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Guidelines for clockspeed acceleration in the US natural gas transmission industry

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ABSTRACT

This study presents the clockspeed analysis of a peer group comprising six major integrated US energy companies with substantial US interstate natural gas pipeline business activities: El Paso, Williams, NiSource, Kinder Morgan, MidAmerican and CMS Energy. For this peer group, the three clockspeed accelerators have been benchmarked at both corporate level and gas transmission business level, using time-series analysis and cross-sectional analysis over a 6-year period (2002–2007). The results are visualized in so-called clockspeed radargraphs. Overall *corporate clockspeed winners* – over the performance period studied – are: Williams, El Paso and Kinder Morgan; MidAmerican is a close follower. Corporate clockspeed laggards are: CMS Energy and NiSource. The peer group ranking for the *natural gas transmission business segment* shows similar *clockspeed winners*, but with different ranking in the following order: Kinder Morgan, MidAmerican and El Paso; Williams is a close follower. Clockspeed laggards for the natural gas transmission segments coincide with the corporate clockspeed laggards of the peer group: CMS Energy and NiSource (over the performance period studied); laggards of the past may become clockspeed leaders of the future if adjustments are made. Practical recommendations are formulated for achieving competitive clockspeed optimization in the US gas transmission industry as a whole. Recommendations for clockspeed acceleration at individual companies are also given. Although the US natural gas market is subject to specific regulations and its own geographical dynamics, this study also provides hints for improving the competitive clockspeed performance of gas transmission companies elsewhere, in other world regions.

1. Introduction

The present study is first in introducing the concept of clockspeed acceleration into the US gas transmission industry, which can benefit from better insight and monitoring of its clockspeed settings. Natural gas transmission systems, with lifecycles of up to 50–100 years, can be regarded as part of a traditionally slow-clockspeed industry. The transmission and distribution apparatus for natural gas needs careful forward planning to anticipate changes in both production regions capacity as well as in the regional market demand. A globally emerging LNG market has begun to bring more flexibility to the world's natural gas markets and heightened the competition.

Over the past decade, the US natural gas industry's clockspeed cycle had already begun to accelerate by the maturation of market liberalization. The principles of natural gas market liberalization and de-regulation were pioneered in the US under strong federal legislation – first by regulation – and then by de-regulation. The essence of de-regulation of wellhead prices and coeval regulation of third party pipeline access (any shipper can utilize the same gas transport infrastructure) is to bring in more competition by creating real liquidity in the natural gas market place [1]. Such liquidity and competition increases the need for competitive strategic planning. Clockspeed fastening provides a strategic opportunity for individual companies to manage their corporate clockspeed better than their competitors, and thus for outperforming them.

The generic concept of industry clockspeed was first introduced in the automotive industry (late 1990s) based on supply chain design optimization techniques [2,3]. Although widely applied in studies that focus on the efficiency of supplier networks [4–7] the clockspeed concept has received little attention in other industry sectors. Nonetheless, the acceleration of operational performance remains an important mechanism for achieving competitive advantage in virtually all businesses subject to time-based competition. Time links operational asset building projects

Abbreviations: CAPM, Capital Asset Pricing Model; DOE, Department of Energy; EBIT, Earnings Before Interest payments and Taxes; EU, European Union; FERC, Federal Energy Regulation Commission; HSE, Health, Safety and Environment; LDC, Local Distribution Company; LNG, Liquefied Natural Gas; RF, Risk-free Rate of Return; ROCE, Return On Capital Employed; RONOA, Return On Net Operating Assets; TSO, Transmission System Operator; TSR, Total Shareholder Return; US, United States.

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to returns on investment, and companies that build faster value can beat competitors. This means accelerating clockspeed is a key strategy tool for gaining competitive advantage in a world where speed is increasingly critical to business survival. For example, the energy business is under considerable pressure to match supply and demand at anyone time and at affordable price ranges. Translation of the clockspeed concept to the upstream Oil and Gas business led to the introduction of three distinct dimensions of clockspeed acceleration [8,9]:

- *Accelerator 1:* lever of workflow efficiency.
- *Accelerator 2:* lever of improvement rate of risk management.
- *Accelerator 3:* lever of accrual speed of portfolio value.

Fig. 1 shows the clockspeed performance space and cases of sub-optimum (A), improved (B) and optimum (C) clockspeed acceleration settings. The relative performance in the three critical dimensions of clockspeed can be benchmarked for a peer group of companies using the methodology introduced by Weijermars [8]. Some examples serve to illustrate the role of accelerators in the clockspeed concept:

- *Clockspeed accelerator 1:* workflow clockspeed is accelerating positively when operational efficiency or productivity is improving over time. This may require the adaptation of organizational structures and culture, or adaptation of new technology or training and recruitment of employees to expand the available skills and experience base.
- *Clockspeed accelerator 2:* risk mitigation is improved when delays in projects are minimized and HSE performance is optimized, in order to avoid negative impacts on the IRR. For example, fraud, project failures and delays, impact of regulatory changes and market dynamics may all impede improvements in the setting of clockspeed accelerator 2.
- *Clockspeed accelerator 3:* portfolio value is growing fastest when projects are phased such that the company's resources (people, equipment and capital) are not unduely strained such as to depress profitability (e.g., ROCE – previous studies [8,9] – or RONOA – this study; for acronyms see list on the first page of this article). In particular, major acquisitions that are capital intensive provide the risk that IRR is not coming on stream fast enough to provide cash for new projects.

A precise definition of clockspeed has not yet been formulated. Fine [2] referred to the mutation rate of fruit flies as an analogue for business adaptation speed. Fine's industry clockspeed has subsequently been interpreted as the velocity of change in the external business environment that sets the pace for a firm's internal operations [10]. A definition of clockspeed acceleration is proposed here as follows: *clockspeed acceleration refers to a company's ability to perform better than its peers by simultaneously speeding up the workflow efficiency, risk mitigation success and value growth of the business (either in a business segment or at corporate portfolio level).* Clockspeed in the energy business can be linked to the concept of strategic realignment [8,9,11], whereby companies that move at too slow a clockspeed run the risk to enter into strategic drift (Fig. 2). Companies that fail to reconnect to best practice become progressively disconnected from the competitively changing business environment and may fail if their clockspeed is not readjusted in time.

This study examines the impediments to achieving faster clockspeeds in the US gas transmission industry, taking into account both *internal* clockspeed dependencies and *external* factors. The performance in each of the three dimensions of clockspeed acceleration (Fig. 1) is identified for each of the companies in the peer group to establish which best-in-class practices are critical to become a clockspeed leader in the industry's peer group. Benchmarking is a continuous and systematic process for comparing the relative efficiency of two or more companies in terms of productivity, quality and best practices with those companies and organizations that represent excellence [12]. Dale and Bunney [13] suggest three principal types of benchmarking: (a) competitive benchmarking, whereby the best-in-class company is identified to reveal best practice leaders, (b) internal benchmarking, which reveals the best practices that can then be shared across corporate boundaries, and (c) functional benchmarking, which compares specific processes to identify steps that could be optimized. All three types of benchmarking are incorporated in the clockspeed benchmark elaborated here.

This study continues as follows: The major US natural gas transmission companies are identified in Section 2, which then are subjected to a benchmarking of their three principal dimensions of clockspeed acceleration (Sections 3 and 4). The benchmark results are discussed in Section 5. The clockspeed accelerators serve as managerial gearshift levers and recommendations for optimization of their setting are summarized in a final Section 6.

