

MANAGING R&D ALLIANCE PORTFOLIOS : THE CASE OF MOBILE SERVICE PROVIDERS

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Abstract:

Many companies in high technology fields engage with alliance partners to reduce risks, create synergies and learn. While the challenges of managing individual alliances are well documented, little is known on how to manage several R&D alliances simultaneously. Multiple alliance strategies can be observed in several companies engaged in the cross section of telecommunication and mobile technology where increased complexity magnifies managerial challenges. Drawing on modern portfolio theory, this paper offers a model for managing portfolios of R&D alliances. In particular, an analysis of a technology platform leader reveals how companies can reduce several types of risks associated with new technology and gain synergies by engaging in several alliances simultaneously.

Keywords: Portfolio theory, risk, synergy, R&D, dominant-design

1. Introduction

Firms' collaborative activities are increasingly considered as potential sources of strategic asset access and accumulation (Dyer and Singh, 1998; Gulati, Nohria and Zaheer, 2000). Stipulated by a growing body of empirical studies sustaining that leading firms engage in increasing numbers of strategic alliances, an emergent research stream has pointed to the urgency of studying the challenges of simultaneous management of multiple alliances (e.g. Harbison and Pekar, 1998; de Man and Duysters, 2002). To date, the alliance literature has been dominated by dyadic relationship issues such as motives, interorganizational learning, individual alliance governance, management and assessment (e.g. Ireland et al, 2002). Thereby, substantial managerial advice on how to manage individual alliances has been produced (Kale, Dyer and Singh, 2001). An emergent alliance research strand has initiated the study of the increasingly important multiple alliance phenomena. Much scholarly attention has been diverted towards building alliance capabilities to improve alliance management practices, since numerous studies have found that strong alliance capabilities improve the otherwise notoriously high alliance failure rates and even stock market responses to alliance announcements. However, individual alliance management issues have so far dominated the best practices harnessed by such alliance capabilities (Alliance Analyst, 1996; Anand and Khanna, 2000; Kale, Dyer and Singh, 2001). Most notably within multiple alliance research, the network literature has shifted the unit of analysis from the firm-level to the network-level, and build fundamental knowledge on e.g. network structures, network positions, access to network resources, socially embedded ties, network densities, and structural holes (e.g. Powell et al, 1996; Gulati, 1998; Burt, 1992; Walker et al, 1997; Gnyawali et al, 2001). Recently, managerial implications have been derived for decisions on the firm's membership of a multi-firm network, firm positioning within network groups, mapping of competitors' networks, and network management (Comes-Casseres, 1996; de Man, 2002; de Man, Geurts and van Dulleman, 2001; Booz, Allen Hamilton, 2000). However, from a firm perspective, the challenges of firms' increasing number of alliances are far from covered by expanding the analysis from two-partner alliances (dyads) to multi-partner alliances (networks). Indeed, a firm may participate in numerous multi-partner networks as well as numerous dyadic alliances that connect the firm with networks of partners' partners. Moreover, as elegantly noted by Dyer and Singh, "changing one's mindset from the firm to the dyad/network as a key unit of analysis may be uncomfortable because the firm is the 'unit of accrual' for performance [e.g. profits and share value]" (1999:186). In filling the research gap and keeping the 'unit of accrual' at the centre of analysis, alliance portfolio management is emerging as the firm discipline of building and managing a focal firm's entire portfolio of two-

partner and multiple-partner alliances. However, with a few notable exceptions very limited managerial guidance is available to inform managerial decisions on e.g. which specific alliances to include in the firm's alliance mix to pursue strategic objectives, how to operationally maximize the value creation from a portfolio of often interrelated alliances, and how to on a continuous basis reengineer the firm's alliance web to accommodate the firm's changing strategic intents and changing market and technological environments (Hamel and Doz, 1996 and 1998; Lorenzoni and Baden-Fuller, 1995; Duysters, de Man and Wildeman, 1999; Dyer and Nobeoka, 2000; Booz Allen Hamilton, 2000). Thus, this paper sets out to improve managerial guidance on alliance portfolio management, and thereby expand the managerial principles underlying alliance capabilities. A recent McKinsey study (2002) points to the urgency of improving alliance portfolio management guidance. Through work with above 500 firms and executive interviews, the strategy consultancy found that too often alliance portfolios grow into a random mix of ventures assembled over the years by various business units, that overall performance measurement of the portfolio is lacking, and that often overall alignment between a company's overall competitive strategy and its alliance activities is missing.

The paper's aim is to elevate available managerial guidance on alliance portfolio management and contribute to the emergent research stream concerned with the opportunities and constraints of alliance portfolio management (Stuart, 2000; George et al, 2001; McKinsey, 2002; Deloitte, 2001; Doz and Hamel, 1996 and 1998). To this end, a managerial framework is proposed that introduces risk diversification and portfolio synergies as two valuable managerial levers for alliance portfolio management. Thereby, an effort is made to reconcile academic studies of alliance networks as potential sources of competitive advantage with the firm perspective (Dyer and Singh, 1998; Molina, 1999; Dyer and Singh, 1999). Given the immense diversity of alliance types (Contractor and Lorange, 2002), the paper focus on the management of multiple R&D alliances. This because the propensity of firms to form strategic alliances has been found particularly high in high-tech and turbulent industries due to increasing technological complexity, a brutal pace of technological development, technology convergence between previously unrelated fields and an increasing global spread of R&D competencies (e.g Hagedoorn, 1993; Teece, 1996). Empirical evidence also suggests that especially large platform companies choose to build comprehensive and diverse portfolios of R&D alliances to drive their innovative efforts, while specialized technology firms strive to successfully navigate industry networks by team-up with a one or few platform firms to commercialize their inventions (Cusumano and Gaver, 2002; Duysters et al, 1999). Consequently, this paper studies alliance

portfolio management from the corporate perspective of large high-tech platform firms. Empirical evidence is obtained from the leading Japanese wireless operator NTT DoCoMo that manages a vast and diverse R&D alliance portfolio. In support of the aim to build a managerial framework for high-tech platform firms' alliance portfolio management efforts, Williamson and Meegan recently proposed as a route of fruitful future research "the need to model more completely the dynamic optimization problem posed by the challenge of forming, structuring and evolving a partnership network that facilitates efficient and speedy innovation" (2002:18).

The managerial framework provided in this paper posits that alliance portfolio management be guided by two valuable managerial levers. Firstly, alliance managers can optimize the risk-return properties of the firm's alliance portfolio by diversifying three R&D alliance-related risk classes (i.e. market risks, technology risks, and capability risks). Secondly, the alliance manager can maximize the total returns of the firm's alliance portfolio by reaping portfolio synergy effects at four distinctive levels in the portfolio (i.e. between multiple alliances with the same partner, between same types of alliances, between different types of alliances, and among all alliances in the portfolio). The framework builds on early research on multiple alliance management, analogue reasoning from Modern Portfolio Theory (MPT) and illustrative empirical evidence from NTT DoCoMo. Since the early 1950s, MPT has emerged as the core theory on multi-asset management of interdependent financial investments (Elton and Gruber, 1997). Now, this paper holds it worthwhile to explore the theory's full potential to inform alliance portfolio management beyond previous loose attempts by means of rather rigorous analogue reasoning (see e.g. Deloitte, 2001). The case company NTT DoCoMo was chosen because it has successfully deployed multiple types of R&D alliances as a fundamental element of its competitive strategy (Standard & Poors, 2001; Ratliff, 2002, Williamson and Meegan, 2002; Annual report, 2002). Specifically, the company develops new wireless service applications, wireless handsets, wireless infrastructure, technology standards and new business concepts in collaboration with partners (Press releases, 1997-2002). Being a large platform firm in a high-tech and turbulent industry, NTT DoCoMo provides illustration of the managerial framework (Cusumano and Gawer, 2002).

2. Background literature: From individual alliances to alliance portfolios

2.1 Gap in the alliance literature and best practice

In the past two decades, a substantial alliance literature has been stipulated by an unprecedented growth of strategic technology alliance formations identified by a plurality of empirical studies (Hergert and Morris, 1988; Hagedoorn and Duysters, 1999; Hagedoorn, 2002). As evident from numerous literature reviews (Parkhe, 1993; Osborn and Hagedoorn, 1997; Inkpen, 2001; Ireland et al, 2002), the research stream has focussed on dyadic partnerships in terms of e.g. motivations for forming such alliances, building appropriate interorganizational processes for joint value creation to meet strategic intents, designing effective governance structures with contractual and relational mechanisms, and alliance management of conflicts and evolving partner strategies. Academic research has been paralleled by an increasing establishment of dedicated alliance functions in firms and emerging best practices for individual alliance management (Alliance Analyst, 1996). For instance, Anand and Khanna observe an “increasing formalization of processes by which a firm can systematize the acquisition or development of an ‘alliance capability’” (2000:298). In the hitherto most detailed study of alliance management practices, Kale, Dyer and Singh (2001) found that dedicated alliance functions significantly improve alliance success rates and stock market gains after alliance announcements. Such alliance functions “provide an important formalization mechanism through which allianzing know-how can be articulated, codified, shared and internalized within the organization” (Eisenhard and Martin; 2000:1114). Currently, alliance best practices that inform the daily work of dedicated functions are primarily concerning individual alliance management issues including partner selection, alliance design, -management and -evaluation (Dyer, Kale and Singh, 2001).

