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Abstract

Real Option valuation has been identified as an appropriate way to assess IT Investment projects that face high levels of future uncertainties. The challenge with the Real Option approach is that project risk, expressed as the variance in the Black-Scholes Formula, is difficult to estimate. This paper tries to identify the parameters that influence the risk of an IT investment project, considering both the external autonomy of the player in implementing a new technology and the internal properties in technology adoption. The risk parameters are operationalized step-by-step and integrated into a decision model to help each individual firm put the IT investment decision into real numbers. In order to better visualize the parameters of this decision framework, four company profiles, based on the theory of technology diffusion, will be introduced and mapped against the risk parameters of the Black-Scholes formula.

Introduction

The key question for companies is not whether to invest in new Information Technology at all, but rather when and to what extent. Most IT projects today (EDI, SAP, ebXML, etc.) have high network externalities. Thus, such a technology will be more valuable, the more other companies have implemented the same technology. The inherent risk is whether business partners and competitors will use the same technology, or might possibly invest into different technologies, or not invest at all. The latter case applies when, making new IT investments will influence the ROI on past IT investments.

Traditional capital budgeting techniques for investment decisions under certainty, which are most commonly used in practice, fail to show the real value of strategic IT investments, as they do not consider the stages of the diffusion process of a new technology. While discounted cash flow (DCF) evaluation methods can work well when a project generates predictable cash flows, they can perform poorly when a project provides managers with flexibility regarding future decisions.

Since most IT investments incorporate highly uncertain future outcomes, methods of investment under uncertainty like probabilistic methods and Real Option methods have to be applied (Dixit et al. 1994). The downside of the option pricing approach is, that the data is difficult to estimate. This especially applies to the estimation of the variance of the expected return of an IT investment. In the case of a financial option, the variance is the variability of the underlying stock, which the option trader can obtain by option valuation. But how is a company going to estimate the variability of future project cash flows of an IT investment?

This paper will briefly introduce the core ideas of the Real Option approach as well as the variable of the formula. The core part will analyze different sources of risk in an IT investment project. A risk assessment framework will be presented enabling companies to assess the risk parameter of IT investment projects. Finally the risk parameters will be mapped against 4 company profiles to makes the parameters less theoretic, and more intuitively understandable.

Assessing Strategic IT Investments – Real Options Approach

The concept of a Real Option arose from earlier research on financial options by Fischer Black and Myron Scholes (Black et al. 1973) as well as Robert Merton (Merton 1973). It was noted by Stewart Myers (Myers 1977) that similar ideas could be applied to real (i.e. non-financial) assets and the term, Real Option was born.

Myers saw that many business investment decisions have similarities to a financial call option. A financial option conveys the right but not the obligation, to buy or sell an asset at a predetermined price at a future time. By investing into an uncertain research and development project, a firm has in effect purchased an option. At various stages in the future, the firm's managers will be able to respond to the preliminary results of the research and will have the option to continue, abandon, scale up or scale down the project (Trigeorgis 1996). Typical applications of DCF appraisal techniques ignore this option value and could undervalue the project by using inappropriately high discount rates, causing it to be rejected.

The formula for pricing European call options,[1] c, on financial assets developed by Black and Scholes (Black et al. 1973) has been described as a function of five parameters: The price of the underlying asset, S; the instantaneous variance of the assets returns, σ^2; the exercise price, X; the time to expiration, t; and the risk-free rate, r_f.