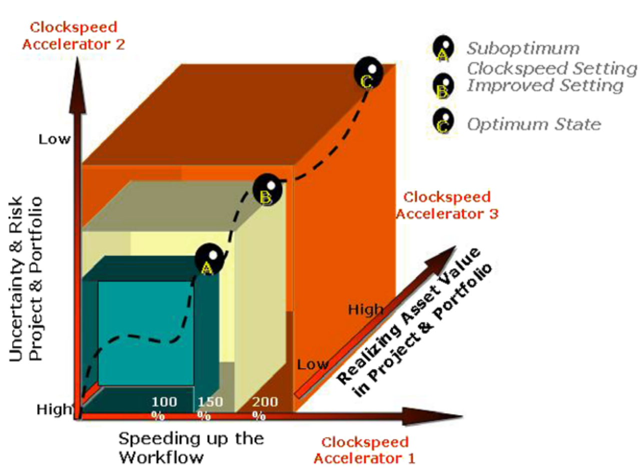

Fig. 1. Industry clockspeed can improve in three dimensions: (1) accelerating workflow efficiency, (2) accelerating risk mitigation and quality of uncertainty control, and (3) accelerating corporate value adding process. The improvement of 'best practice' in all three dimensions helps to accelerate a sub-optimum clockspeed (Case A), to an improved clockspeed (Case B), in pursuit of the optimum state (Case C).

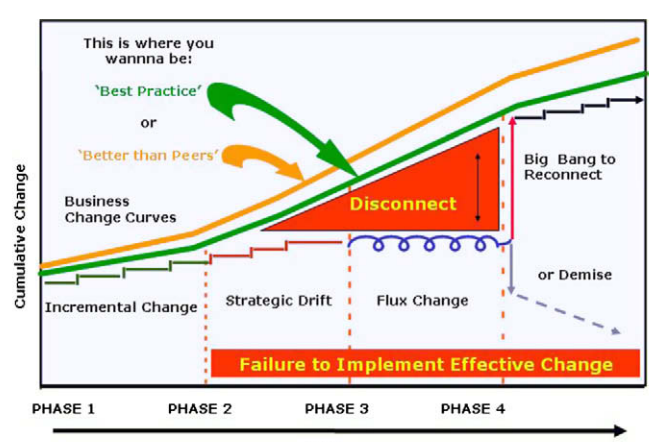

Fig. 2. Individual companies that cannot keep up with the speed of transformational change for their peer group in the gas transmission industry will disconnect and run the risk to fail. Four phases of increased disconnect with the transformational change are indicated. Only a major change (i.e., 'Big Bang') can save a gas transmission company that has erred for too long in strategic flux (cf. Weijermars [11]).

Table 1
Major US interstate pipelines (ranked in order of 2007 mileage as reported in *Oil & Gas Journal*, September 1, 2008, p. 56).

Rank	Company	Owners	Mileage
1	Northern Natural Gas Company	MidAmerican Energy Holding Corporation, part of Berkshire Hathaway Inc. (NYSE: BRK.A)	15,487
2	Tennessee Gas Pipeline Co.	El Paso (NYSE: EP)	14,463
3	Columbia Gas Transmission Co.	NiSource (NYSE: NI)	10,339
4	Transcontinental Gas Pipe Line Co.	Williams (NYSE: WMB)	10,325
5	El Paso Natural Gas Co.	El Paso (NYSE: EP)	10,240
6	ANR Pipeline Co.	TransCanada (NYSE: TRP)	9587
7	Texas Eastern Transmission Co.	Spectra (NYSE: SE)	9115
8	Natural Gas Pipeline of America	Kinder Morgan (NYSE: KMP)	9045
9	Southern Natural Gas Co.	El Paso (NYSE: EP)	7636
10	Gulf South Pipeline Co. LP	Boardwalk Pipeline Partners (NYSE: BWP)	6499

2. Major players in the concurrent US natural gas transmission industry

The present study established that the leading parent companies as well as the ownership of US pipeline subsidiaries have both undergone significant mutations in the past decade. As a starting point, Table 1 lists the major US pipeline companies according to a 2007 mileage inventory. The US interstate pipelines, which spanned 212,000 miles in 2002 [14], has been expanded to 278,000 miles by 2009 [15]. The US gas transmission network serves a national consumer market of 62.5 Bcf/d (2008 data [16]), or 20% of the world's natural gas consumption totalling 315 Bcf/d [17]. For comparison, the EU holds 18,542 km (equivalent to 11,521 miles, 2007 data) transmission pipelines [18] to deliver an averaged total consumer demand of 58 Bcf/d (equivalent to 1.65 bcm/d).

The consolidation among the US interstate pipeline transmission companies that had started since 1992 [19] continued well into the 21st Century. The early consolidation followed the 1989 Natural Gas Wellhead Decontrol Act and the 1992 Energy Policy Act, which made use of natural gas instead of oil mandatory for all federal US public service organizations. Also, full third party access to the US gas transmission system became mandatory.

Table 2 lists the 10 US parent corporations that hold major natural gas transmission assets based on primary data from 2008 annual reports of the major US energy groups. The pipeline transmission subsidiaries and major brand names of these integrated energy majors are included in Table 2. It also followed from this study that the top 10 transmission companies now already account for 95% of the US natural gas transmission volume (Table 3, using 2007 transmission data from company reports). Consolidation in 1990s had clustered 90% of the US transmission volume in the top 10 companies by 2001 [20], but these companies differ from the ones identified here (see below).

What is not immediately apparent from company rankings based on pipeline mileage (cf. Table 1) is the fact that many pipelines have now been consolidated into so-called integrated energy groups. The major US integrated gas transmission companies have chosen various portfolio strategies, whereby corporate alignment is sought between natural gas transmission services and other assets and services in their corporate portfolios.

Fig. 3 classifies the major integrated energy companies based upon the portfolio type. For example, five firms (EP, SE, WMB, KMP and BWP) are exclusively dedicated to the natural gas value chain, and five other firms (MidAmerican, Ni, D, CMS and PGE) have substantial holdings in both the electricity and natural gas value chains. This includes MidAmerican Energy Holding Corporation (MidAmerican), which holds a major US natural gas pipeline (NNGC, Table 1), but is not itself listed on NYSE (only via a Berkshire Hathaway Incorporated [BRK.A]).

Table 2
Brand names and subsidiaries interstate pipelines; major US gas transmission companies market capitalizations as per 10 September 2009.

Parent company of energy group (NYSE symbol)/market capital (in billion USD)	Brand names and subsidiaries (50% stake or more) natural gas transmission
El Paso Corporation (EP)/6.55	Tennessee Gas Pipeline (TGP) El Paso Natural Gas (EPNG) Mojave Pipeline (MPC) Cheyenne Plains Gas Pipeline (CPG) Southern Natural Gas (SNG) Colorado Interstate Gas (CIG) Wyoming Interstate (WIC) Florida Gas Transmission (FGT) LLC
Spectra Energy Company (SE)/12.16	Texas Eastern Transmission (Texas Eastern) LP Algonquin Gas Transmission (Algonquin) LLC East Tennessee Natural Gas (East Tennessee) LLC Maritimes & Northeast Pipeline (Maritimes) LLC/LP Gulfstream Natural Gas System (Gulfstream) LLC
Williams Energy Services (WMB)/9.98	Williams Gas Pipeline Company (WMZ) Transcontinental Gas Pipeline Corporation (Transco) Northwest pipeline (GP) Gulfstream Natural Gas System (Gulfstream) LLC
MidAmerican Energy Holding Corporation, part of Berkshire Hathaway Inc. (BRK.A)/NA	Northern Natural Gas Company (NNGC) Kern River Gas Transmission Company (KRGTC)
NiSource Incorporated (NI)/3.66	Columbia Transmission Columbia Gulf Crossroads Pipeline Granite State Gas
Kinder Morgan Energy Partners (KMP)/15.11	Natural Gas Pipeline Company of America (NGPL) Gulf Coast Line
Dominion Resources Incorporated (D)/19.50	Dominion Energy Properties
CMS Energy (CMS)/2.96	Consumers Energy, mainly serving Michigan Consumers
Pacific Gas and Electricity Corporation (PCG)/14.70	PC and G Transmission Company, mainly serving Californian Consumers
Boardwalk Pipeline Partners (BWP)/4.40	Gulf South Pipeline LP Texas Gas Transmission LLC Gulf Crossing Pipeline

Table 3
Interstate pipeline and mileage throughput for the major US interstate gas transmission companies (2007 data).