As noted previously, empirical research has reported that leading firms engage in an increasing number of R&D alliances (Harbison and Pekar, 1998; Booz, Allen and Hamilton, 2000). Concurrently, an emergent literature body points to severe challenges of engaging in multiple alliances for the firm’s pursuit of competitive advantage (George, Zahra, Wheatley and Khan, 2001; Stuart, 2000; Duysters, de Man and Wildeman, 1999, Gulati, 1998, Doz and Hamel, 1998; Gomes-Casseres, 1996). Such difficult alliance portfolio management decisions include when to change the alliance mix by entering, changing and/or terminating alliances. This parallels financial investors’ decisions on which company stocks to buy and sell, and whether to raise or lower holdings (i.e. investments) in the individual company stocks constituting the portfolio. Intuitively, such critical portfolio decisions must build on assessments of e.g. alliance fit and value-added to portfolio, alliance redundancy, conflicting alliances, achieved access and

accumulation of strategic assets, strength of portfolio compared to competitors, scope for improved portfolio performance through active management of e.g. knowledge flows and sharing, and the positive and negative effects of partners' partners to the portfolio's value creation. Currently, however, extant alliance literature falls short of providing sufficient guidance on alliance portfolio management. The alliance research has been overly focused on bilateral alliance issues and only recently, scholars have encouraged elevation of the literature towards perspectives on multiple alliances (Gulati, 1998; Ireland et al, 2002; Williamson and Meegan, 2002). Moreover, the majority of multiple alliance research has shifted the unit of analysis from the firm to the network level, and thereby studied the dynamics of multi-partner networks. In particular, network scholars have refined traditional structural industry analysis (e.g. Scherer and Ross, 1990) to span insights on e.g. the impact of firms' embeddedness in networks on the nature of competition and industry profitability (Gulati, Nohria and Zaheer, 2000; Gnyawali and Madhavan, 2001; Gomes-Casseres, 1996), firms' innovative activities and output (Powell, Koput and Smith-Doer, 1996; Ahuja, 2000), and the patterns of network formation (Walker, Kogut and Shan, 1997). A range of network properties are central to this research in determining a firm's asymmetric access to valuable network resources and information flows. Following the above studies, the most important properties of network structure are (1) a firm's network membership, (2) the centrality of the firm's network position, as it increases network advantages (Gulati, 1998), (3) the event of structural holes in the network that creates possibilities for network arbitrage (Burt, 1992), (4) the density of the firm's network increasing asymmetric advantages (Gnyawali and Madhavan, 2001), (5) tie modalities defined by the norms and rules governing network ties, and (6) the incident of both direct and indirect ties. The derived implications for firms of this research are largely confined to managerial tools such as are network mappings and network structure analysis (Comes-Casseres, 1996; de Man, 2002; de Man, Geurts and van Dulleman, 2001). With the few notable exceptions deployed in this paper's below framework development, thus, the multiple alliance literature lacks firm perspective research to inform the emergent discipline of alliance portfolio management to simultaneously manage a focal firm's multiple, diverse and often interdependent alliance portfolio consisting both of single-partner alliances dealt with by traditional dyad alliance and multiple-partner alliances studied by the emergent network research (Doz and Hamel, 1996 and 1998; Booz, Allen Hamilton, 2000, Duysters et al, 1999; Lorenzoni and Baden-Fuller, 1995; Deloitte, 2001; Dyer and Nobeoka, 2000; Stuart, 2000; McKinsey, 2002). In sum, there is a need to elevate theorizing on the simultaneous management of multiple dyadic and multi-partner

alliances and to develop best practices on alliance portfolio management to inform especially high-tech platform firm's dedicated alliance functions.

2.2. Research scope

As outlined in the introduction, this paper studies alliance portfolio management in the context of high-tech and rapidly changing environments. Here, global competitive battles constitute Schumpeterian worlds of innovation-based competition and creative destruction of existing competences requiring successful firms to adapt to and at best capitalize on the rapidly changing environment (Schumpeter, 1934; Teece and Pisano, 1994; Teece Pisano and Shuen, 1997). Consequently, firms face a substantial need to continuously innovate and promptly respond to competitors' innovations in regimes of rapid technological change (Nelson, 1991; Narula and Hagedoorn, 1999). Under such conditions of high degrees of strategic and technological uncertainties, R&D alliances often outperform go-it-alone and acquisition-based strategies as efficient vehicles for performing a range of strategic innovation-related functions (Teece, 1992; Hagedoorn, 1993; Doz and Hamel, 1996; Narula and Hagedoorn, 1999; Hagedoorn and Duysters, 1999). The alliance literature on alliance motives has formally studied why firms increasingly make make-or-buy choices in favour of R&D alliances in high-tech industries. Hagedoorn (1993) identified three key categories of motives in the alliance literature and tested them with large sample analysis of nearly 10.000 technology alliances involving around 3500 different partnering firms. Firstly, the motives that relate to R&D and characteristics of technological development are a) the increased complexity and convergence of technology, b) reduction, minimization and sharing of uncertainty of R&D, and c) reduction and sharing of costs of R&D. Secondly, the motives that relate to innovation processes are d) capturing partner tacit knowledge and technologies and that e) shortening PLC necessitates reduction of time-to-market from invention. Lastly, motives related to market access and search for opportunities are f) to monitor environmental changes and opportunities, g) internationalization, and h) new product development and expansion of product range (also Mowery, Oxley and Silverman, 1996). For these reasons, R&D alliances are becoming fundamental for innovative activities such as rapid, flexible and innovative R&D, product development, technology development, process development, and production (Kogut, 1988; Doz and Hamel, 1998; EIU, 1999; Mowery, Oxley and Silverman, 1996; Teece and Pisano, 1994). Additionally, R&D alliances are increasingly important for the rapid diffusion of technologies to develop and promote industry standards (Teece, 1992; Hagedoorn and Duysters, 1999).

The paper's research scope is delineated to high-tech platform firms that orchestrate innovation through webs of R&D partnerships (Cusumano and Gaver, 2002). These central firms often assume nodal network positions from which they build, manage, and maintain multiple alliance classes to fulfil strategic innovation objectives (Lorenzoni and Baden-Fuller, 1995). Indicative examples of such firms include Sony, Microsoft, Intel, NTT DoCoMo, Hewlett-Packard, Cisco, software integrators tapping into large webs of small software developers, and big Pharma pursuing drug discovery and development through multiple alliances with biotech firms. In high-technology settings, extant alliance literature suggests that key central firm competencies are firstly, sustained leadership in their own strategic technologies and competences (Doz and Hamel, 1998), and secondly, core competences in assuming a nodal position such as the creation of novel business ideas and visions, strong brands, the ability to foster trust and reciprocity among multiple partners, knowledge and capability sharing with partners, moderation of network conflicts, prioritization of limited firm resources to multiple demanding partners, and partner selection, development and exclusion (Lorenzoni and Baden-Fuller, 1995; Duysters et al, 1999). Hence, the role of the central platform firm is to actively manage the alliance portfolio, and this task requires alliance portfolio management capabilities additional to individual alliance management capabilities. This paper sets out to contribute to available guidance for central firms on the managerial principles that underlie such capabilities.

3. R&D Alliance Portfolio Management

To advance extant multiple alliance research and managerial guidance for the perspective of a high-tech platform firm, the paper posits a managerial framework for alliance portfolio management. Below, the managerial framework and its two managerial levers risk diversification and portfolio synergies are introduced for overview. Secondly, to initiate the framework development, antecedents to portfolio analysis and to MPT are briefly reviewed. Thirdly, the framework is developed through analogue reasoning based on MPT with translations of its core concepts into the context of R&D alliances, relevant multiple alliance research, evidence from NTT DoCoMo and inspiration from the corporate diversification literature. Based on the conceptual framework development and following the papers ambition to span managerial guidance, the two managerial levers are applied to empirical evidence from NTT DoCoMo and the global wireless sector. This operationalization both serves for generally illustration and identification of the main managerial steps involved in the framework's application. These managerial implications are summarized after the two in-depth sections on risk diversification and portfolio synergies.

Objective:

**Alliance Portfolio
risk and return optimization**

Managerial
levers:

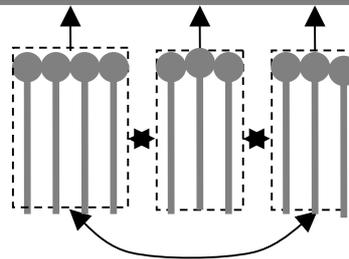
Diversifying 3 portfolio risk classes:
– Technology risks
– Market risks
– R&D/capability risks

Reaping portfolio synergies at 4 portfolio levels:
– Across alliances with same partner
– Within a portfolio class
– Across a subset of portfolio classes
– Across the entire portfolio

Portfolio
analysis and
selection:

How optimize risk/return by entering, managing and terminating R&D alliances?

Analysis of R&D
alliances and
classes:



The four framework levels are briefly introduced. Following Modern Portfolio Theory, the managerial objective pursued by the framework is to optimize the risks and returns of the high-tech platform firm's R&D alliance portfolio. For this end, two valuable managerial levers are identified. The first lever is *risk diversification* through R&D alliances of three critical risks faced by high-tech platform firms, namely (1) technology risks, (2) market risks, and (3) R&D/capability risks. The second lever is *portfolio synergies* that increases overall portfolio returns by exploring synergy potentials at four distinctive levels in the R&D alliance portfolio. While the managerial objective and the managerial levers provides the overall purpose and structure of the framework, the real thrust and managerial value lies in the guidance delivered to alliance portfolio managers on how to achieve risk diversification and portfolio synergies. Based on key principles derived from Modern Portfolio Theory and alliance antecedents, thus, a portfolio analysis approach to inform portfolio management level decisions. Lastly, implications for the retrieval of input to the portfolio analysis from the complementary managerial layer of individual alliance management are addressed.

3.1 Introduction to Portfolio Analysis and Modern Portfolio Theory

Since the early 1950s, MPT has informed portfolio management of stock and corporate bond investments by optimizing risk-return properties of asset portfolios (Markowitz, 1952; Markowitz, 1999). Theory founder and Harry M. Markowitz formulated the portfolio problem as a choice of the mean and the variance of a portfolio of assets that exploits the effects of asset return correlation to diversify portfolio risks. With the mean variance portfolio theory, he proved that an asset portfolio can be optimized by either keeping constant the expected return and minimizing risks (i.e. variance), or keeping risk constant and maximizing expected returns (Elton and Gruber, 1997). Markowitz's student and originator of the most widely used empirical application of MPT, the Capital Asset Pricing Model (CAPM), William F. Sharpe (1963, 1970), encouraged application of MPT outside the original domain of financial asset management. At a higher level of abstraction, he suggests that "portfolio theory is concerned with decisions involving outcomes that cannot be predicted with complete certainty ... [and that] the theory insists that uncertainty be acknowledged and dealt with explicitly. It also insists that interrelationships among outcomes be treated explicitly" (Sharpe, 1970:1-2). Therefore, he proposed an alternative name for the theory: "The Theory of Making Decisions Involving Interrelated Uncertainty Outcomes". Since R&D alliances are highly signified by 'interrelated uncertainty outcomes', analogue reasoning from MPT for R&D alliance portfolio management is argued to be a promising starting point to elevate academic research and managerial guidance.

