.9471	- 0.0057	0.3507	0.3450
NSB	Norway	22.9	10.2	0.7421	0.0386	0.3661	0.4047
OBB	Austria	56.4	33.6	0.8288	- 0.0719	0.6475	0.5756
RENFE	Spain	85.0	44.3	0.8680	0.5966	0.4894	1.0860
SJ	Sweden	64.1	40.7	0.8822	0.1989	0.2376	0.4365
SNCB	Belgium	64.4	21.9	0.8585	- 0.0724	0.5551	0.4827
SNCF	France	261.3	204.1	0.9237	- 0.0101	0.5079	0.4978
TCDD	Turkey	20.7	18.2	0.9378	- 0.0004	1.2485	1.2481
VR	Finland	25.2	18.4	0.8744	- 0.0478	0.7812	0.7334

Table 2
CEM production frontier for the European railways

Independent variables[a]	Estimated coefficients[b]
$\ln x_1$	0.6546 (0.3906)*
$\ln x_2$	- 0.3272 (0.6435)
$\ln x_3$	0.1835 (0.1381)
$\ln x_4$	0.6828 (0.1016)***
$(\ln x_1)^2$	- 0.1666 (0.0495)***
$(\ln x_2)^2$	- 0.0033 (0.0672)
$(\ln x_3)^2$	- 0.0013 (0.0050)
$(\ln x_4)^2$	0.0095 (0.0021)***
$\ln x_1 \ln x_2$	0.1248 (0. 0993)
$\ln x_1 \ln x_3$	0.0989 (0.0329)***
$\ln x_1 \ln x_4$	0.0872 (0.0138)***
$\ln x_2 \ln x_3$	- 0.0318 (0.0374)
$\ln x_2 \ln x_4$	- 0.0655 (0.0233)**
$\ln x_3 \ln x_4$	- 0.0679 (0.0187)***
t	0.0050 (0.0123)
t^2	- 0.0010 (0.0001)***
$t \ln x_1$	- 0.0078 (0.0025)**
$t \ln x_2$	0.0117 (0.0027)***
$t \ln x_3$	- 0.0008 (0.0006)
$t \ln x_4$	- 0.0035 (0.0006)***
$\ln \bar{x}$	0.4484(0.0296)***
intercept	7.6950 (1.7998)***
$\lambda = \sigma_u / \sigma_v$	1.9718 (0.3562)***
σ_ε	0.2007 (0.0114)***
Log-likelihood	296.33

*** significant at the level of 1%; ** significant at the level of 5%; * significant at the level of 10%.

[a] The variables are defined in the text.

[b] Standard errors are presented in brackets; There are 532 observations.

What can be deduced from these results for policy purposes ? Let us take the example of a company which currently has a low level efficiency. First, one should try to see whether this is the result of a declining trend or whether it has been the case throughout the 27-year period. In either case, one should attempt to trace the main reasons of such a standing. Second, one could look for the variables for which inefficiency is the most blatant. Finally, one could check whether the environment, geographical as well as institutional, could be invoked as an extenuating circumstance of poor performance. We have tried to control for factors such as the population density and the hilliness of each country but they don't explain differences in efficiency. Electrification has been explicitly introduced. We now turn to the effect of institutional factors, which is the theme of this paper.

4. Correcting for autonomy

Through a survey conducted among the 19 companies, an index of the institutional autonomy of each of them was constructed. The survey was aimed at evaluating the relations between public authorities and railways' management and at assessing the nature and the extent of government intervention. The main support of this survey was a 12 page questionnaire including more than 50 questions that have been answered by the managers of each individual company. These questions concerned every aspect of the activity, from human resources management to financial policy, from marketing and pricing to technical operations. Three types of autonomy indexes were derived pertaining respectively to the pricing, hiring and commercial policy of companies. An index of aggregate autonomy (ranging between 40 and 100) was also contructed and it is presented in Table 3. As reported in Table 4 both aggregate autonomy and autonomy in pricing exhibits a significant positive coefficient on gross efficiency for the period 1986-88 which is also the relevant period of the survey[15]. These equations correspond to (10) in section 2. We have used the index of aggregate autonomy to purge gross efficiency from differences in autonomy. The resulting ranking changes have quite important implications. A company with a low autonomy index may hope to increase its uncorrected level of efficiency by obtaining more autonomy and less regulation. Take the case of the Finnish railways. On the basis of gross efficiency, it is ranked in the midlle of the pack whereas if given full autonomy, it would be ranked first. In other words, the problem of the Finnish railways does not appear to be its mangement but its regulatory environment. Admittedly, in a number of cases, both managerial and regulatory efficiency indicators are similarily ranked, e.g., in the Netherlands and Germany.