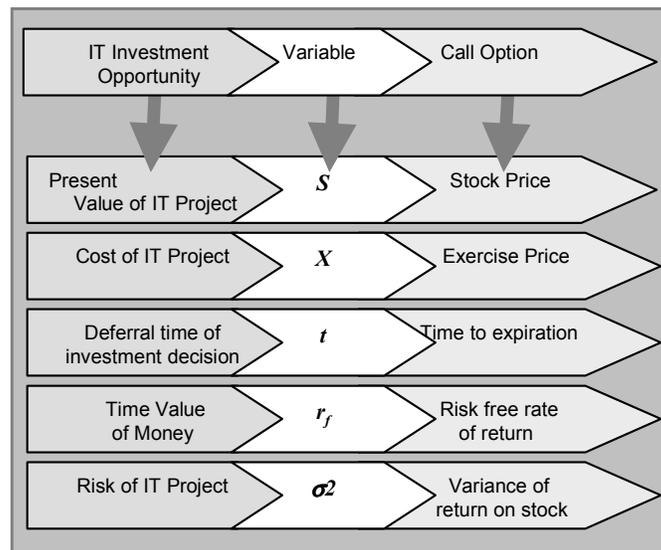$$c = f[S, X, r_f, t, \sigma^2]$$

Figure 1. Mapping the Option Pricing Parameters on an IT Investments Decision

The exact Black and Scholes formula is expressed below: $N(d)$ is the probability that a normally distributed random variable will be less than or equal to d. $N(d_1)$ in the Black-Scholes formula is the option delta.[2] Thus the formula tells that the value of a call is equal to an investment of $N(d_1)$ in the common stock less borrowing of $Xe^{-r_f t} N(d_2)$.

c = Present Value of a call option = $SN(d_1) - Xe^{-r_f t} N(d_2)$

where:

$d_1 = [\log(S/X) + r_f t + \sigma 2t/2] * 1/\sigma\sqrt{t}$

$d_2 = [\log(S/X) + r_f t - \sigma^2 t/2] * 1/\sigma\sqrt{t}$

$N(d)$...cumulative normal probability density function

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[1] European options can only be exercised upon their maturity, as opposed to American options, which can be exercised at any date up to maturity.

[2] Option Delta, also referred to as the hedge ratio, represents the number of shares that are needed to replicate the payoff from a call option.

On first sight, the relevant formula appears intimidating and it can be difficult to obtain the values of certain parameters of the option-pricing model. Research has shown that managers find the formula too mathematical, and the values for the variables too hard to obtain (Bonduelle et al. 2000; PriceWaterhouseCoopers). In particular, the calculation of an estimate for volatility is much more difficult for Real Option than for financial options.

Today, many dealers on the option exchanges using this formula are for the most part not trained in the formula's mathematical derivations. Instead, they just use special computer programs or a set of tables to find the value of an option. Furthermore concepts have been developed to make the Real Option pricing more intuitively understandable to managers who have not yet been acquainted with this method. (Luehrman 1998a; Luehrman 1998b). The Problem that remains unsolved is how to estimate the variables of this formula, in particular the volatility (risk) of an IT investment project.

Parameters of IT Investment Project Uncertainty (σ^2)

Making a closer look one can say that the future cash flows of a strategic IT project are influenced by different sources of risk, where the sources of the project value uncertainty have been recognized as (1) market uncertainty r_M, (2) technical (project) uncertainty r_P, (3) uncertainty of conversion effectiveness r_{CE}. These sources of uncertainty are assumed not to be correlated with each other. When $\sigma^2(S)$ is the variance of the IT project, then:

> *Variance of IT Project σ^2 (S) =*
> *f [*
> *Market Variance $\sigma^2(r_M)$,*
> *Project Variance $\sigma^2(r_P)$,*
> *Variance of Conversion Effectiveness $\sigma^2(r_{CE})$*
> *]*
> *or: σ^2 (S) = f [$\sigma^2(r_M)$, $\sigma^2(r_P)$, $\sigma^2(r_{CE})$]*

Market Risk r_M

r_M represents the market uncertainty contributing to the uncertainty of the future cash flows of an IT Project *(S)*, and σ^2 *(r_M)* represents direct contribution of r_M to the variance of S. The market variance r_M is a function of:

> $\sigma^2(r_M)$ = f [BPs, BPc, MP]