When searching for antecedents for such an endeavour, one finds that portfolio analysis and the intuitively powerful construct of risk diversification are widespread concepts. In the *Merchant of Venice* written at the end of the 16th century, Shakespeare has the merchant Antonio say: "My ventures are not in one bottom trusted. Nor to one place; nor is my whole estate. Upon the fortune of this present year; Therefore, my merchandise makes me not sad " (Act 1, Scene 1 as quoted by Markowitz,1999). More recently, portfolio analysis tools have gained ground in several management fields including the management of product portfolios, technology portfolios, R&D project portfolios, and portfolios of strategic options, as well as in the corporate diversification literature (e.g. Henderson, 1970; Day, 1977; Williamson, 1999; Cooper, Edgett and Kleinsmidt, 2001; Roussel et al, 1991; Chien, 2002; MacMillian and McGrath, 2002; Lubatkin and Chatterjee, 1994). Moreover, a few endeavours have been made into alliance portfolio analysis from the firm perspective of one company (i.e. not the network perspective of many companies). George et. al (2001) identify distinctive alliance portfolio characteristics that significantly contribute to a company's financial performance, but their results are conferred to

individual alliance descriptors such as individual alliances' vertical and horizontal structure rather than portfolio level descriptors. Stuart (2000) argues that benefits gained from a portfolio of strategic alliances are determined in part by partner characteristics and technological competencies of the firms in the portfolio. Moreover, leading management consultancies are developing alliance portfolio management services, but unsurprisingly available reports rather points to challenges and problems than managerial solutions (e.g. Deloitte, 2001; Booz Allen Hamilton, 2000; McKinsey, 2002). Among these antecedents, a few make sporadic references to MPT, but most study portfolios and diversification without drawing explicitly on MPT. Thus, while portfolio analysis is not unique to MPT, the theory provides the best elaborated, refined and operationalized mechanism to optimize asset portfolios. Specifically, it builds on the core concepts of asset return correlation and portfolio level returns and risks, as well as an analytical approach breaking down portfolio analysis with the objective to maximize portfolio returns and minimize portfolio risks. This paper explores these core constructs as encouraged by Sharpe (1970) to explore the theory's full potential to inform R&D alliance portfolio management.

3.2 Analogue reasoning

The use of analogue reasoning demands careful consideration of how core MPT concepts meaningfully translate into the context of R&D alliance portfolios. In their application of biology as an analogy for their evolutionary theory, Nelson and Winter (1982) note as a crucial yardstick that while parts of the analogue theory are used, other elements are completely excluded from their analysis when the elements do not make sense in the new context. Gould encourages similar caution by warning against "the fallacy of unwarranted analogy" (1987, as cited by Burgelman and Rosenbloom, 1989).

The endeavour to draw implications from MPT for alliance portfolio management finds support in the similar fundamental characteristics shared by financial portfolios and R&D alliance portfolios. In both cases, the objective of multiple asset management is maximization of one entity's portfolio outcomes. Sharpe defines a portfolio as "the totality of decisions determining an individual's future prospects [in terms of consumption] is called a portfolio" (1970:19). Similarly, the alliance literature defines R&D alliance portfolios as multiple R&D alliances that are managed by one central firm (i.e. the investor) (Hamel and Doz, 1996; 1998; Booz Allen Hamilton, 2000). Specifically, the financial investor seeks wealth maximization in terms of the realized rate of return from share and bond investments (Sharpe, 1970). Likewise, the central firm maximizes the total cost-benefit performance (i.e. return) of its R&D alliance portfolio,

rather than individual alliance performance (Duysters et al, 1999). Another shared fundamental characteristic is that the outcomes of financial investments and R&D alliances are both uncertain and often interdependent. Thus, the tasks of stock portfolio managers and R&D alliance portfolio managers are fundamentally comparable.

Conversely, however, on some key dimensions R&D alliances fundamentally differ from shares and bonds as an asset type. Firstly, a financial investor rarely is in the position to impact the performance of individual bonds and shares, but optimizes portfolio performance exclusively by combining financial assets (Lubatkin and Chatterjee, 1994). In contrast to such passive management of individual assets, active alliance management fuelled by the central firm's alliance capabilities has been found to significantly impact the performance of individual R&D alliances (Kale, Dyer and Singh, 2001; Anand and Khanna, 2000). Secondly, whereas monetary returns from financial investments are easily absorbed, the appropriation of R&D alliance returns such as partner or jointly developed resources is inherently more difficult (Hamel, 1991; Inkpen and Beamish, 1997). Following extant multiple alliance literature, these differences are resolved by positioning the alliance portfolio management framework as a complementary managerial layer to individual alliance management that simultaneously works to optimize individual alliance performance and value extraction (Duysters et al, 1999; Hamel and Doz, 1996). Indeed, a portfolio of failing R&D alliances is unlikely to generate value no matter the portfolio management efforts.

3.3 Framework development

Through analogue reasoning, this paper uses especially two MPT elements to develop a framework for R&D alliance portfolio management. Firstly, Sharpe's (1970:31-32) three-step analytical approach to portfolio management provides structure for the framework development. Secondly, MPT's underlying logic of interaction between individual assets' return correlation and portfolio level return and risks provides the specific mechanisms through which R&D alliance portfolios are optimized. Below, thus, MPT's core constructs and their implications for R&D alliance portfolios are discussed following Sharpe's three-step approach; (1) Asset analysis, (2) portfolio analysis and (3) portfolio selection.

3.3.1 Asset analysis

Portfolio management builds on knowledge about the portfolio's individual assets, and MPT involve estimation of three key dimensions: (1) the expected rate of return, (2) the uncertainty

associated with the expected rate of return, and (3) the correlation of the asset's expected return with the other assets in the portfolio.

The expected rate of return

The *expected rate of return* express the proportion of expected cash inflows and outflows (e.g. (share dividends + share gains)/(share price)). Similar definitions of R&D alliance returns are emerging in the slipstream of the alliance motives literature (Hagedoorn, 1993). Inherently, however, R&D alliance returns are more difficult to measure, monitor and evaluate (Park and Ungson, 2001). For instance, a recent study found that only 11% of alliances have sufficient performance metrics (Dyer, Kale and Singh, 2001). In response, valuation tools deploying a cost-benefit conceptualization of alliance returns have been proposed such as monetized NPV frameworks (McKinsey, 2002) and more qualitative strategic planning tools weighing key alliance costs and benefits given the firm's strategic objectives for the R&D alliance (Contractor and Lorange, 1988a, 1988b; Inkpen, 1996; Madhok and Tallman, 1998; Keil, 2000). As alliance managers develop an understanding of R&D alliance economics, they will be able to estimate expected rates of returns either in straightforward financial terms, and/or in the qualitative terms by understanding the expected comparable cost-benefits of executing a R&D project through an R&D alliance as opposed to internal R&D or acquisitions. Such analysis will provide the necessary knowledge of a R&D alliance's expected rate of return for alliance portfolio management.

Uncertainty

The second key dimension of asset analysis is *uncertainty*. Broadly speaking asset risks can be thought of in numerous ways, but MPT provides a clear and useful core conceptualization of uncertainty. Asset risks are defined as the likelihood that expected and actual rates of return will diverge, and the potential discrepancy is caused by *uncertain future events* that influence the return rate's cost and benefit components. For instance, the financial investor is concerned with the uncertain future events that potentially but not predictably may alter the share price and dividend payments that determine his rate of return (Sharpe, 1970). For financial assets, the variability of the rate of return (i.e. standard deviation) is widely accepted as a useful risk measure (Brealey, Myers and Marcus, 1995; Elton and Gruber, 1997). Again, for financial assets, MPT and its empirical analogue, the CAPM, divide the issuing firm's risk into non-systematic and systematic risks each of which is caused by fundamentally different types of uncertain future events. Systematic risks stem from uncertain future macroeconomic events such "changes in monetary and fiscal policies, the cost of energy, tax laws, and the demographics of

the marketplace” that affect all firms and thereby all stocks and bonds in the same market (Lubatkin and Chatterjee, 1994:110). Non-systematic risks stem from uncertain future firm-specific events such as “the loss of a major customer [...], the death of a high-ranking executive, a fire at a plant, and the sudden obsolescence of a key product technology” (Lubatkin and Chatterjee, 1994:110). MPT informs investors to diversify non-systematic risks through efficient portfolio selection, whereas it argues that systematic market risks cannot be reduced.

For R&D alliance portfolio management, this paper identifies three key non-systematic risk classes that R&D alliance managers can successfully diversify. These are (1) market risks (i.e. likelihood of the event that customers will not buy the new products or technologies developed in the R&D alliance), (2) technology risks (i.e. likelihood of the event that the R&D alliance’s pursued technological trajectory will not prevail), and (3) capability risks (i.e. likelihood of the event that the R&D alliance partners cannot achieve the joint goals together). To clarify, it may be intuitively confusing for the attentive reader that market and technology risks are argued to be non-systematic, since the CAPM identifies general macroeconomic movements as systematic (i.e. non-diversifiable) risks. This difference arises from the shift in unit of analysis from the original firm-level for financial assets to the sub-firm-level of R&D alliances. At this level market and technological developments may affect individual R&D alliances’ risks differently. This parallels corporate diversification research’s MPT-based reasoning on unrelated diversification holding that business-unit (i.e. sub-firm-level) specific risks are diversifiable by bringing together unrelated business units offering different products and/or serving different markets (i.e. “putting all one’s eggs in different baskets”) (Rumelt, 1974; Amit and Livnat, 1988; Lubatkin and Chatterjee, 1994). The three risk classes are derived from the alliance evolution literature’ treatment of alliance change forces. The competitive and technological environments have been identified as the two key external change forces that are uncertain but nevertheless latently threatens to disrupt the initial (i.e. expected) alliance strategy, organizational design, as well as the terms of cost and benefit sharing. Likewise, the literature identifies internal changes forces stemming from e.g. changing partner strategic objectives, differential learning, conflicts, and the uncertainty inherent in R&D. For simplicity, these are combined into one risk class, namely capability risks (Harrigan, 1985; Hamel, 1991; Inkpen and Beamish, 1997; Doz, 1996; Ring and Van de Ven, 1994). Later, each risk class is elaborated further through explanation of their theoretical underpinnings.