NYSE	Company	Miles interstate pipeline 278,000	Percent of US total mileage 100%	Peak capacity and [actual through-put] 153 Bcf/d [62.5 Bcf/d]	Percent of US total capacity and [through-put]100% [100%]	Storage capacity [UGS]
EP	**El Paso Corporation**	42,000	15%	24.5 Bcf/d [17.5 Bcf/d] 71% utilization	16% [28%]	230 Bcf
SE	Spectra Energy Company	18,000	6.5%	– [9.9 Bcf/d]	[16%]	265 Bcf
WMB	**Williams Energy Services**	15,000	5.4%	13.7 Bcf/d [7.4 Bcf/d] 54% utilization	9% [12%]	216 Bcf
BRK.A[*]	**MidAmerican Energy Holdings**	16,900	6%	7.1 Bcf/d [5.3 Bcf/d] 75% utilization	4.6% [8.5%]	73 Bcf
NI	**NiSource Incorporated**	16,000	5.8%	– [4.5 Bcf/d]	[7.2%]	637 Bcf
KMP	**Kinder Morgan Energy Partners**	8700	3.1%	5.2 Bcf/d [4.4 Bcf/d] 85% utilization	3.4% [7%]	400 Bcf
D	Dominion Resources Incorporated	7800	2.8%	– [2.0 Bcf/d]	[3.2%]	975 Bcf
CMS	**CMS Energy**	1669 partly intrastate	0.6%	– [0.6 Bcf/d] 'local'	[1%]	143 Bcf
PCG'PG&E'	Pacific Gas & Electricity Corporation	6136 partly intrastate	2.2%	– [3.09 Bcf/d] 'local'	[5%]	47 Bcf
BWP	Boardwalk	14,000 (includes laterals)	5%	7.6 Bcf/d [4.8 Bcf/d]	5% [7.7%]	160 Bcf
Totals		146,205	52.2%	[59.5 Bcf/d]	[95%]	3.15 tcf

Companies printed in bold were selected for the peer group in the clockspeed benchmarking analysis.
[*] Privately held in Berkshire Hathaway.

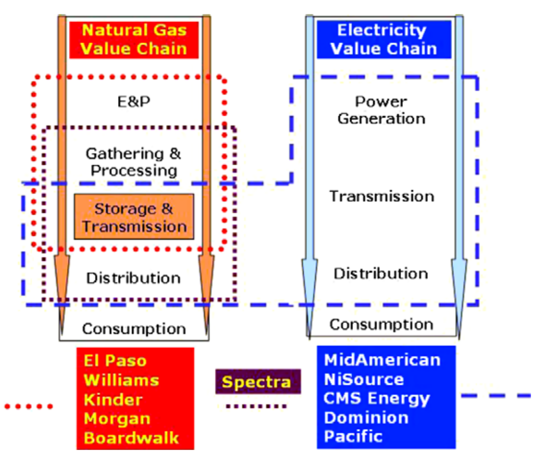

Fig. 3. Major US Energy companies with natural gas storage and transmission core assets.

One firm (KMP) also holds unique CO_2 extraction, transmission and injection business related to Texan oil field production flooding – amounting to 1.75 Bcf/d – in addition to its natural gas transmission activities.

Based upon the new inventory of this study, it became clear that the five leading players in the US natural gas transmission business (EP, SE, WMB, BRK.A and NI) hold 45% of the pipeline mileage and account for 70.2% of the actual natural gas transmission volume (Table 3).

3. Benchmarking the concurrent US natural gas transmission industry

The peer group of major US gas transmission companies selected here is first based on a ranking of the largest interstate pipeline mileage holdings and 2007 natural gas throughput volumes (Table 3). The total US interstate pipeline capacity (for 2007) stood at 153 Bcf/d with a time-averaged throughput of 62.5 Bcf/d (Table 3), which means the overall US natural gas system utilization is 41%. This capacity utilization is confirmed by systems statistics annually published by RexTag [21]. Clearly, companies like KMP (85% utilization), BRK.A with Northern Natural Gas Company (75% utilization), EP (71% utilization) and WMB (54% utilization) outperform the market in utilization of their pipeline asset capacity (Table 3).

For a quick comparison, Europe's pipeline utilization of the total constructed transmission capacity of 57.3 Bcf/d with 48.4 Bcf/d consumption throughput (taking 500 bcm/y or 17.67 tcf/y, for 2007) stands at 84.5% – more than double that of the US average capacity utilization and throughput load. The top three energy companies (EP, SE, WMB) jointly hold 1/3 of the total US interstate pipeline mileage and account for 56% of the domestic volume throughput (Table 3). In another view, the first seven US companies listed in Table 3 jointly hold 45% of the national interstate transmission pipeline mileage, and jointly transport 51 Bcf/d or 81.6% of the average daily consumption.

This study narrowed down the peer group for the clockspeed benchmark analysis as follows. Six major players in the US natural gas transmission business were selected for further analysis: El Paso, Williams, NiSource, Kinder Morgan, MidAmerican and CMS Energy. Three of these peer group companies occupy only the natural gas value chain (El Paso, Williams and Kinder Morgan), while the other three hold substantial assets in both the natural gas and electricity value chains (MidAmerican, NiSource and CMS Energy); see also Fig. 3. Spectra Energy, the second major US natural gas transporter, has been excluded from the peer group for practical reasons. That is because its demerger from Duke Energy in 2006 involved complex asset transfers, which precludes a full comparative time-series analysis over the period 2002–2007 chosen in this study. Boardwalk has emerged as a major new interstate gas trans-

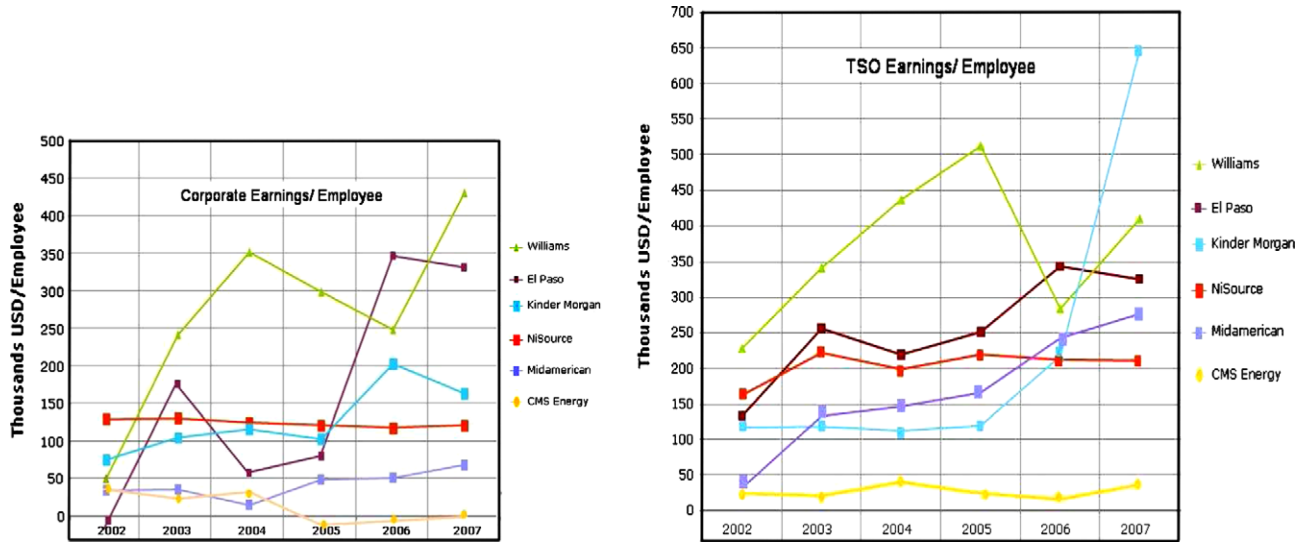

Fig. 4. (a) Corporate net income per employee for the peer group of six US Energy majors. (b) Net income per employee for the gas transmission business segment in the same peer group. (All data abstracted from annual reports).

mission company, but annual results are only available since the company's formation late 2005 for full fiscal year 2006 and onwards, deemed too short for the 6 year time-series analysis performed for this study. Dominion and PG&E annual reports did not allow simple extraction nor deduction of specific revenues for their gas transmission business segments, and therefore were excluded from the peer group analysis.