BPc is a parameter representing the bargaining power of a company vis-à-vis its customers. It can take any value between 0 and 1, with 1 indicating a low bargaining power. This would be the case for a company, which is relatively small compared to its customers. In the automotive industry, the suppliers of automotive parts are big companies per definition, but have low bargaining power compared to their customers, the even bigger international car manufacturers. If the customers or suppliers decide not to invest in a new technology and happen to have higher bargaining power, the company investing in this new technology is taking a big risk of occurring sunk costs.
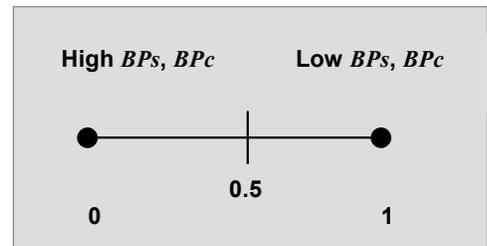
In some cases it does make a difference for a company to consider the bargaining power vis-à-vis its customers and suppliers separately, due to the differences in bargaining power up and down the supply chain. *Thus, BPs* stands for the bargaining power vis-à-vis a company's suppliers. The same values and logic as with *BPc*, vice versa, apply to this parameter.
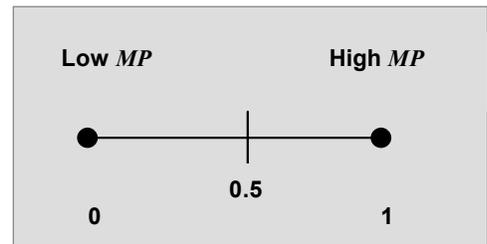
MP is the parameter describing the market position. A company with a small market share and/or a lot of competitors depends very much of the technical

standards that its competitors might set, or implement. If its competitor, the market leader, decides not to invest in a new technology, it might be hard for the competitor with the smaller market share to convince its trading partner of the importance of this new technology

Project Risk r_P

r_P represents the project uncertainty contributing to the variance of S (present Value of IT Project), thus $\sigma^2(r_P)$ is the direct contribution of r_P to the variance of S.

$$\sigma^2(r_P) = f\,[\text{PM, Comp}]$$

$$PM = f\,[\text{in time, in budget, meet technical targets}]$$
$$Comp = f\,[\text{n, No. of multilateral agreements}]$$

PM is the parameter assessing the project management, which is determined by three aspects: whether a project will be completed (1) in time, (2) in budget, and (3) whether it will meet technical targets. A late project delays the benefits a company is expecting from investment. In the worst case, the project is too late to meet a competitive challenge or a deadline and ends up being cancelled. An over-budget reduces the return that one expected when deciding to make an investment in information technology. A small budget overrun is probably not a problem, but anything significant could dramatically alter the expected return on investment. Last but not least, when project management fails technical project targets, there are no monetary benefits to expect. These three aspects are highly correlated with each other. Usually when a project is in overrun, the costs will be higher, or if the project fails technical targets in time, project management will assign more people to it and extend project duration, all causing the project to be over time and over budget. For better assessment of this parameter it would be helpful to have statistics on how late similar projects are on average, and how much they are over budget.
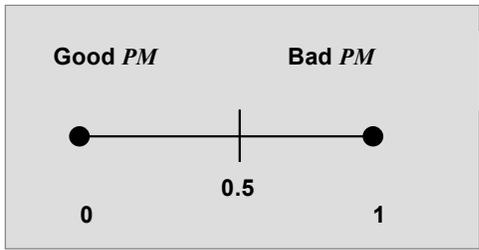
Forecasting IT projects is very hard due their complexity. While not excusing cost and time overruns, the prudent project manager should factor their likehood into any return on investment calculations.