Correlation: risk diversification

The third key dimension of asset analysis is *correlation*, which measures the extent to which the outcomes of two assets move together and has two dimensions: degree and direction. The *degree of outcome correlation* can in the extreme cases be either perfectly correlated or uncorrelated, and otherwise lie in-between. The *direction of outcome correlation* can be either positive or negative. Correlation between two assets is not necessarily rooted in a causal relationship, but only the extent to which two assets are likely to have same outcomes (Sharpe, 1970). Asset outcome correlation informs portfolio analysis to achieve risk diversification and thereby reduce portfolio return variability (i.e. uncertainty). Diversification reduces portfolio risks, when the uncertain future events that influence asset returns are neither uncorrelated nor perfectly correlated, but correlated to a degree and at best negatively correlated (Sharpe, 1970; Brealey, Myers and Marcus, 1995). Risk diversification is also found in the emerging research on interdependencies among R&D alliances outcomes. In line with MPT's risk diversification logic, thus, the "reduction, minimizing and sharing of uncertainty in R&D" has been identified as a leading motive for high-tech firms to engage in R&D alliances (Hagedoorn, 1993:373; Mowery, Oxley and Silverman, 1996). However, extant literature's advice to R&D alliance managers that want to explore the promises of risk diversification fails to expand beyond that more alliances are better than few. Departing from this initial evidence that R&D alliance correlation as discussed in the alliance literature is broadly consistent with MPT's logic of risk diversification, this paper will later enhance managerial advice on how to exploit risk diversification by identifying the specific conditions (i.e. uncertain future events) under which R&D alliances' market risks, technology risks and capability risks can be diversified.

Correlation: portfolio synergies

Risk diversification alone does however not cover the full potential for exploration of R&D alliance outcome correlation to improve R&D alliance portfolio returns and risks. A literature review reveals that most alliance research on the discreteness or interdependence (i.e. correlation) of multiple alliances concerns the *positive correlation of synergetic R&D alliance returns*, which is a distinctively different kind of correlation than the one exploited with risk diversification. At the low end of this correlation scale, no correlation may exist across the platform firm's alliance portfolio, when being "but the sum of individual discrete alliances with little co-ordination and cumulativeness between alliances" (Hamel and Doz; 1996:9). In such cases, portfolio synergies are unlikely to increase the portfolio returns above the weighted sum of individual R&D alliance returns as defined by MPT. Scale upwards, however, researchers

have explored numerous types of interdependence among alliances. Examples include the degree of which the central firms' partners interact with each other and not merely the central firm itself, the degree to which the achievement of individual alliance objectives are dependent on other alliances, the degree of applicability of the central firm's technologies and capabilities to several alliances, and the degree of coordination between alliances (Booz, Allen and Hamilton, 2000; Doz and Hamel, 1996 and 1998). In agreement with MPT, hence, research on portfolio synergies stresses the importance of studying interdependence degrees for alliance portfolio management (Hamel and Doz, 1996).

Based on interdependence discussions, scholars distinguish between portfolio synergies that either accrue internally in the central firm, or externally across R&D alliances. *Internal portfolio synergies* can e.g. be spanned from (1) applying the central firm's resources and capabilities in a complementary manner to partners' e.g. different product and geographical markets (Doz and Hamel, 1998), (2) improved bargaining position vis-à-vis new portfolio members accumulated from collaboration with existing members, (3) improved industry structure or e.g. technology standards development from the perspective of the focal firms core competences, (4) development of multiple options on technology development at an affordable cost (Hamel and Doz, 1996). Thereby, an alliance portfolio enables the central firm to fill multiple and diverse resource and capability gaps, and hence rely on the alliance portfolio for a substantial fraction of the total resource and capability base underlying its competitive offerings (Booz, Allen, Hamilton, 2000). *External portfolio synergies* (i.e. those accrued across partnering firms) have been found in interfirm networks that leverage, share and diffuse knowledge not only between the central firm and its individual partners as in discrete alliances, but also across partners improving the quality of a class of interdependent alliances as excelled e.g. by Toyota (Duysters et al, 1999; Dyer and Nobeoka, 2000). Thereby, the central firm creates value by acting as a broker between the members of the portfolio (Lorenzoni and Baden-Fuller, 1995).

Following the above, portfolio synergies stand out as a second interesting portfolio effect that together with MPT's risk diversification effect hold great potential in enhancing R&D alliance portfolio management. In essence, the reviewed literature suggests that synergetic correlation increases aggregated alliance portfolio returns by *lowering costs* (e.g. through leverage of knowledge required to perform alliance activities) and/or *increasing benefits* (e.g. complementarities across newly developed products and technologies). Thereby, R&D alliance portfolio synergies build on a different logic than risk diversification, as the objective is to

increase the portfolio level return rather than to reduce portfolio level risks. In terms of the MPT core construct correlation, portfolio synergies accrue when R&D alliance returns are positively correlated and at best to high degrees. Whereas the discussion of MPT's risk diversification lead to associations with the corporate diversification literature's treatment of unrelated diversification, R&D alliance portfolio synergies parallel the corporate diversification literature's treatment of related diversification that favours bringing together synergistically interrelated business units (i.e. putting all of one's eggs in similar baskets) (Bettis and Hall, 1982; Lubatkin and Chatterjee, 1994). In related diversification, valuable business synergies are especially reaped from (1) scale economies from combined performance of value chain activities, (2) supply-side economies of scope through transferring existing strategic assets and competencies in building new strategic assets between related business units, (3) demand-side economies of scope through enhanced product line differentiation, and (4) improved market power through multipoint form of competition (i.e. conglomerate power) (Amit and Livnat, 1988; Montgomery, 1994; Lubatkin and Chatterjee, 1994; Markides and Williamson, 1996). The evident overlaps between portfolio synergies and related diversification lend further support and inspiration to this second managerial lever of the alliance portfolio management framework.

The alliance antecedents and the corporate diversification literature indicate that portfolio synergies are quite diverse. To systematize portfolio synergies, the alliance portfolio management framework posits four distinctive portfolio levels to guide the search for R&D alliance portfolio synergies. The *first* portfolio level is synergies between alliances with the same partnering company. The individual alliance literature has provided ample evidence of such partner-specific synergies. The *second* level is synergies reaped among R&D alliances with similar strategic objectives and hence activities (e.g. R&D in the same technology or product field). The subdivision of the alliance portfolio into groups of different alliances types stems from the multiple alliance antecedents, and arguably improve managerial overview by reducing the analytical complexity of multiple alliance management (Booz, Allen and Hamilton, 2000; Duysters et al, 1999). The *third* level of portfolio synergies suggested by the framework concerns portfolio synergies reaped across a subset of alliance types, which were inspired by evidence from NTT DoCoMo. Lastly, the *fourth* level considers portfolio synergies reaped across the entire portfolio that are not specific to neither individual partners, particular types of R&D alliances or combinations thereof. Rather these portfolio synergies improve the aggregate R&D alliance portfolio return by positively influencing all R&D alliances in the portfolio.

In sum, based on discussions of R&D alliance return and return correlation, two managerial levers for alliance portfolio management are proposed, namely risk diversification and portfolio synergies. Whereas the above asset analysis concerned how to analyze individual alliances in terms of return, risk and correlation, the below portfolio analysis is concerned with the aggregate analysis of multiple R&D alliances to unleash the value of risk diversification and portfolio synergies for alliance portfolio management.

3.3.2 Portfolio analysis

The second step in Sharpe's three-step approach to portfolio management is portfolio analysis, which produces predictions about alternative portfolios' expected portfolio return and risks. Portfolio analysis is based entirely on the individual asset analysis' estimates of the expected rates of return, the associated uncertainty and the correlation of individual asset outcomes. The aim is to identify efficient portfolios (i.e. specific combinations of potential investments in various assets) at the so-called efficient frontier, which are the portfolios that offer the highest return at a given risk or alternatively the lowest risk at a given return (Sharpe, 1970). The two measures used for portfolio performance measurement are the portfolio's *expected rate of return* and the *associated risk* expressed in terms of its standard deviation. In numeric terms, a portfolio's expected return is the weighted average of the assets' expected returns weighted according to the proportions of invested capital. The standard deviation of a portfolio's rate of return is a function of the standard deviation of return for its component assets, their correlation coefficients and the proportions invested (Sharpe, 1970). Thus, the interrelationships of individual asset outcomes influence a portfolio's associated risk, which as explained earlier is exploited through *risk diversification*. Consequently, a portfolio's assets cannot be selected on characteristics unique to the asset only, because the interaction between assets returns must also be considered (Elton and Gruber, 1997).

This paper posits *risk diversification* and *portfolio synergies* as the portfolio optimization principles (i.e. managerial levers) for R&D alliance portfolio management. The risk diversification lever constitutes a direct analogy to MPT, whereas the portfolio synergy lever constitutes an indirect analogy to MPT. This because (1) MPT is only concerned with risk diversification and (2) for portfolio synergies, only the core principle of portfolio return optimization based on individual asset return correlation is derived from MPT. Having established the two controlling managerial levers, the next issue is how to analyze information gathered about the individual R&D alliances' return, return uncertainty and return correlation to

construct efficient frontier portfolios. MPT has formulated the portfolio analysis for financial assets as a mathematical optimization problem (Sharpe, 1970). However, the paper chooses to develop the R&D alliance portfolio management framework as a strategic planning tool intended to focus managerial attention on key portfolio issues and guide decisions (see Contractor and Lorange (1988a, 1988b) for similar argumentation for alliance cost-benefit analysis). Hence, in the below framework illustration the portfolio analysis is conducted qualitatively rather than quantitatively.

3.3.3 Portfolio selection

In the final step of Sharpe's three-step approach is portfolio selection. A specific efficient portfolio is chosen and materializes, when the financial investor carries out the implied investments, or when the R&D alliance portfolio manager forms new, terminates existing and/or changes existing R&D alliances according to the portfolio analysis' recommendations. MPT requires the investor to decide on risk-return preferences, which are then matched with a financial asset portfolio at the efficient border (i.e. maximum return at given risk, or minimum risk at given return) (Sharpe, 1970). When translated into the context of R&D alliance portfolio management, portfolio selection involves careful consideration and cost-benefit analysis of the alternative portfolio scenarios based on the firms competitive strategy, technology strategy, financial resources and identified needs for product, process and technology development. Based on the below detailed illustration of the alliance portfolio management framework, managerial implications for portfolio analysis and portfolio selection are presented in the papers concluding part.