One may ask: "How well are the US energy utility groups, with major natural gas transmission assets, performing?" They are diversified – but there remain synergies in their portfolios. For each of the companies included in the peer group analysis, corporate and natural gas transmission business clockspeed performance have been simultaneously benchmarked. This reveals how the gas transmission segment contributes to the corporate performance relative to the other business segments in the corporate portfolio. The key question for individual companies remains: 'How is our performance in comparison to the leader of best-in-class-practice?'

3.1. Clockspeed accelerator 1

Clockspeed accelerator 1 is a lever of workflow speed aiming for higher workflow efficiency. The workflow clockspeed is accelerating positively when operational efficiency or productivity is improving over time. The measure chosen here for workflow effectiveness focuses on the optimization of core asset exploitation. This can be monitored by the net income per employee, generated by the natural gas transmission system capacity utilization and performance, as well as at corporate level. Companies that have realized high annually-averaged throughput volumes relative to the transmission system design capacity demonstrate the ability to optimize their system-wide flow rates relative to system peak throughput. If peak-day usage rates are effectively balanced with baseload system deliveries, this shows how the system effectively matches demand from shippers with peak-day needs. Employees per segment dedicated to the gas transmission business company are either specifically stated by the peer group companies or estimated based on asset values; there is a proportional allocation of corporate staff to the transmission segment.

The annualized net income per employee is taken here as the most concise macroscopic measure connecting operational workflow efficiency and financial performance. Pipeline complexity can either suppress or increase system efficiency and is implicitly accounted for by the analysis. Effective utilization of existing capacity per pipeline length is also accounted for by this approach (see also discussion in Section 5).

Fig. 4a shows the ratio of corporate earnings per employee, and Fig 4b earnings per employee involved with the gas transmission business. These plots were subjected to time-series and cross-sectional analysis of the peer group, which allows a comparison of net income (profit) of pipeline operations and corporate net income or profit. The *time-series analysis* in this study classifies the trend and shape of time-series in Fig. 4a and b and then ranks them in terms of strongest (maximum mark of six in peer group of six

Table 4a
Corporate peer group ranking of clockspeed accelerator 1 for US natural gas majors.

Company	Time-series analysis	Cross-sectional analysis	Total points	Rank*
El Paso	5	5	10	5
Williams	6	6	12	6
MidAmerican	3	2	5	3
NiSource	2	3	5	2
Kinder Morgan	4	4	8	4
CMS Energy	1	1	2	1

* Time-series prevails for equal total points.

Table 4b
Gas transmission business peer group ranking of clockspeed accelerator 1 for US natural gas majors.

Company	Time-series analysis	Cross-sectional analysis	Total points	Rank*
El Paso	4	4	8	4
Williams	3	5	8	3
MidAmerican	5	3	8	5
NiSource	2	2	4	2
Kinder Morgan	6	6	12	6
CMS Energy	1	1	2	1

* Time-series prevails for equal total points.

companies) and weakest acceleration (minimum mark of one in peer group of six companies), see Tables 4a and b.

Cross-sectional analysis was subsequently applied for each time-series in the peer group. This provides an additional benchmark for their relative performance in clockspeed accelerator 1, and ranks absolute productivity strength for 2007 (maximum mark of six in peer group of six companies) and weakest productivity for 2007 (minimum mark of one in peer group of six companies), see Tables 4a and b. The scores from the time-series analysis and cross-sectional analysis are totalled and ranked to establish the relative performance of clockspeed accelerators 1 in the peer group for both the overall corporate and gas transmission business results (see Tables 4a and b, last column).

3.2. Clockspeed accelerator 2

Clockspeed accelerator 2 is a lever of improvement rate of risk management aiming to avert negative impact on the business (at project and portfolio level). Risk management is concerned with identifying risks and mitigating their effect on projects and the corporate portfolio. Risk mitigation is successful when volatility in the core asset exploitation is minimized. Natural gas transmission businesses traditionally focus on operational risks and HSE improvements. These risks translate into exploitation loss when planned an unplanned interruptions of transmission services suppress net income. Accidents and the attendant litigation could also severely impact company profitability. Integrity expenditure is essential for long-term success. Project risks affect schedule or resources; it may also affect the quality of performance and software solutions may play a crucial role. Software integrity problems can jeopardize both efficiency and safety of pipeline systems.

A concise measure of success in avoiding high-impact events is the steadiness and growth of the company's return on equity. In this view, the prudent investor reacts to performance failures of the company. The company is penalized for disappointing results and rewarded by results that satisfy the shareholders. The Capital Asset Pricing Model and time-value of money demand from prudent investors (both public and private sectors) to hold shares only in those companies and projects that can be expected to yield risk premiums adequately compensating above the rate of return on investment in the more secure capital markets [22]. Fig. 5 plots the Total Shareholder Return (TSR) over a 5-year period for the 6 peer group companies studied here. The TSR is the compounded value made up of capital gain both by real growth and market expectation (P/E ratio effect), plus dividend payments and share repurchase programs. The reference is a 100 USD investment on 31 December 2002. Berkshire Hathaway was taken as a proxy for MidAmerican Energy Holding Corporation, which itself is not a NYSE traded entity but part of Berkshire Hathaway Inc. (NYSE: BRK.A).

The TSR time-series of Fig. 5 shows an exceptional performance by Williams Energy Services, which outperformed all indexes as well as all peer companies. This performance can be ascribed to exceptional capital gains over the period studied (2002–2007) after the 2002 restructuring of Williams, whereby the number of employees that remained in the consolidated energy holding was more than halved. Also 2002 was a year of extremely low share prices for Williams, meaning that steep capital gains were possible from that reference year onward. The performance of Williams also pulled up all peer group indexes over the study period (S&P Oil Gas Storage & Transportation Index, Bloomberg Pipeline Index, and the Utility Index, see Fig. 5). In fact, taking 31 December 2003 as a reference still shows Williams as a winner (plot not included here), but with much smaller differences with El Paso an others in the peer group. Noteworthy, El Paso also laid off 2/3 of its employees

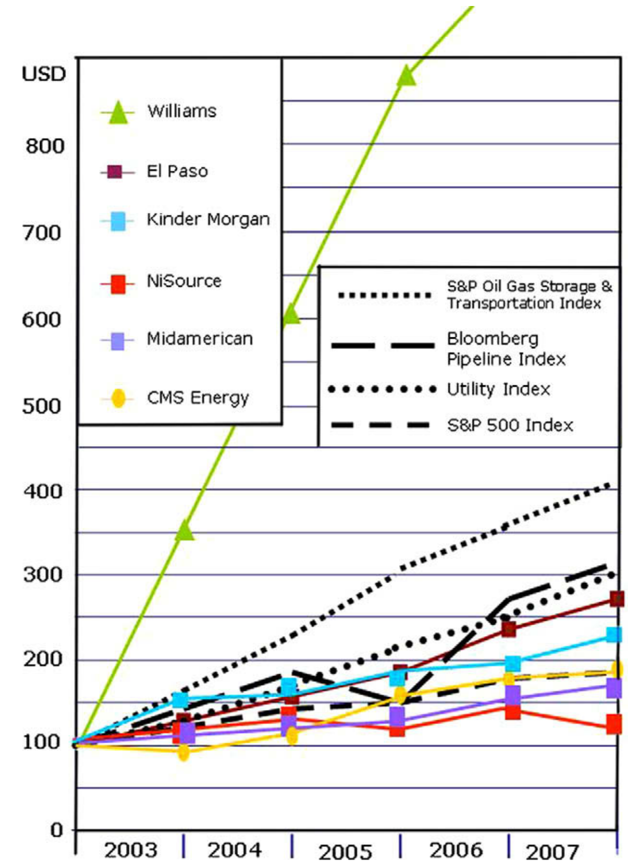

Fig. 5. TSR for peer group companies, showing value development of 100 USD invested in company on 31 December 2002. Williams goes off the scale with TSR accrual of 1005 USD for 2006 and 1393 USD for 2007 (data from company reports).