Comp refers to the complexity of an IT implementation project. The complexity itself depends on the number of transactions *n* supported and the number of business partners. The higher *n* and the more multilateral agreements the new standard must meet the higher *Comp*.
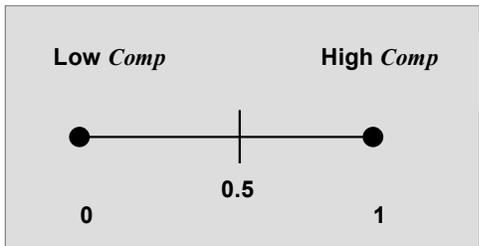
Risk of Conversion Effectiveness r_{CE}

An IT project that may be successful in theory, must not necessarily meet these demands, since management does not always take advantage of the opportunities that such an investment provides. the critical parameter in management's ability to use the new system to extract economic benefits. That critical variable is referred to as *conversion effectiveness* (Lucas 1999; Strassmann 1985; Weill 1990).

Conversion effectiveness measures the ability of an organization to convert its IT investments into working applications. r_{CE} is the uncertainty of conversion effectiveness contributing to the variance of S, thus $\sigma^2\,(r_{CE})$ being the direct contribution of r_{CE} to the variance of S.

Lucas (Lucas 1999) states many variables that determine conversion effectiveness. He believes that failure on any one of the parameters listed below can doom the projects, even if every other aspect of development is successful. The variables he quotes are: (1) Size and scope of project; (2) Amount of unknown technology involved; (3) Project management; (4) Support and encouragement of managers, sponsorship; (5) The urgency of the problem/opportunity addressed by the technology; (6) Norms

in the organization; (7) User commitment and involvement; (8) Technical development environment; (9) Quality IT staff; (10) Strength of project team; (11) Level of expertise of participants; (12) Type of technology employed, (13) Type of application; (14) Amount of custom code written; (15) Nature of packaged software included; (16) Use of external consultants; (17) Degree of understanding between users and developers; (18) *Presence of a project champion;* (19) *Senior management involvement;* (20) *Amount of organizational change required;* (21) *Threat to existing personnel, vested interests;* (22) *User's view of the quality of the system*

Lucas' extensive list covers some parameters (1, 3, 10, and 14), which have been already used to determine project uncertainty r_P. For the definition of conversion effectiveness as presented in this paper Lucas' parameters 18, 19, 20, 21, and 22 are of relevance. Conversion effectiveness in this paper is described as function of management commitment, *MC,* and the ability of an organization to cope with transformation, *ACT*.

$$\sigma^2(r_{CE}) = f\,[MC,\ ACT]$$

MC represents management's commitment when integrating new IT Systems. The idea behind this parameter is that without management commitment to an IT project conversion effectiveness will be low. The higher *MC,* the higher conversion effectiveness will be, thus the lower an overall project variance. *MC* covers every aspect of a manager's task from awareness creation with end-users to managing the required business process redesign.
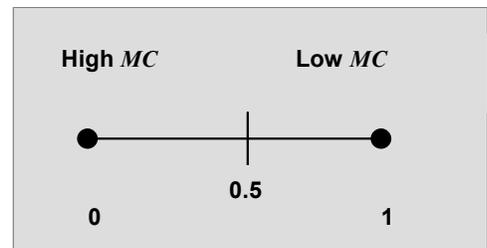
ACT defines the ability of organization to cope with transformation. A company with high *ACT* is a flexible organization, possibly one, which is used to organizational change due to frequent implementations of new Information Systems. An organization with cannot easily cope with organizational change will have a very low *ACT*. *ACT* deals with the average ability of all personnel of an organization to cope with change. Even if management commitment is high and if responsible managers have good awareness creating skills, they will have a hard time in a company with low *ACT*.
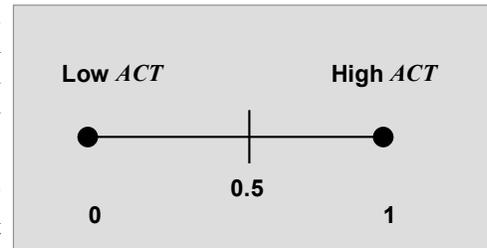
A company usually has low *ACT* if managements commitment (*MC*) for IT projects in the past has been low. Vice versa the probability that *MC* is high might depend on past levels of *ACT*. Lower *ACT* results in lower conversion effectiveness, thus a higher project variance.