Summary table of extension of MPT for alliance portfolio management

Step	Financial asset portfolio management	R&D alliance portfolio management
1. Asset Analysis		
Return	Expected rate of return	Expected cost-benefits of R&D alliance to individual partners from pursuing joint objectives.
Risk	Expected outcome uncertainty (std. deviation).	R&D alliance outcome uncertainty caused by market, technology and capability risks
Interrelationships	Correlation coefficient	R&D alliance outcome interdependency leveraged through diversification of outcome risks and realization of outcome synergies.
Weight in portfolio	Investment	Resource commitments (input), strategic value (output)
2. Portfolio Analysis		
Portfolio return	Expected portfolio rate of return	Expected cost-benefits of R&D alliance portfolio improved above average returns of individual alliances through portfolio synergies.
Portfolio risk	Expected portfolio outcome uncertainty	R&D alliance portfolio outcome uncertainty reduced through risk diversification
3. Portfolio Selection		
Risk-return properties	Efficient frontiers of alternative constellations of portfolio return and portfolio risk	Cost-benefit properties of an R&D alliance portfolio for development of specified technology, product and process assets.
Risk-return preferences	Preferred preferences of portfolio return and portfolio risk	Technology strategy of platform firm in terms of innovation targets, allocated resources and risk willingness.

3.4 Risk diversification

This section elaborates and operationalizes the framework’s three diversifiable R&D alliance risk classes, namely (1) market risks, (2) technology risks, and (3) capability risks. Firstly, theoretical backgrounds on each of the three risk classes provide an intimate understanding of the uncertain future events that cause the R&D alliance return uncertainties. Secondly, each of the three risk classes are operationalized through illustrative evidence from NTT DoCoMo and the wireless telecommunications sector at large. The correlation premise for risk diversification (i.e. R&D alliance returns should be neither uncorrelated nor perfectly correlated, but correlated to a degree and at best negatively correlated) controls the operationalization.

3.4.1 Market risks

In highly turbulent environments, market risks such as customer adaptation and willingness to pay for new products are often substantial. In the tail of technological progress, indeed, uncertainties prevail on how to exploit the technological potential commercially. For such environments, Porter (1980) stress (1) technological uncertainties on what product configuration customers will ultimately demand and (2) strategic uncertainties on which firm strategies as to product and market positioning will be superior. Often, buyers of newly developed products are first time buyers, which further adds to the risks. These uncertainties are reflected in frequently used product frameworks such as the S-curve for product life cycles and the Boston Matrix product portfolio tool. Market risks relate to the early introduction and expansion stage of the PLC curve, and the Boston matrix's 'question marks' defined by low market share and high growth products (Bass, 1969; Boston Consulting Group, 1970). Against this background, market risks are defined as the uncertainty of product configuration and commercial uptake.

New wireless service development

In wireless telecommunications, market risks for new data services are both substantial and dominating future growth sources, as traditional voice growth and revenues are maturing. High uncertainty prevails as to which future killer applications will drive revenue generation, which content types will attract customers, and customers' willingness to pay (Financial Times, November 2002; Communications International, February 2002; Credit Swiss First Boston fatphone series; Standard & Poors, 2002). NTT DoCoMo CEO Tachikawa recently pinpointed that experience from the infamous I-mode wireless Internet service launched in 1999 on the surprising success of entertainment content (and one may add the success of SMS in Europe) renders up-front predictions of future killer applications illusive (Economist, 18.07.2002). In response, NTT DoCoMo emphasizes resources and time for experimentation "because our customers will decide [the commercial success of new applications]" and hence, "experimentation is key" (Boston Consulting Group, 2002). Such exploration based strategy finds strong support in the learning and innovation literature in dealing with fluctuating and uncertain demand (March, 1991; Anderson and Tushman, 2001).

NTT DoCoMo's experimentation strategy is enacted through rapid and continuous service launches based on internal as well as collaborative R&D activities. Specifically, the R&D projects explore new business concepts and enabling application platform technologies for new service platforms (e.g. Internet, multimedia, car services, location-based services) and new

enhancing service platform features (e.g. JAVA and Flash) (Natsuno, 2003). The R&D also involves the integration of new application platforms into the hardware and software of the wireless telecommunication subsystems including content server systems, wireless transmission infrastructure and handsets. Evidently, NTT DoCoMo pursues a substantial proportion of new service application through R&D alliances to leverage partnering firms' complementary technologies and converging industry expertise in developing services unreachable for internal R&D (see below table). Thereby, it is argued that NTT DoCoMo diversifies uncertain outcomes of wireless application R&D in terms of product configuration parameters such as viable business models and product concept, as well the applications' commercial success (i.e. the two elements of market risks).

Service type	Development partners	Alliance objectives
Graphic rich content applications	1. Sun Microsystems (03/1999) 2. Macromedia Inc (02/2003)	Deploy Internet technologies to wireless
Video distribution technology via 3G and 4G	1. IBM (12/2000) 2. Hewlett-Packard (12/2000) 3. Packet-Video (01/2001)	Video technology R&D, test and diffusion
Video applications	1. FOMA Live-Video Consortium with 32 partners (09/2001)	Develop and study video applications
Gateway portal for both fixline and wireless Internet	1. JV with AOL and Mitsui (09/2000)	R&D and venture investments in PC-Mobile convergence services
Gaming	1. Sony (08/2000) 2. Sega (02/2001)	R&D in services combining i-mode and FOMA with gaming.
Corporate solutions	80. Corporate solution partners (2001) 81. SAP (04/2001) 82. IBM Lotus (11/2001) 83. Oracle (03/2002)	Develop and market wireless business applications
Physical service points	1. I-vending with Coca-Cola (09/2000) 2. I-convenience store JV with Lawson, Matsushita and Misubishi (10/2000)	Develop and market services with physical service points
Wireless advertising	1. JV with Dentsu (06/2000)	Develop and market wireless advertising
Car services	1. JV with Mitsui and NEC (07/2000) 2. Nissan (02/2002) 3. Lucky Strike Honda F1 (07/2002) 4. Multi-partner Business Telematics Committee with Nissan (12/2002)	Develop and market telematics services
E-Payment services	1. Payment First (06/2000) 2. JV Japan Net Bank with Sakura Bank, Sumitomo Bank, Fujitsu, KDDI (10/2000)	Develop and market e-payment and e-banking wireless services
Network identify	1. Liberty Alliance Project with 17 partners (12/2001)	Create open network identify for Internet
<i>Sources: Company press releases (1997-2003), Natsuno (2003), UBS Warburg (2001), Williamson and Meegan (2002).</i>		

The evidence from DoCoMo fuels illustration of the potential for risk diversification for managing its multiple application alliances. The following discussion departs from the

aforementioned correlation premise for R&D alliance returns that is discussed conceptually for the two elements of market risks, namely product configuration and commercial uptake. The R&D alliance returns related to market risks include expansion of existing product ranges through R&D and commercialization, monitoring and pursuing new business opportunities, and development of convergence products that especially challenge product configuration, as often no existing product market exists (Hagedoorn, 1993). NTT DoCoMo engages in R&D alliance working in 11 wireless service fields as demonstrated by the table's first column grouping of the application alliance class. The return of R&D alliances engaged with different service types is not perfectly correlated because applications such as video distribution, gaming, corporate solutions and car services may target different consumer segments with varying preferences and purchasing power. This implies differences in the potential for commercial uptake of wireless applications. Conversely, network externalities such as critical mass in overall customer base driven by all services for wireless advertisements and relevance of multiple services to individual users may have a positive effect on the uptake of otherwise different wireless services (Natsuno, 2003; Ratliff, 2002). Provided budget constraints, different service types targeted to similar customer groups such as multimedia services and gaming for young segments may even be negatively correlated.

The number of R&D alliances within each service type category listed in the tables second column is another source of correlation within the application alliance class. Each R&D alliance may represent alternative configurations of similar applications and in the case of e.g. gaming and corporate solutions NTT DoCoMo collaborates with direct competitors. Hence, alliance outcomes are not perfectly uncorrelated as similar services compete for the same budgets and, thus, R&D alliance outcomes may even display negative correlation. To the degree that services within the same category are complementary and a certain breath of services thus attracts customers such as the graphic rich content applications, the alliance outcomes may be positively correlated. In sum, the correlation premise finds preliminary support for wireless application development as alliance R&D returns arguably are neither perfectly correlated nor uncorrelated, but correlated to a degree and at times negatively.

Wireless corporate solutions is explored in more detail to further illustrate risk diversification of market risks routed in uncertainty on whether customers will ultimately like and pay for new wireless services. Wireless corporate solutions count to the most promising applications of wireless technologies and NTT DoCoMo assumes market leadership in this segment with 10%

corporate part of the total customer base (Economist, 2001; UBS Warburg, 2001). The wireless industry projects great expectations on the corporate segment due to its high data-transfer requirements and large communication budgets. To pursue this market, NTT DoCoMo formed above 80 R&D alliances with software developers and big client enterprises leading to commercialization of numerous services including management systems connected to corporate networks for sales representative support, customer information, product information, business reporting, and university campus message boards. By 2001, the above 100 services are offered under the DoCoMo Value and Link to DoCoMo brands (UBS Warburg, 2001). Through this alliance web, market risks for corporate solutions were diversified across a large number of R&D alliances. Specifically, the uncertainty of which specific software types, configurations and bundles would attract corporate users and induce a sufficient willingness to pay was spread out and shared with the many partners. Given the increased global penetration of standardized ERP software, in April 2001 NTT DoCoMo teamed up with German software leader SAP to develop systems and services, as well as explore possibilities to jointly market such services in the firms existing markets. By November 2001, a similar alliance was forged with IBM's Lotus Software unit to jointly develop and globally market wireless multimedia business solutions. Following announcements in February 2002 that NTT DoCoMo was seeking additional system integrator partners to "help harness the full capabilities of its high-speed 3G services" (Reuters, 08.02.2002), a R&D alliance with the worlds biggest enterprise software maker Oracle. In total, three R&D alliances have been formed with global software leaders that integrates global accounting, database management, marketing and production operations for companies (Company press releases). Thereby, NTT DoCoMo has diversified market risks of the three global enterprise software competitors' different software offerings in the wireless context.