Table 5
Corporate & TSO peer group ranking of clockspeed accelerator 2 for US Natural Gas Majors.

Company	Time-series analysis	Cross-sectional analysis	Total points	Rank*
El Paso	5	1	6	3
Williams	6	2	8	5
MidAmerican	2	4	6	2
NiSource	1	3	4	1
Kinder Morgan	4	6	10	6
CMS Energy	3	5	8	4

* Time-series prevails for equal total points.

in a 2002 restructuring, and its TSR performance since then has been second best in the peer group.

The TSR time-series of Fig. 5 are ranked as most reliable and stable returns (maximum mark of six in peer group of six companies) and least reliable and unstable returns (minimum mark of one in peer group of six companies), see Table 5. The volatility of TSR in the time-series analysis is a proxy for factors such as the business impact of operational risks. However, it can be concluded that shareholders of the companies studied have not been negatively surprised by any extreme impact situation over the period 2003–2007, as can be concluded from the absence of long-term volatility in TSRs (Fig. 5).

For the cross-sectional analysis of risk perception and stock volatility relative to the market, Beta values were used as per 31

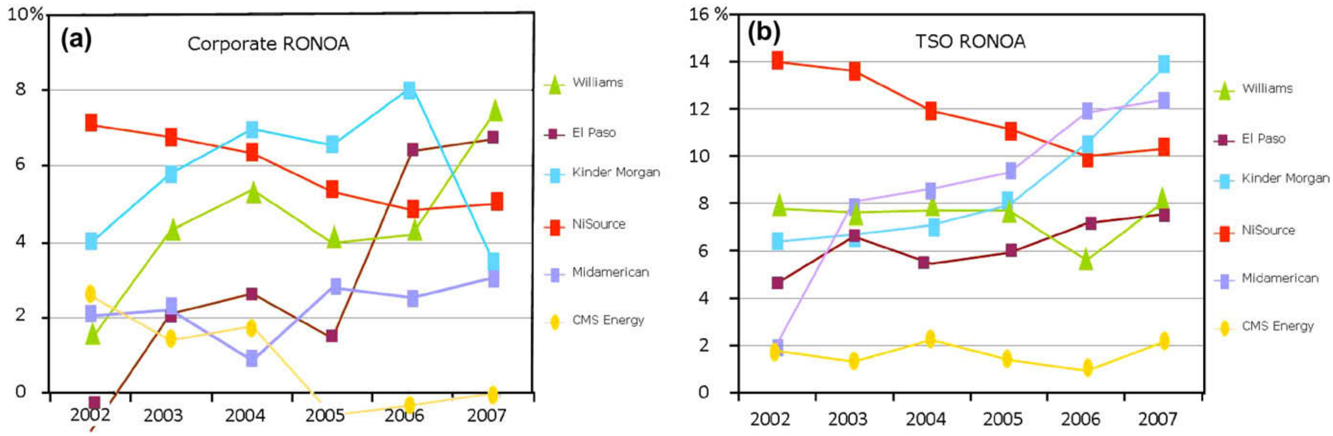

Fig. 6. (a) RONOA for the peer group of six US energy companies. (b) RONOA for their gas transmission business. (Data abstracted from annual company reports).

December 2007. The Beta values were, respectively: EP-1.20, WMB-1.28, BRK.A-0.62, NI-0.78, KMP-0.25, and CMS-0.60. These Betas provide an additional benchmark for the relative performance in clockspeed accelerator 2. Remember that the S&P index has Beta = 1, which means that company stocks with Beta > 1 have performed with a systematic risk higher than the market. In contrast stocks with Beta < 1 have a lower volatility, meaning lower systematic risk than the market; Betas below 1 are 'less risky' than the market.

Beta values also can be related to the relative change in a share's risk premium relative to the 'market' portfolio (e.g., [22]):

$$\mathrm{ROE} = \mathrm{RF} + \text{Market Return Premium} * \text{Beta} \tag{1}$$

ROE is return on equity and RF is the Risk-free Rate of Return set by short-term Treasury bills. All other things being equal (*Ceteris Paribus*), Eq. (1) shows that the ROE for low-Beta stocks will be lower than for high-Beta stocks. For example, if the S&P market portfolio (which has Beta = 1 by definition) rises 10%, than a company like El Paso with a Beta of 1.20 (on 31 December 2007) is expected to yield returns of 12%. Likewise, a lower risk company like Kinder Morgan with Beta of 0.25 (on 31 December 2007) is expected to yield returns of only 2.5%. Table 5 ranks absolute Beta values in the cross-sectional analysis (the lowest Beta – 'less risky' – gives a maximum mark of six in peer group of six companies, and the highest Beta – 'more risky' – gives minimum mark of one in peer group). The total scores from the time-series analysis and cross-sectional analysis are summed and ranked to arrive at relative ranking for clockspeed accelerators 2, which holds for both the overall corporate and gas transmission business (see Table 5, last column).

3.3. Clockspeed accelerator 3

Clockspeed accelerator 3 is a lever of accrual speed of true portfolio asset value, aiming for the highest growth. Portfolio value is growing fastest when projects are phased to avoid that the company's resources (people, equipment and capital) are not unduely strained such as to depress profitability (e.g., ROCE – previous studies – or RONOA – this study). In particular, major acquisitions that are capital intensive provide the risk that the return on investment by the company is not coming on stream fast enough to provide cash for new projects.

The Return on Net Operating Assets (RONOA), here taken is the ratio of operating income (EBIT) and net operating assets. Net operating assets are tangible fixed assets plus inventory plus trades receivables less payables; in natural gas business, fixed assets values are a good approximation of net operating assets. Fig. 6a graphs the corporate RONOA for the six peer group companies over a 6-year period. Fig. 6b graphs similar results for the peer group's respective natural gas transmission business segments.

Table 6a
Corporate peer group ranking of clockspeed accelerator 3 for US natural gas majors.

Company	Time-series analysis	Cross-sectional analysis	Total points	Rank*
El Paso	6	5	11	6
Williams	5	6	11	5
MidAmerican	4	2	6	4
NiSource	2	4	6	2
Kinder Morgan	3	3	6	3
CMS Energy	1	1	2	1

* Time-series prevails for equal total points.

Table 6b
Gas transmission business peer group ranking of clockspeed accelerator 3 for US natural gas majors.

Company	Time-series analysis	Cross-sectional analysis	Total points	Rank*
El Paso	4	2	6	4
Williams	3	3	6	3
MidAmerican	6	5	11	6
NiSource	1	4	5	2
Kinder Morgan	5	6	11	5
CMS Energy	2	1	3	1

* Time-series prevails for equal total points.

The time-series analysis classifies the trend and shape of the RONOA of Fig. 6a and b. The corporate RONOA time-series shows positive slopes for the regression lines of El Paso, Williams, and MidAmerican; alternating positive and negative slopes for Kinder Morgan, and negative slopes for CMS Energy and NiSource. The RONOA for the gas transmission business shows positive slopes: for MidAmerican, Kinder Morgan, and El Paso, neutral slopes for CMS Energy and Williams, and a negative slope for Ni Source. These slopes have been ranked in terms of strongest (maximum mark of six in peer group of six companies) and weakest acceleration of RONOA (minimum mark of one in peer group of six companies), see Tables 6a and b.

Cross-sectional analysis was subsequently applied for each time-series of the peer group companies. This provides an additional benchmark for their relative performance in clockspeed accelerator 3, and ranks absolute RONOA strenght in 2007 (maximum mark of six in peer group of six companies) and weakest RONOA in 2007 (minimum mark of one in peer group of six companies), see Tables 6a and b.

Table 7a
Corporate peer group ranking of clockspeed accelerators 1, 2 and 3 for US natural gas majors.