Diffusion of New Technologies with Network Externalities – Company Profiles

Network externalities (Shapiro et al. 1998) occur when the value of a product or service to one user or firm depends on how many other users there are; think of telephone, Internet, e-mail, modems, as well as pure business applications like EDI, ebXML, SAP, etc. As the installed base of users grows, more and more users find the product useful to adopt. It is quite easy to make ex post explanations as to why a certain technology has been a good investment due to network effects. The challenge lies with investments in new technologies where the installed base of users is not yet big enough to exclude the risk of sunk costs.

Many researchers have committed their work to the subject of the diffusion of innovations in general, and the diffusion of new technology in particular. On a macro level they studied the pattern of diffusion over time, trying to (1) classify the type of adopters of a new technology, and (2) identify parameters that determine the difference in diffusion patterns. One of these parameters is market structure, and consequently the individual market power of a firm.

Type of Adopters

Technology diffusion theories devote their work to identifying and analyzing the type of adopters. Most theories (Bass 1969; Fisher et al. 1971; Mansfield 1961; Rogers 1983) identify *early adopters* and *late adopter* of innovation. This paper is based on the assumption that a (i) <u>*Late Adopter*</u> is a company that prefers to apply new technologies later than average. "Wait and see"

strategy is applied to gain more information and to avoid the risk of sunk costs. Management or owners might even be technology averse; and the (ii) *Early Adopter* is a company that tries to use new information technology before everybody else does in order to gain a competitive advantage, thus being an early adopter is the general company strategy. In some cases technology freaks sit in key positions forcing early adoption, possibly without any particular strategic motivation.

Market Power

Different factors influence the individual adoption decision, thus the general diffusion pattern. These factors are: *relative cost advantage* (Rogers 1983)*, triability of investment* (Rogers 1983)*, complexity and size of investment* (Rogers 1983)*, market concentration* (Götz 1996; Mansfield 1961; Reinganum 1981a; Reinganum 1981b)*, collusive conduct of market players* (Quirmbach 1986)*, number of previous adopters* (Bass 1969; Mansfield 1961)*, technology substitution* (Fisher et al. 1971), etc.

As opposed to other IT investment projects that only affect efficiency of internal business processes, the success of IT investment decisions with network externalities depend on the number of business partners and competitors adapting a new technology. Thus, *Market Power* of an individual firm is an important parameter in diffusion theory, in particular for IT investment decisions with network externalities. *Market Power* of a company depends on different parameters: the market structure of an industry (*structural concentration)*, and whether some form of *collusive conduct* exist.

Market Power in this paper is defined as followers: (i) *Low Market Power* usually applies to small or medium sized companies. It may also apply to large companies, which are small in relation to their business partners or competitors. As an example in the automotive industry the suppliers for the car manufacturing companies are big per definition, but small compared to their customers. Thus, low market power applies to any company that faces perfect competition or has low market share. (ii) *High Market Power*, vice versa, applies to companies, that are big in relation to their business partners and/or competitors (i.e. Monopsony). A monopolist has the highest Market Power. Any form of collusive conduct also results in higher Market Power. Two ore more companies could decide to boycott a new technology in order to protect their return on investment in a current technology. They might as well decide to jointly adopt a new technology, in that case the natural diffusion process is altered by collusive conduct.
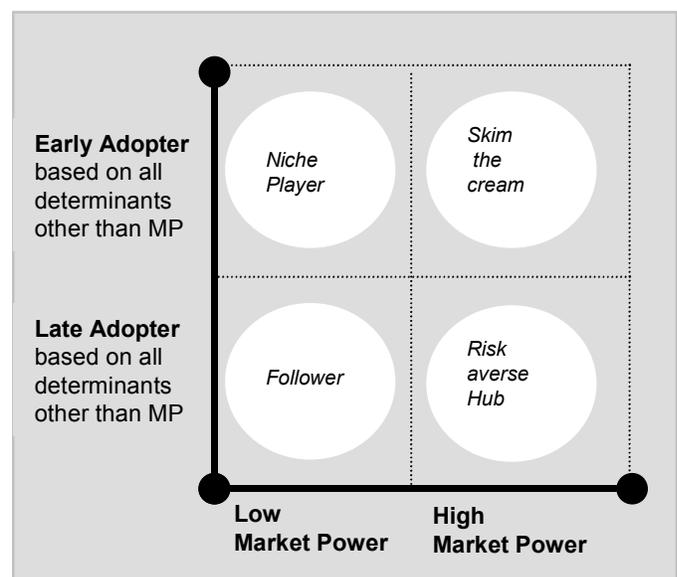
Diffusion Matrix