3.4.2 Technology risks

In high-tech regimes of rapid technological change, technology standard races among competing technology trajectories imply technology risks at the firm level of betting on ultimately obsolete technology versions (Anderson and Tushman, 2001). Following evolutionary theory, technological risks are critical due to path dependencies shaping firms competence bases, time compression diseconomies and the cumulative nature of asset accumulation activities such as R&D, and implied irreversibilities thwarting firms from shift trajectory (Dierikx and Cool, 1989; Teece, 1996).

In establishing the context for this risk class, traditional models of technological development suggest that “technological progress constitutes an evolutionary system punctuated by discontinuous change [...] representing technical advance so significant that no increase in scale, efficiency, or design can make older technologies competitive with new technology” (Anderson and Tushman, 1986:440-441). Dosi (1982) provides an alternative discontinuous equilibrium model defining discontinuous technological change as the emergence of new technological paradigms defined as “a ‘model’ and a ‘pattern’ of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies” (emphasis in original Dosi, 1982:152). Technological progress ‘actualizes the promise’ of a new technological paradigm and is reflected in the emergence of multiple technological trajectories defined as a “pattern of ‘normal’ problem solving activity (i.e. of ‘progress’) on the ground of a technological paradigm” (Dosi, 1982:152).

Discontinuous change initiates an era of ferment during which the new technology competes against both old technologies and multiple emerging versions of the new technology. In the emerging selection environment, the latter design competition rests upon uncertainty about superiority of alternative versions and the incentives of pioneering firms to differentiate its variant from their rivals. The variation in versions of the technological discontinuity in the era of ferment that drives the substitution and design competition implies high uncertainties for both manufactures, suppliers, customers and regulatory agencies. For instance, competing firms face uncertainty about the design, production and commercialization of their respective versions and customers face uncertainty about the product performance and the risk of switching costs in case another design later emerges as the industry standard. These uncertainties fuel the emergence of a dominant design ending the era of ferment, which is a single architecture that establishes dominance in a product class or process type (Anderson and Tushman, 1990). In sum, positioning in relevant technological trajectories becomes critical for platform firms to reduce their exposure to technology obsolescence risks.

Wireless transmission standards

Technological progress of the core wireless telecommunications technologies responsible for the transmission of wireless signals has received substantial scholarly attention that posits that the technological progress largely follows the above models of innovation (Funk and Methe, 2001; Davies and Brady, 1998; Bekkers, Duysters and Verspagen, 2002). Specifically, technological progress has evolved in technology generations (see technology migration map in appendix).

First generation analogue transmission technologies with bulky receivers emerged for early marine and car telephony such as the US AMPS standard, the Scandinavian NMT standard, and TACS. From the early 1990s, second generation technologies such as US IS-95, European GSM, and Japanese PDC introduced digital telephony. Digital technology both provided radical performance improvements and build on new problem-solving approaches – a discontinuous change that initiated the IT convergence through microelectronics of telecommunications (Teece, 1996). In recent years, a plurality of so-called 2,5G generation technologies such as GPRS, EDGE and CDMA20001X enabling packet-switched and higher-speed data transfers than 2G technologies have blurred the borderline between 2nd and 3rd generation technologies. Whereas, 2,5G technologies provide performance improvements e.g. from 9,6 kbps to above 100 kbps transfer speeds, they are largely incremental improvements of key 2G standards such as CDMA, TDMA and GSM. Essentially, the two key 3G technologies, CDMA2000 and WCDMA are also incremental improvements of the original 2G CDMA technology invented by US Qualcomm, and future 4G networks will continue to build on existing 2G and 3G networks (Nakajuma and Yamao, 2001).

In developing the technology risk class, it is essential that the premise of risk diversification apply well when a focal company seeks access to the competing technology standards. In this case, negative correlation of alliance returns driven by causality is apparent, when one standard emerges as the dominant design and renders other standards obsolete to some extent. Moreover, degrees of positive correlation exist among related competing technological trajectories of a technology generation (i.e. paradigm). The managerial implication for risk diversification is to build an alliance portfolio with alliances representing competing technology trajectories and standard versions within each trajectory to diversify the risk of only having accumulated and/or secured access to technology standards that render obsolete.

NTT DoCoMo: a wireless transmission standard leader

NTT DoCoMo, however, provides only indirect illustration of technology risk diversification. NTT DoCoMo experienced how the internally developed 2G PDC technology that lost to the European GSM standard that emerged as the dominant global 2G standard due to open standard setting through the ETSI committee with representatives from wireless operators, governments and equipment manufactures (Funk and Methe, 2001). Given the company's international ambitions, the firm changed its approach for 3G and technology standardization alliances have been instrumental to its efforts to proliferate the 3G WCDMA technology and 4G technologies

as de facto regional and global wireless standards (Ratliff, 2002). Specifically, NTT DoCoMo formed a constellation with mainly Nokia and Ericsson that successfully proliferated WCDMA in competition with a US constellation proliferating the IS95 standard in the European ETSI standardization committees formed by European governments to choose a single European 3G wireless transmission standard (UMTS) in late 1997. The constellation refined NTT DoCoMo's WCDMA technology by deploying GSM as technology interface instead of the ISDN as originally planned. The compromise was driven by Nokia and Ericsson's specialization in GSM, their vulnerability to the emergence of a 3G dominant standard non-compatible with GSM, and NTT DoCoMo's need for critical mass and political connections for their endeavour (Funk and Methe, 2001). Thereby, NTT DoCoMo co-opted the emergence of competing technology standards from the constellation members by turning potential competitors into partners (Doz and Hamel, 1998). Thus, technology risk diversification occurred not through multiple R&D alliances, but multiple partners within one R&D constellation.

Wireless transmission standard followers

Outside domain of NTT DoCoMo, more clear-cut illustrations of technology risk diversification related to wireless transmission technologies can be found. South Korea's leading wireless operator, SK Telecom, has acquired 3G licenses both for CDMA2000 and WCDMA networks, and while current MMS services run on CDMA2000 1x ED-VO, UBS Warburg expects initial rollouts of WCDMA networks to commence in 2003 (Global Wireless, 2001; Electronic Engineering Times, 2001; UBS Warburg, 2002). Thus, risk diversification applies better to technology followers (i.e. SK Telecom) than technology leaders setting industry standards (i.e. NTT DoCoMo) in transmission standards. In contrast, network infrastructure and handset vendors while holding expertise in only a few transmission technologies, spread their product portfolio across multiple trajectories by means of e.g. multi-band handsets to be able to supply dominant design technology. Indeed, global vendors must be well positioned in multiple trajectories to compete effectively. For instance, global network leader Ericsson acquired Qualcomm's CDMA infrastructure business in May 1999 to complement its strong position in the competing 3G standard WCDMA (Deloitte, 2001).

3.4.3 R&D/Capability risks

The alliance portfolio framework's third diversifiable risk class concerns capability accumulation risks that stem from the uncertainty inherent to innovation. The risk mediates between the initially intended R&D output and the ultimate R&D alliance outcome. The

riskiness of alliance based R&D stems both from the uncertainty of R&D itself (Teece, 1996), and the uncertainty of R&D alliance outcomes due to alliance dynamics (Doz, 1996). Thus, whereas technology and market risks relate to R&D outcomes such as new technologies and products, the capability risks relates to the joint R&D process. More specifically, the uncertainty concerns whether the partners will achieve their joint goals together.

Sources of R&D uncertainty include the tacitness of knowledge underlying many innovative efforts (Kogut and Zander, 1992). The complex tacit knowledge component increases along March's dichotomy of (1) the exploration of new possibilities through experimentation processes and (2) the exploitation of existing competencies through refinement and extension processes reflected e.g. in the choice between inventing a new technology or the refinement of an existing one (March, 1991; Nonaka, 1994). March (1991) argues that returns from exploration are systematically less certain, have longer time horizons, and often negative as opposed to always positive for exploitation. Similarly, Iansiti (2000) argues that increasing radicalness of innovation increases the required numbers of parallel experiments. Innovation targeting embedded technologies resulting from technology convergence of previously unrelated technology fields also has highly uncertain outcomes (Hamel and Doz, 1996).

Capability risks also stem from the R&D alliance itself in terms of initial conditions, the interfirm processes and governance structures that are setup to enact the joint R&D project. As for the processes Hamel and Doz (1996) argue that the more tacit, embedded and systemic the involved assets are, the more co-practice (i.e. joint interaction) is essential. Teece (1992) argues that innovation of increasingly complex technological assets requires operational coordination granting access to complementary assets, coupling of the project team to users and suppliers, coordination of technical standards, and the establishment of the necessary connections to other relevant technology assets. The latter include prior technologies as innovation is a cumulative process, complementary technologies to integrate and consider system interdependencies, and lastly to enabling technologies. Moreover, to setup such processes relation- and transaction specific investments such as upfront investments in specialized equipment, training and dedication of human resources are required to enable the generation of relational rents, which increases the stakes at risk (Dyer and Singh, 1998). The inherent uncertainties of the complex interorganizational processes can only partly be mitigated through efficient governance structures. Oxley point to hazards stemming from "difficulties in adequately specifying payoff-

relevant activities, monitoring the execution of prescribed activities and/or enforcing contracts through courts” (1997:389).

The capability risks of R&D alliances often underlie the high alliance failures rates, and the managerial complexity makes inadequate management of alliance evolution rather than insufficient business fundamentals a frequent failure cause (Bleeke and Ernst, 1991; Arino and Doz, 2000). Thus, given the high uncertainty implied by R&D itself, complex interorganizational processes and incomplete contracts, there exists ample indication that joint R&D is a risky business. Management of the uncertainty through efficient individual alliance management and successful risk diversification across a number of similar R&D alliances determine whether the partnering firms can achieve their joint objectives together.

Wireless service application development

In wireless telecommunications, the number of R&D alliances is increasing as a result of e.g. the convergence between telecom, IT and media industries, increasingly complex technologies and the rapid pace of development (Duysters and Hagedoorn, 1998; OECD, 2000). Consequently, capability risks are increasingly important to manage. Again, NTT DoCoMo portfolio of service application alliances presented previously in this paper provides illustration of the phenomenon. While NTT DoCoMo also engages in multiple R&D alliance with e.g. wireless infrastructure and wireless handset vendors that illustrate capability risk diversification, the discussion is kept on service application alliances to clarify the interplay between simultaneous portfolio management of a R&D alliance class according to multiple sources of risk diversification.