Company	Accelerator 1	Accelerator 2	Accelerator 3	Total points	Rank
El Paso	5	3	6	14	5
Williams	6	5	5	16	6
MidAmerican	3	2	4	9	3
NiSource	2	1	2	5	1
Kinder Morgan	4	6	3	11	4
CMS Energy	1	4	1	6	2

Table 7b
Gas transmission business peer group ranking of clockspeed accelerators 1, 2 and 3 for US natural gas majors.

Company	Accelerator 1	Accelerator 2	Accelerator 3	Total points	Rank
El Paso	4	3	4	11	4
Williams	3	5	3	11	3
MidAmerican	5	2	6	13	5
NiSource	2	1	2	5	1
Kinder Morgan	6	6	5	17	6
CMS Energy	1	4	1	6	2

The total scores from the time-series analysis and cross-sectional analysis are summed and ranked to arrive at relative ranking for clockspeed accelerators 3 in the peer group for both the overall corporate and gas transmission business results (see Tables 6a and b, last column).

Tables 7a and b ranks the cardinal measures for scoring each of the three clockspeed accelerators, based on the data listed in Tables 4a and b, 5 and 6a and b. In the corporate ranking of the peer group, overall *corporate clockspeed winners* are: Williams, El Paso and Kinder Morgan; MidAmerican is a close follower. *Corporate clockspeed laggards* are: CMS Energy and NiSource. The peer group ranking for the *natural gas transmission business segment* shows similar *clockspeed winners*, but with different ranking in the following order: Kinder Morgan, MidAmerican and El Paso; Williams is a close follower. *Clockspeed laggards for the natural gas transmission segments* coincide with the corporate clockspeed laggards of the peer group: CMS Energy and NiSource.

4. Radargraph presentation of clockspeed accelerators for US energy utilities

A concise graphical representation for the three clockspeed dimensions above can be practical to quickly assess the relative clockspeed performance of the peer group companies; a tri-axial radargraph adequately serves this purpose. Fig. 7 plots a clockspeed radargraph for the near optimum case, where improvement of workflow speed, improvement rate of risk mitigation (reflecting state-of-the-art decision-making and risk analysis) and accrual speed of portfolio value or full asset value in the corporate portfolio are all realized.

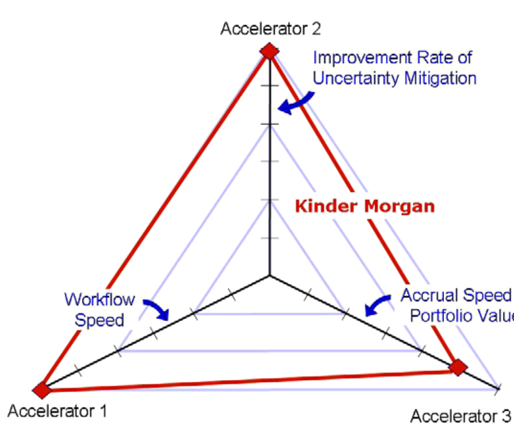

Fig. 7. Optimum clockspeed accelerator settings (6, 6, 6). The example shows clockspeed settings for Kinder Morgan's gas transmission business segment (6, 6, 5), based upon the peer group scaling of Table 7b.

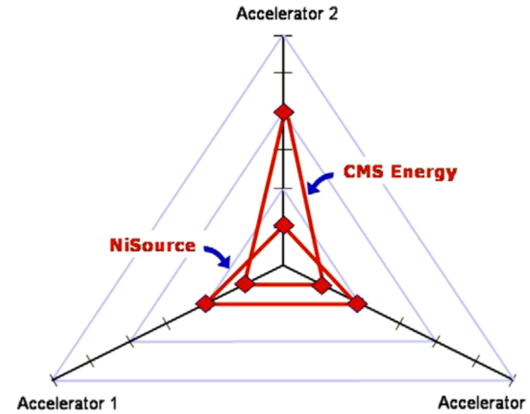

Fig. 8. Suboptimum clockspeed accelerator settings. For example, this applies to the both the corporate and gas transmission businesses of CMS Energy and NiSource, based on the peer group scalings of Tables 7a and b.

In contrast, sub-optimum clockspeed settings occur when workflow speed is less effective, risk mitigation is insufficiently rewarded by the market, and portfolio value growth is slower than that of peers. For example, NiSource and CMS Energy show sub-optimum clockspeed accelerator settings (for both Corporate and gas transmission business) in the present peer group analysis over the period 2002–2007 as indicated by the time-averaged (under) performance of each of the three clockspeed accelerators for these companies (Fig. 8).

More examples of clockspeed radargraph representations of the clockspeed accelerators for companies in the peer group (listed in Tables 7a and b), are given in Fig. 9. Assessing for positive or negative changes in clockspeed accelerators settings provides a powerful monitoring concept for the effects of strategic choices and operational efficiencies. Clockspeed benchmarking is an intelligent method to steer for growth and predict the efficiency of competitive performance. As further efforts are needed to enhance clockspeed acceleration in the US gas transmission industry, the critical drivers of the three clockspeed accelerators are discussed in the next section.

5. Discussion of benchmark results

Clockspeed accelerators have been benchmarked in order to monitor the competitive performance of six peer group companies. Clockspeed accelerators are managerial levers, linking strategic and operational effectiveness, and need adjustment when performance is lagging. The optimization of clockspeed accelerator settings generally involves efficiency measures, commonly improving workflow speed, with reliable quality and focus on value creation.

Clockspeed winners in the gas transmission business segment (e.g., Kinder Morgan, MidAmerican and El Paso) have *accelerator 1 settings* with earnings per employee well above 250,000 USD and amounts to 650,000 USD/employee per year for Kinder Morgan (in 2007, see Fig. 4b). An alternative measure of efficiency is pipeline capacity utilization. Table 3 shows that Kinder Morgan, MidAmerican (Northern Natural Gas), and El Paso operate transport throughput volumes at 85%, 75%, and 71% of their pipeline design

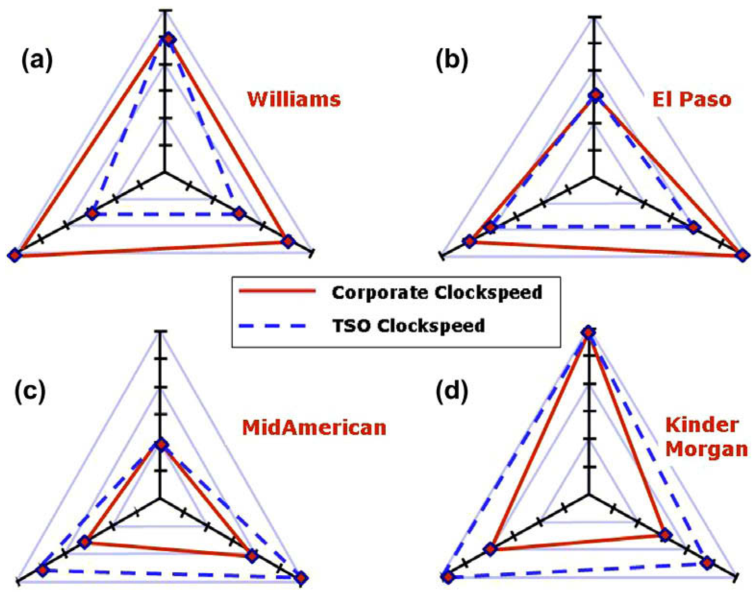

Fig. 9. Clockspeed accelerator settings for peer group companies: Williams, El Paso, MidAmerican and Kinder Morgan. For Williams and El Paso, the corporate clockspeed accelerator settings (in red, solid line) outperform their gas transmission business settings (in blue, dashed). For MidAmerican and Kinder Morgan, the reverse holds: corporate clockspeeds accelerators score less optimum than their gas transmission business accelerators. Based upon benchmark data in Tables 7a and b. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

capacity. That is well above the 41% average for US transmission pipeline utilization. Clockspeed accelerator 1 setting is more competitive when system utilization is higher and translates to a high profit per employee.

The optimization of clockspeed accelerator 1 settings occurs by regular, dynamic upgrading through talent management (improving skills) and enabling through innovation (improving system operation technology tools and processes/best practices). At the corporate level, improving the speed of workflow also includes the optimization of vision sharing by the top management, strategy planning, alignment and operational excellence in executing the corporate strategy. The workflow process effectiveness commonly benefits from a well-defined workflow architecture, with decision-gate stages and set criteria for all major business decisions.