In the diffusion matrix presented here, the horizontal axis represents the Market Power of an individual firm, and the vertical axis shows how fast a company adopts a new technology based on all other parameters influencing the time of adoption other than Market Power.

Underlying assumption of this diffusion matrix is that adoption costs of IT investments with network externalities are assumed to be falling over time. Diffusion is assumed to be sequential rather than simultaneous. There are two reasons for this assumption. Potential users of a new technology may differ in a way that the expected returns from adoption are different due to firm size, market share, R&D expenditure, etc. Differences in prior believes about the 'true' profitability of a new technology may result in different expected benefits from adoption and therefore in distinct adoption dates.

One way to interpret this matrix is to define four company profiles based on the combination of two possible states of the vertical axis (early adopter, late adopter), and two possible states on the horizontal axis (low BP, high BP).

A **Follower** is a *Late Adopter* with *low Market Power*. A Follower is possibly a company with low market share fearing (justified or not) that investing in an new technology could

Figure 2. Company Profiles in IT Diffusion Matrix

induce sunk costs, since this technology is not yet sufficiently diffused in the industry and competitors as well as business partners could decide not adopt this technology in the future. Furthermore a Follower tends to be technology averse or generally prefers to implement new technologies later rather than early. Other reasons for late adoption might be the size and the scope of an IT investment project in case of a small company with no/ or low risk capital.

The **Risk-averse Hub** is a *Late Adopter* with *high Market Power*. This type of company implements new technology only to cut costs (not to expand market share) or out of competitive necessity (to avoid loosing market share). Factors like complexity and size of an IT investment, triability of investment, compatibility, observability that influence volatility of future project cash flows out weight the fact that the company has high market power (and could be opinion leader). Thus, the risk-averse hub avoids the risk of sunk costs, maybe also for the reason of increasing the return on investment of previous IT investments.

The **Skim-the-Cream** company is an Early Adopter and has high Market Power. This type of hub implements IT for strategic reasons to make use of "First mover advantage". The Skim-the-Cream Hub takes advantage of its Market Power in order to influence the diffusion process and timing of a new technology in its industry, while maximizing its own benefits. Sensitivity to the risk of sunk costs is relatively low, either because of the fact that the company big enough that a possible project failure would not hurt so much, or because of the fact that the company is less risk averse.

The **Niche-player** is an *Early Adopter* and has low *Market Power*. A Niche-player uses innovation to survive competition by differentiating itself. Market power of the Niche-player is low, so that it cannot significantly influence the diffusion process and timing of a new technology in its market. The Niche-player does not fear the risk of sunk costs as much as competition. By investing in such a new technology it hopes to be able to differentiate itself visa-a-vie its competitors. Factors like complexity and size of a project, triability of investment, compatibility, are important aspects of the investment decision. As opposed to the follower the Niche-player can afford (from a financial point of view) to invest into the new technology project at an early diffusion stage. The borderline between *Niche-player* and *Follower* can be very thin. If the investment project is not possible due to budgetary reasons, then this company will be a *follower* because of financial restrictions.