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[15] This was a mail survey conducted by one of the authors in October-November 1989. In some instances, it was completed by personal interviews. Fore more details, see H.J. Gathon's PH.D. thesis (Gathon, 1991).

Table 3
Efficiency decomposition into managerial and regulatory efficiency

Railways	Country	Autonomy %	Efficiency measure (CEM) 1986-88 Railways	Managerial efficiency	Railways	Regulatory efficiency	Railways	Gross efficiency
BLS	Switzerland	100.0	VR	1.000	BLS	1.000	NS	0.897
BR	United-Kingdom	76.3	TCDD	0.987	SJ	0.955	TCDD	0.888
CFF	Switzerland	66.0	NS	0.964	BR	0.946	CFF	0.883
CFL	Luxembourg	63.5	CIE	0.963	NS	0.930	BR	0.877
CH	Greece	47.3	CFF	0.962	SNCF	0.929	SNCF	0.875
CIE	Ireland	58.3	SNCF	0.942	FS	0.921	BLS	0.873
CP	Portugal	64.0	RENFE	0.939	CFF	0.918	CIE	0.862
DB	Germany	61.0	OBB	0.939	SNCB	0.914	CP	0.856
DSB	Denmark	41.5	CP	0.938	CP	0.912	SJ	0.835
FS	Italy	67.0	BR	0.927	CFL	0.911	FS	0.830
NS	Netherlands	70.3	FS	0.901	DB	0.903	VR	0.828
NSB	Norway	45.3	SNCB	0.890	TCDD	0.900	RENFE	0.822
OBB	Austria	41.8	DB	0.888	CIE	0.895	SNCB	0.813
RENFE	Spain	52.3	SJ	0.875	RENFE	0.875	DB	0.802
SJ	Sweden	80.0	BLS	0.873	CH	0.857	OBB	0.785
SNCB	Belgium	64.5	CH	0.867	NSB	0.850	CH	0.743
SNCF	France	69.8	DSB	0.830	OBB	0.836	CFL	0.731
TCDD	Turkey	60.0	NSB	0.827	DSB	0.834	NSB	0.702
VR	Finland	40.0	CFL	0.803	VR	0.828	DSB	0.693

Table 4
Impact of autonomy on technical efficiency in the European railways
(in 1986-1988[a])

Independent variables[b]	Estimated coefficients	
Aggregate autonomy	0.2059 (0.062)***	
Hiring autonomy		0.1013 (0.072)
Pricing autonomy		0.0620 (0.023)***
Commercial autonomy		0.0024 (0.032)
Intercept	-0.988 (0.254)***	-0.844 (0.328)**
Adj. R^2	0.3590	0.3748
F	5.207**	4.597**

*** significant at the level of 1%; ** significant at the level of 5%.

[a] Mean values over this period.

[b] The variables are expressed in log; standard errors are in brackets; there are 19 observations.

5. Conclusions

In this paper, we have introduced the idea that the type of technical inefficiency measures that one generally uses to assess the performance of firms might not just reflect slack in management. It could well include a component which pertains to the institutional environment faced by those firms. Such a decomposition has important policy implications as those two types of inefficiency, managerial and regulatory, do not call for the same type of cure.

We then applied this idea to the European railways, which operate quasi monopolistically at the country level and are subject to a set of rules and constraints which vary across countries. Both the levels of efficiency and the ranking thus obtained appear to change quite a lot before and after controlling for these factors which escape the control and the responsibility of management.

The present exercise points to avenues of future research. Limits result mainly from the data that has been used and that fails to encompass the quality of services as well as a number of environmental features.

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