Clockspeed winners avoid undue volatility in their *accelerator 2 settings*. When such volatility occurs, that would reflect the accumulation of poor corporate governance, poor strategic decisions, poor project management and a poor safety record. For example, extreme volatility in accelerator 2 occurred for ENRON when still active. Each organization must learn from past mistakes and select and excel in best practice by rapid organizational learning. Risk management (at project level and at corporate portfolio level) is a key topic in the company's strategy realization process.

The optimization of clockspeed accelerator 2 settings requires good corporate governance, attention for and optimization of HSE, working cleaner and making fewer mistakes. Project risks, commonly hedged by diversity in portfolio, within the transmis-

Table 8
Business portfolios of El Paso Corporation and Williams energy services (2007 data).

NYSE	Company	Major business units	Major assets, products and services	Asset value billions USD	Asset value %	Operating net income EBIT millions USD	Net income %
EP	El Paso Corporation	– Gas pipelines	42,000 miles 17.5 Bcf/d	16.8	46.3	1273	73.4
	5344 employees	– E&P	289 Bcf prod 2.8 tcf reserves Incl. Int. operations Brazil and Egypt	19	52.3	909	55.2
		– Gas marketing				(202)	(12.3)
		– Power (divested)	549 MW Brazil and Pakistan	0.5	1.4	(37)	(22.5)
		– Corporate				(283)	(17.2)
		– Others				(15)	(0.1)
		Total		36.3	100	1645	100
WMB	Williams energy services	– Gas pipelines	15,000 miles 7.4 Bcf/d	9.5	41.7	622	33.4
	4319 employees	– E&P	360 Bcf prod. 4.1 tcf reserves	7.7	33.8	731	39.2
		– Midstream gas and liquids		5.3	23.2	1011	54.2
		– Gas marketing		0.06	0.3	(337)	(18.2)
		– Corporate		0.25	1.0	(161)	(8.6)
		– Others				(1)	(–)
		Total		22.8	100	1865	100

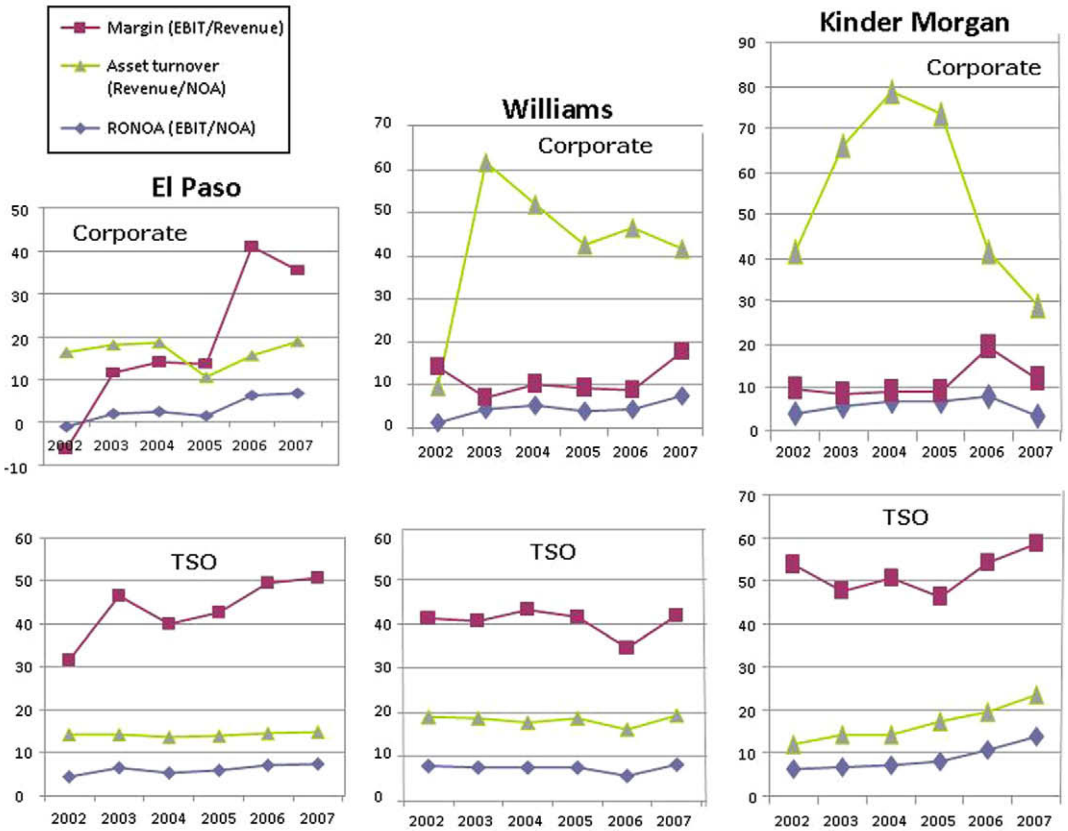

Fig. 10. Margin, turnover and RONOA (all as percentage ratios) for corporate and gas transmission (TSO) assets of El Paso, Williams and Kinder Morgan. These companies are exclusively active in the natural gas value chain (see also Fig. 3).

sion segment reside in operational issues and risk mitigation is improved when delays in projects are minimized and HSE performance is optimized, in order to avoid negative impacts on IRR. Noteworthy, internationalization means becoming less risk averse. Nearly all US gas transmission companies have divested their earlier ventures into international holdings, except for MidAmerican which holds major utility companies in the UK, and El Paso which holds E&P operations in Egypt (Brasil 2007 holdings in process of being divested). The volatility of TSR in the time-series analysis and Beta in the cross-sectional analysis serve as proxies for factors such as the adverse business impact of detoriating operational risks. However, it can be concluded that shareholders of the companies studied have not been negatively surprised by any extreme impact situation over the period 2003–2007, as can be concluded from the positive growth of TSR for all companies (Fig. 5). Betas for El Paso and Williams are 1.20 and 1.28, respectively, which indicates these stocks bear higher risk than the market (Beta = 1). This volatility reflects the impact of the 2001 and 2002 restructurings and a certain exposure to trading risks as these two companies are the only ones in the peer group with marketing activities (i.e., shipping and natural gas trading). The portfolio profiles of El Paso and Williams are summarized in Table 8. This inventory reveals that natural gas marketing activities have incurred losses in 2007, for both companies.

Clockspeed winners in the gas transmission business segment have *accelerator 3 settings* that add asset value (RONOA) of between 8% and 12%, but with clockspeed leaders like Kinder Morgan reaching 14% RONOA in 2007 (see Fig. 6b). Interestingly, the RONOAs for gas transmission business assets range between 8% and 14% in 2007 for five of the six peer companies studied (Fig. 6b). In contrast, the corporate RONOAs range between 3% and 7% (Fig. 6a), which means that gas transmission is a most profitable business segment in the overall portfolio. Fig. 10 confirms this by showing margin, asset turnover and RONOA, for both the corporate and the gas transmission assets.

The further optimization of clockspeed accelerator 3 settings involves optimization of the core asset exploitation and innovation in transportation and storage services. The RONOA (=EBIT/net operating assets) can be optimized when EBIT is maximized by enhancing the sales of throughput volumes utilizing the system capacity to the maximum and by minimizing operational costs (OPEX of fuel, labor, maintenance, security). RONOA is also boosted by keeping net operating assets as small as possible, utilizing the tangible fixed asset to the maximum and avoiding inventory and receivables, while maximizing payables. Control over expenses in project execution covers detailed issues such as operation and maintenance, contractor and employee cost, fuel and electricity costs, and insurance (OPEX is included in the net profit process outcome as a workflow process input). At corporate level, the rate-making negotiations with the regulator set the constraints for the corporate earnings. Stakeholder management also is at the core of the Open seasons and consultation process for forward capacity planning.