Mapping the Real Option Parameters on the Company Profiles

The factors that influence risk discussed in this paper will be mapped on the company profiles, in order to better visualize the concept of risk assessment. Table 3 shows the company profiles in the columns and the single risk parameters of the option-pricing framework in the rows. The result shows whether, and to what extent, a parameter depends on a specific company profile.

Conclusion and Outlook

The success of IT investments with network externalities depends on the number of companies using a new technology, as it increases efficiency on an intra-organizational level. Thus, it is necessary to consider the possible diffusion process. At an early stage of the diffusion process the risk of sunk costs of such a project is relatively high. This implies a high level of uncertainty that needs to be carefully considered in the process of an investment decision.

Probabilistic methods like the Real Options Approach with the Black Scholes Formula consider this type of risk. For better assessment of the risk variable (variance σ^2), 3 different sources of project value uncertainty have been recognized and analyzed in detail; market risk, project risk, and risk of conversion effectiveness. Based on the theory of technology diffusion, four company profiles were identified that fit into a two times two matrix, with market power defining one axis, and adoption timing of a new technology the other; and Table 3 showed how the company profiles influence each risk parameter discussed before.

Hitherto the risk parameters and the matrix has not been validated against empirical data. Further research will focus on case studies in order to gather data that can be used for the identification of parameters, which significantly influence the outcome of the formula.

Figure 3. Mapping Risk Parameters $\sigma^2 (S) = f[\sigma^2(r_M), \sigma^2(r_P), \sigma^2(r_{CE})]$ on Company Profiles

		Company Profiles			
		A **Follower** Low Market Power Late Adopter	**B** **Risk Averse Hub** High Market Power Late Adopter	**C** **Skim the Cream** High Market Power Early Adopter	**D** **Niche Player** Low Market Power Early Adopter
R I S K V A R I A B L E S	$\sigma(r_M) = f[BP_s, BP_c, MP]$	Since MP is low there is the risk that if A decides to invest, business partners or competitors might invest in a different technology. On the other hand if A decides to follow business partners with technology, no sunk costs.	With a high market power risk of sunk costs due to business partners or competitors is low.	With a high market power risk of sunk costs due to business partners or competitors is low.	Since MP is low there is the risk, if D decides to invest, business partners or competitors might invest in a different technology. On the other hand if D decides to follow business partners with technology, no sunk costs.
	Bargaining Power vis-a-vie Supplier BP_s	probably low	probably high	probably high	probably low
	Bargaining Power vis-a-vie Customer B_{pc}	probably low	probably high	probably high	probably low
	Market Position *MP*	probably high	probably low	probably low	probably high
	Project Risk $\sigma(r_P) = f[PM, Comp.]$	—	—	—	—
	Project Management *PM*	Quality of internal PM team might be low, if company is technology averse and therefore low commitment. They do because they have to. External PM is independent (but might not be adequately supported).	Quality of internal PM team low, if company is technology averse and therefore low commitment. External PM is independent (but might not be adequately supported).	Quality of internal PM team is high, if the have more IT implementation experience and commitment. External PM? External PM is independent; success depends on level of internal support.	Quality of internal PM team is high, if the have more IT implementation experience and commitment. External PM? External PM is independent; success depends on level of internal support.
	Complexity of Project *Comp.*	May be lower for smaller companies if fewer trans-actions have to be handled and less trading partners exist (external interfaces).	May be higher for bigger companies if more transactions have to be handled and more trading partners exist (external interfaces).	May be higher for bigger companies if more trans-actions have to be handled and more trading partners exist (external interfaces).	May be lower for smaller companies if fewer transactions have to be handled and less trading partners exist (external interfaces).
	Risk of Conversion Effectiveness $\sigma(r_{CE}) = f[MC, ACT]$	probably low	probably low	probably high	probably high
	Management Commitment *MC*	low	low	high	high
	Ability to cope with transformation *ACT*	probably low	probably low	probably high	probably high

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