To recapture, the company has formed R&D alliances in multiple service fields and in most cases with several partners within each field. Market risk diversification was argued to influence the breath of service fields (i.e. car services, multimedia, payment services, corporate solutions and more) following uncertainty of commercial uptake of different applications of wireless technology to converging industries. Moreover, market risk diversification was argued to influence the formation of multiple R&D alliances within the same service field to diversify across product configuration variations. Indeed, however, in explaining the latter capability risk diversification suggests that multiple R&D alliances are forged to diversify the uncertainty related to the R&D process and alliance-type risks jeopardizing the successful completion of joint objectives. NTT DoCoMo’s three multimedia distribution technology alliances illustrate this point.

NTT DoCoMo's multimedia alliances with IBM, HP and Packet-Video

In 2000 and 2001, NTT DoCoMo formed three R&D alliances to develop multimedia distribution technologies with IBM, Hewlett-Packard and US Packet-Video, a multimedia software house, respectively. From December 2000 to September 2001, the IBM alliance developed a technology for compiling excerpts ("digests") of video content according to user-specified keywords (e.g. a football players name) and then stream the content to the user's mobile phone (e.g. clips with the player). This technology is complementary to the larger scopes of the HP and Packet-Video alliances that both develop full-scale video-streaming distribution platform systems. Since capability risk diversification is most powerful for R&D alliances with similar scopes the two other alliances become of interest. In January 2001, the Packet-Video alliance initiated R&D on a video distribution technology platform for both live and archived content for NTT DoCoMo's 3G FOMA service. By September 2001 the two partners formed a consortium with 32 other companies to develop and study marketability of service applications to be delivered on the technology platform. As soon as April 2002, NTT DoCoMo launched a trial service dubbed FOMA V-live featuring music, sports, highlights, news, tourist information, English conversation lessons, security services and investor relation tools that users can download or stream. Based on a successful trial period NTT DoCoMo recently announced that the FOMA V-live service will be commercially launched nationwide in Japan in May 2003. Just a month before the Packet-Video alliance was formed, NTT DoCoMo and Hewlett-Packard had joined hands to develop multimedia delivery and network applications for 3G and 4G networks. In this case, DoCoMo teamed up with a streaming and server technology expert to develop similar systems to those pursued by the Packet-Video alliance. By September 2002, the Hewlett-Packard alliance announced that future generation multimedia content delivery system particularly strong in streaming of large-volume content such as video had been developed integrating effective management of transmission infrastructure based on HPs capabilities. Thereby, NTT DoCoMo has created a second option on multimedia delivery technology and thereby diversified capability risks.

NTT DoCoMo's Corporate solution partners

Apart from market risk diversification, the enterprise software alliances with 80 software developers and three global software integrators (SAP, IBM Lotus, and Oracle) also offers

capability risk diversification as more options are created for similar R&D projects. Thus, in case of alliance failure, NTT DoCoMo may still achieve successful application development with other partners.

It is noteworthy that the underlying correlation of R&D alliance outcomes arguably is less solid in the case of capability risk diversification compared to the two other risk classes. Whereas causality drives correlation of R&D alliance outcomes for market and technology risks, there is no diversifiable causal correlation between the success and failure of independent R&D alliances. Although one correlation source would be the partnering firm's alliance capabilities, such correlation improves project success rates for all R&D alliances and hence diversification considerations are irrelevant (instead since alliance capabilities can be leveraged across multiple R&D alliances to improve average success rates they constitute a synergy source as explained later in this paper). Following Modern Portfolio Theory, however, causality is no requirement to establish correlation between asset outcomes. Moreover, given the need for large-scale experimentation in radical R&D, intuitively speaking, the capability risks would be diversifiable through several similar R&D alliances. Hence, the nature of correlation is not causal, but builds on the simple notion that provided a type of R&D alliance has for instance 20% success rates, the platform firm can diversify capability risk through a portfolio of five similar R&D alliances.

3.5 Portfolio synergies

This section elaborates and operationalizes the second managerial lever, portfolio synergies. The approach is slightly different from the approach used for risk diversification. In the latter, an exhaustive list of three risks was identified and in-depth theoretical backgrounds and empirical evidence were instrumental to illustrate and operationalize each of the three risk classes. The previously reviewed antecedents to alliance portfolio synergies and the corporate diversification literature on related diversification revealed that the numerous sited synergies were quite diverse in nature, and thus, more difficult to produce an exhaustive taxonomy of. For instance, the review gave indication to internal portfolio synergies, external portfolio synergies, synergies accrued from economies of scale, and synergies accrued from economies of scope on both the supply-side and demand-side. Thus, instead of proposing an exhaustive taxonomy of specific portfolio synergies, this paper introduces a search heuristic in terms of four levels in R&D alliance portfolios to guide alliance portfolio managers' search for various types of portfolio synergies. The four levels in a multi-type R&D alliance portfolio are (1) synergies reaped across alliances with the same partner, (2) synergies reaped among same-type alliances, (3) synergies

reaped across a subset of alliance types, and (4) synergies reaped across the entire alliance portfolio. For each level, this section presents illustrative examples of valuable synergies each with a theoretical background to elevate the application of the examples to other contexts, and empirical evidence from NTT DoCoMo and the wireless telecom sector. The correlation premise for portfolio synergies (i.e. R&D alliance returns should positively correlated) controls the search for synergies at the four portfolio levels.

3.5.1 Portfolio synergies across multiple alliances with the same partner (partner-specific)

Three illustrative partner-specific synergies are identified for this first portfolio level. In general, these synergies take advantage of accumulated assets such as trust and interfirm routines across multiple alliances between the same partners.

Repeated ties between NTT DoCoMo and Hewlett-Packard

In R&D alliances, synergies are frequent in terms of new business ideas and collaborative opportunities generated by success in previous collaboration. Over time, thus, the scope of joint activities may increase as partnering firms experience efficient fulfilment of individual strategic objectives, successful conflict management supporting continued collaboration despite high uncertainties signifying R&D activities, and the accumulation of interfirm trust and partner-specific absorptive capacity (Ring and Van de Ven, 1994; Doz, 1996; Arino and Doz, 2000; Arino and De la Torre, 1998; Lane and Lubatkin, 1998; Mowery, Oxley and Silverman, 1996; Reuer, Zollo and Singh, 2002). In such cases, R&D alliances with the same partner have improved stakes in make-or-buy decisions as previous alliances are factored into the equation.

In December 2000, NTT DoCoMo and Hewlett Packard initiated a joint R&D effort to develop 3G and 4G multimedia content delivery platform and network equipment enabling provision of large volumes of content such as movies and live video via the mobile Internet. By September 2002, the R&D alliance announced successful completion of the platform and infrastructure such as management servers monitoring network traffic (Company press releases). Fuelled by high satisfaction with the joint collaboration and R&D outcome NTT DoCoMo shifted to HP as its preferred enterprise server vendor in replacement of former vendor SUN.

Leveraging interfirm product development routines with handset and network vendors

A strong argument in the individual alliance literature is the necessity of building interorganizational routines matching the strategic objectives of partnering firms to

accommodate the intended value creation (Dyer and Singh, 1998). For instance, alliance learning is argued to take place by design and careful attention rather than through coincidence or random processes (Hamel, 1991; Makhija and Ganesh, 1997). Thus, interorganizational routines for joint R&D, product and technology development build for the initial R&D alliance between two partnering firms present a source of synergies, as established patterns of interaction may be leveraged across multiple R&D projects and future R&D alliances.

To illustrate, NTT DoCoMo has engaged in long-lasting partnerships with handset and network infrastructure vendors and thereby reaped synergies from repeated transactions through established channels. Alliance partner inherited from parent NTT's family include Japanese NEC and Matsushita. Since mid-1990s, repeated joint R&D has also been performed with international partners such as Ericsson.

Leveraging initial equity investment in KPN Mobile across subsequent joint alliances

Alliance governance mechanisms established with a R&D partner can be deployed across several R&D projects. Within the contractual governance literature, for instance, hostages such as equity investments in joint ventures or in-kind hostages in bilateral contracts are instrumental to align partner incentives and thereby obstruct opportunistic behaviour and motivate behaviour in favour of the joint objectives (Williamson, 1991; Oxley, 1997; Ring and Van de Ven, 1994; Dyer and Singh, 1998). In parallel, the relational governance literature suggests that accumulated interfirm trust and relational capital can be deployed across future alliances, which decreases the need for costly formal contractual governance mechanisms (Ring and Van de Ven, 1992; Gulati, 1995; Kale, Singh and Perlmutter, 2000; Poppo and Zenger, 2002).

To illustrate, NTT DoCoMo has engaged in multiple non-equity alliances with its European partner Dutch KPN Mobile through their equity joint venture. Specifically, joint market access alliances have been formed with wireless operators in UK together with the Hong Kong partner Hutchison Whampoa (June 2000), and Italian TIM (January 2001). Through KPN Mobile, NTT DoCoMo also gained access and joint ownership to the partner's existing market access alliances with other European and Asian wireless operators, namely E-Plus (Germany), KPN Orange (Belgium), Pannon GSM (Hungary), Telkomsel (Indonesia) and Ukraine Mobile Communication (Ukraine) (Company press releases).

3.5.2 Portfolio synergies among same-type R&D alliances (R&D activity specific)

Three illustrative examples of R&D alliance type-specific synergies are provided. In general, such synergies are reaped across R&D alliance performing similar activities and/or producing similar outputs.

Critical mass for proliferation of the WCDMA technology standard

Innovation research suggests that technological superiority alone does not determine the outcome of competitive standardization races among alternative technological trajectories (Anderson and Tushman, 1986, 1990). Standard agents' proliferation of a standard may lead to high early adaptation of a technology that creates an early installed base and helps establishing the technology as the dominant design through network externalities (Katz and Shapiro, 1985). Indeed, GSM emerged as the 2G dominant design due to network externalities reaped from early adaptation causing lower costs and higher quality of wireless transmission systems and handsets driven by learning and scale economies for manufactures, and thereby offering improved performance and services for wireless operators (Funk and Methe, 2001; Davies and Brady, 1998).