6. Recommendations and conclusions

It can be concluded that excessive capital gains have not occurred over the past decade in the natural gas business or energy utilities at large. This can be convincingly argued and demonstrated as follows. The US natural gas transmission industry inventory of the late 1990s [19] listed 14 major pipeline parent corporations that accounted for 85% of the US interstate pipeline activity. In 1999, nine of these companies had revenues that still ranked them in the Fortune 500 list of the world's leading companies. By 2009, about half of these 14 companies listed in the study of Johnson's et al. [19] have ceased to exist either by failure, or M&As. What is more, of these consolidated companies none appears listed on the 2009 Fortune Global 500, which has a 2009-threshold revenue of 18.5 billion USD for the last number 500 entry. The 2007 annual corporate revenues for the US peer group energy utilities studied range between 4.6 and 12.4 billion USD. This also means that these US energy utilities have been massively outperformed over the past decade by other growth industries, which did translate capital gains into revenue and profit growth.

The revenues of utilities have remained relatively stable over the past decade, and the same applies to their shareholder returns (Fig. 5). Excessive capital gains that led to steep revenue increase cannot be claimed for the energy utilities, because they have been demonstrably outperformed by the market as outlined above. This also means that FERC and state regulators must be careful in excluding the utility's actual costs from the revenue requirements in rate-making agreements. FERC and state regulators are selective in accepting the cost of providing competitive energy. In fact, the absence of the US energy utilities from the Fortune Global 500 listing could be argued to result from overly stern regulations. Some would call this a success (e.g., consumer advocacy groups), whereas the lack of steep revenue growth (assuming commensurate profit growth) may be called a failure by others (e.g., investors). Nonetheless, energy utilities remain relatively attractive investment vehicles as their Total Shareholder Returns (TSR) are generally positive and the volatility (Beta) of energy utility stocks is traditionally low (Beta < 1) and therefore less risky than the market portfolio (Beta = 1). However, this study showed that the traditional low volatility has been replaced by high volatility for Williams and El Paso (Betas of 1.28 and 1.20, respectively). The increased volatility of these stocks has been compensated for by higher TSRs over the study period (2002–2007, see Fig. 5), which is in line with CAPM and thus satisfactory for prudent investors.

From the point of view of competitiveness, within the constraints of regulation, US energy utilities still are competing for investors' money to ensure their highest return on investment. Although returns are regulated sternly by the FERC (midstream) and the Public Utility State Commissions (downstream), there remains certainly room for clockspeed optimization to gain the competitive edge. The clockspeed accelerators outlined in this study are subject to both *internal* and *external dependencies*, which need continual attention as follows:

– Improved control over internal clockspeed dependencies mandates direction-setting by the corporate leadership. This includes strategy shifts that require adaptations of the workflow to improve the alignment of all key resources: people, technology and processes (e.g., [23]). Effective workflow optimization commonly involves adaptation of the organizational structures and culture, or adoption of new technology, training and recruitment of new employees to expand the available skills and experience base. Implied in workflow optimization is the continual vigilance by the upper management to react to developments in the external business environment that may obstruct the company's workflow progression at the fastest clockspeed.
– The adjustments of external clockspeed dependencies include rate-making, permitting and land use impacted by federal, state, and county regulations. Companies that can best manage the stakeholders will be winners of optimizing external clockspeed dependencies. Balancing stakeholder demands and expectations also is essential for long-term success. Adjustments of the US gas transmission industry's clockspeed as a whole may help to keep this business segment attractive for investors and results in positive stock market valuations. It is particularly here where the role of regulators (FERC and state commissions) is crucial. Regulators can either help to accelerate industry clockspeed or decelerate, depending upon their speed of decision-making in rate cases and other regulatory issues.

In conclusion, executives and other professionals in the natural gas transmission industry and associated organizations (i.e., regulators and policy-makers) may benefit from this study by:

– Enhancing their insight in the concept of clockspeed in natural gas transmission setting.
– Using clockspeed accelerators as gearshift levers to adjust and improve their company's clockspeed, and the industry as a whole.
– Visualizing clockspeed in radargraphs to monitor past results and direct future performance.
– Understanding the critical drivers of clockspeed acceleration in the natural gas transmission industry, based on the companies studied.
– Applying the set of guidelines and recommendations in support of the speeding up and optimization of the gas transmission business at large.

Additional recommendations for strategic optimization of the project portfolios of energy utility companies as well as their financial management tactics are given in a companion study [1].

Trademark

Companies interested in using clockspeed accelerators™ as a strategy tool for competitive advantage are kindly requested to contact the author for further information. The term clockspeed accelerator™ is in the process of being trademarked by Alboran Media Group. The function of this trademark is to exclusively identify the source of this conceptual tool. Alboran will grant permission to any author to use, for non-commercial purposes, the term clockspeed accelerator™ in the conceptual sense outlined in this study.

Disclaimer

This study analyzes company performance in terms of clockspeed acceleration, based on data abstracted from company reports. By its nature, the analysis of empirical data involves a degree of uncertainty connected to the assumptions made. The author and publisher take no responsibility for any liabilities claimed by companies included in this study.

References

[1] Weijermars R. Value chain analysis of the natural gas industry – lessons from the US regulatory success and opportunities for Europe. Nat Gas Sci Eng 2010;2:in press.
[2] Fine CH. Industry clockspeed and competency chain design: an introductory essay. MIT Sloan White paper #147-96; 1996.
[3] Fine CH. Clockspeed: winning industry control in the age of temporary advantage. Reading. MA: Perseus Books; 1998.
[4] Fine CH. Clockspeed-based strategies for supply chain design. Product Operat Manage 2009;9(#3):213–21.
[5] Fine CH. Clockspeed: using business genetics to evolve faster than your competitors. London: Little Brown and Company; 2001.
[6] Guimaraes T, Cook D, Natarajan N. Exploring the importance of business clockspeed as a moderator for determinants of supplier network performance. Decis Sci 2000;33(4):629–44.
[7] Meijboom B, Voordijk H, Akkermans H. The effect of industry clockspeed on supply chain co-ordination. Business Process Manage J 2007;13:553–71.

[8] Weijermars R. Accelerating the three dimensions of E&P clockspeed – a novel strategy for optimizing utility in the oil & gas industry. Appl Energy 2009;86:2222–43.
[9] Weijermars R. Competitive advantage from an E&P clockspeed accelerator. First Break 2009;27:87–94.
[10] Noke H, Perrons RK, Hughes M. Strategic dalliances as an enabler for discontinuous innovation in slow clockspeed industries: evidence from the oil and gas industry. R&D Management 2008;38:129–39.
[11] Weijermars R. Building corporate IQ. Alboran Science Publishing; 2008.
[12] Karloff B, Ostblom S. Benchmarking – a signpost to excellence in quality and productivity. New York (USA): John Wiley & Sons; 1994.
[13] Dale BG, Bunney H. Total quality management blueprint. Blackwell Publishing; 1999.
[14] DOE/EIA. US gas transmission data; 2002.
[15] Miesner T. A practical guide to US natural gas transmission pipeline economics. An oil & gas journal research center™ research report from PennEnergy, Penwell; 2009.
[16] DOE/EIA. US gas transmission data; 2009.
[17] DOE/EIA. Short term energy outlook; September 2009.
[18] Makholm JD. Seeking competition and supply security in natural gas: the US experience and European challenge. Boston: National Economic Research Associates; 2007.
[19] Johnson S, Rasmussen J, Tobin J. Corporate realignments and investments in the interstate natural gas transmission system. Energy information administration, natural gas monthly, vol. 89, 1999. p. 7–23.
[20] Dahl CA. International energy markets. Penwell Books; 2004
[21] Anonymous, Rextag. Interstate natural gas infrastructure map book. Rextag Strategies. Rextag; 2009, p. 327.
[22] Lumby S, Jones C. Corporate finance. Cengage learning, 7th ed. Formerly Thomson Publishing; 2003.
[23] Weijermars R. Balancing Venturi and Laissez-Faire management styles: insights from fluid mechanical analogs. J System, Cybernet Informat 2008;5(#6):1–9.