As part of NTT DoCoMo's efforts to proliferate its 3G W-CDMA transmission standard as the global de facto standard, from 1996 to 1999 the company formed bilateral technology alliances with Asian wireless operators in South Korea, Indonesia, Singapore, the Philippines, Thailand, Malaysia, New Zealand, and China. In this period, such technology alliances were also formed in Italy, Finland and Brazil (Company press releases). The technology alliances strategic scope was to exchange, enhance and test W-CDMA based experimental systems. At an aggregate level, the strategic outcome of these alliances was a substantial level of interest and commitment of most alliance partners to W-CDMA, and the specialization of technological and human resources into W-CDMA constituted an early installed base of the transmission technology. This outcome was leveraged in the standardization constellation formed by NTT DoCoMo with mainly Nokia and Ericsson that successfully proliferated WCDMA in competition with a US constellation proliferating the IS95 standard in the European ETSI standardization committees formed by European governments to choose a single European 3G wireless transmission standard (UMTS) in late 1997 (Funk and Methe, 2001).

Complementary R&D alliances with Sony and SEGA within mobile gaming

The value of economies of scope to achieve product differentiation through complementary product mixes and leverage firm resources across similar products is firmly established in the strategic management literature (Porter, 1985; Chandler, 1990; Lubatkin and Chatterjee, 1994). In high-tech industries signified by converging technologies such scope economies is often inaccessible within the firm, as they require complementary assets held by firms in previously unrelated industries. Thus, multiple R&D alliances with such firms may enable the development of complementary products or technologies to reap economies of scope.

Within mobile gaming, NTT DoCoMo has formed wireless application R&D alliances with the two global leaders, namely Sony Playstation and SEGA. By late 2000, gaming was already a key revenue driver (America's Network, November 2000). In August 2000 NTT DoCoMo and Sony announced plans to link their blockbuster products - DoCoMo's i-mode Internet service enabled with Java for rich graphics and Sony's PlayStation game console to enable users to play the same game at home and outside (Reuters, 01.08.2000; Reuters, 29.01.2001). Shortly after, in February 2001, NTT DoCoMo announced a R&D alliance with a Playstation key competitor at the time, Japanese SEGA, offering its Dreamcast game console. This R&D alliance, however, aimed to fuse i-mode with SEGA's NAOMI video arcade machines installed in arcade centers nationwide in Japan rather than SEGA's home video game consoles (Company press releases). Thereby, the Sony and SEGA R&D alliances were complementary in pursuing NTT DoCoMo's ubiquitous service strategy to increase the locations and settings in which wireless technologies are used (Natsuno, 2003).

Best practice transfers in rolling out I-mode services on GPRS networks

The sharing and transfer of strategic knowledge and technologies across R&D alliances pursuing similar objectives and therefore deploying similar resources in pursuing innovation targets may significantly improve alliances' efficiency. The argument is paralleled by research on corporate diversification based synergies from deploying strategic assets across related business units and research on transfers of best practices within large firms (Markides and Williamson, 1996; Szulanski, 1996; Szulanski and Winter, 2002). In their seminal study of the Toyota knowledge sharing network, moreover, Dyer and Nobeoka (2000) found ample evidence of valuable sharing of product and process technologies across similar suppliers.

NTT DoCoMo pursues internationalization through a global network of equity- and a few non-equity market access alliances with overseas operators in Asia, Europe and US. These alliances comprise a significant R&D component concerned with the export of NTT DoCoMo 3G W-CDMA and I-mode mobile Internet technology, which is challenged by the complexity of integrating NTT DoCoMo technologies and standards with overseas partners' existing network infrastructure and expertise. One significant process synergy has been reaped from the development of an I-mode technology overlay that integrates the mobile Internet systems with overseas partners upgraded 2,5G GPRS networks. The overlay was required as I-mode was initially developed for Japan's 2G proprietary standards PDC that is non-compatible with GSM and GPRS. Accumulated expertise in extending GPRS networks with I-mode infrastructure and an increasingly standardized technology overlay has significantly decreased I-mode roll-out times overseas reflecting a valuable learning curve at the level of the alliance class. For instance, for Taiwanese partner KG Telecom a I-mode license agreement was concluded by June 2001 and I-mode services were launched 12 months after, whereas the time-span for German partner E-plus was only from January 2002 to March 2002. In July 2002, the I-mode consulting firm was established to offer technological support for rollouts and operation of I-mode to European partners. This unit thereby facilitates portfolio synergies within the alliance class and parallels the operations management consulting division at Toyota deployed to leverage accumulated experience and problem-solving skills (UBS Warburg, 2000; Dyer and Nobeoka, 2000; Company press releases; Reuters, 16.07.2002). Another indicative example of such portfolio synergies within one alliances class include leverage of best practices in joint R&D with handset providers and network vendors accumulated through the long-lasting ties with NTT family members such as NEC and Matsushita (Anchordoguy, 2001).

3.5.3 Portfolio synergies across a subset of alliance types (~related diversification)

R&D alliance complementarities and interdependencies also exist across different types of R&D alliances, but not necessarily all types of R&D alliances in a specific portfolio. Below several illustrations are provided from NTT DoCoMo.

Filling multiple resource gaps through platform leadership

In high-tech and rapidly changing industries, platform firms often face multiple and interdependent capability gaps due to rapid technological development, system interdependencies and technology complexity that it cannot fill alone or with or single R&D partners (Booz, Allen, Hamilton; 2000; Teece, 1996). Consequently, the platform firm's

innovation targets convert into an R&D alliance portfolio consisting of several R&D alliance classes each with unique strategic intents and R&D objectives in terms of technologies, products and/or processes. The composition and coordination across subsets of these R&D alliance types, then, becomes crucial to orchestrate innovation and sustain platform leadership. NTT DoCoMo provides substantial evidence of synergies that reflect such orchestration.

The service application alliances outlined previously develop new service platform features for e.g. the wireless Internet service I-mode and the new multimedia platform M-stage targeted for 3G wireless telecommunications and PDAs. These platform enhancements benefit the service features available for another alliance-type, namely content providers of internet information and multimedia content. For instance, the java enabled i-appli and location-based i-area features for i-mode allows content providers to commercially offer richer and more complex wireless content (Nielsen and Mahnke, 2003). To reap synergies between application development and content provision, hence, the technological potential achievable through application alliance and the commercial potential achievable through content alliances must be coordinated. A related synergy is reaped between application alliances and R&D alliances with handset and network infrastructure vendors. Specifically, the systemic interdependencies between wireless services and enabling technological infrastructure and supportive handsets equipped with new application features necessitate technological integration of standards, applications and enabling devices such as colour displays and java-enabled handset browsers across technologies and products that are developed in different R&D alliance classes. Thus, NTT DoCoMo leverages its flagship position by diffusing for instance new wireless applications to handset alliances to spur development of supportive handsets (Natsuno, 2003). Likewise, existing ties with handset and infrastructure vendors are leveraged with overseas market access alliances. For instance, NEC and Panasonic are the key suppliers of I-mode handsets launched during 2002 and 2003 in European markets such as Germany, Netherlands, France and Belgium (Reuters, 17.04.2003; www.nttdocomo.com)

International leverage of network assets

Through its international expansion, NTT DoCoMo deploys jointly developed assets in overseas markets, and thereby reaps portfolio synergies from the R&D alliances in which the assets were developed and the overseas alliances. NTT DoCoMo reaps economies of scale for handset and infrastructure production to overseas markets by keeping its regular vendors during internationalization. For instance, given the increasing diversification of wireless handset

portfolios the thumb rule of 1 million handsets being the threshold for scale economies in handset production is more easily achieved across numerous markets with large aggregated customer bases (Economist 30.03.2002). Also, NTT DoCoMo's experience in building up an wireless data market in Japan and adapting new wireless offerings to a country's specific customer demographics and preferences, as well as its business model for wireless Internet involving the management of a vast web of content providers can be leveraged across its market access alliances (Telecommunications International, February 2001, Natsuno, 2003). Lastly, the standardization efforts pursued through standardization alliances eases the replication of NTT DoCoMo's proprietary technologies in overseas markets due to improved compatibility and interfaces.

3.5.4 Portfolio synergies across the entire alliance portfolio (alliance choice specific)

The last level within the domain of alliance portfolio management concerns synergies realized across the entire alliance portfolio. To clarify, these synergies are not specific to individual partners (level 1), or to specific R&D alliance types (level 2), as well as specific to a subset of R&D alliance types (level 3). Rather, top-level portfolio synergies are specific to the make-or-buy decision of hybrid organizational forms: R&D alliances. The platform firm's overall alliance capabilities illustrate this.

Recently, significant scholarly attention has been paid to firm's alliance capabilities (see introduction). Overall alliance capabilities involve skills and knowledge in searching partnering firms, as well as forming, designing and managing R&D alliances over time (Kale, Dyer and Singh, 2001). Such capabilities are accumulated through alliance experience and careful attention to systematically collect, interpret and diffuse alliance experience within an organization (Anand and Khanna, 2000). Through its extensive alliance strategy inherited from parent NTT, NTT DoCoMo has had the opportunity to accumulate such general alliance capabilities (Anchordoguy, 2001; Kodama, 2001).

4. Managerial value and implications

This section concludes the paper by outlining the managerial value of the alliance portfolio management framework and guidelines on how to implement portfolio analysis and selection based on the two managerial levers.

Overall, the paper contents that the framework adds value by improving R&D alliance portfolios' risk-return properties by means of increasing R&D alliance portfolio returns through reaping synergies and reducing R&D alliance portfolio risks through risk diversification. To develop credible managerial guidelines to capture the value creating potential held by this contention, a closer look at some of the common problems experienced by firms lacking proper alliance portfolio management is instrumental. Such problems include the previously noted findings by McKinsey (2002) that too often alliance portfolios grow into a random mix of ventures assembled over the years by various business units, that overall performance measurement of the portfolio is lacking, and that often overall alignment between a company's overall competitive strategy and its alliance activities is missing. Similarly, in their seminal study of product development portfolio management practices Cooper, Edgett and Kleinschmidt (2001) found that inefficient portfolio management leads to collections of projects poorly aligned to the central firm's strategy due to strategy process integration, the pursuit of low value projects due to lacking stop/go rules, accumulation of too many projects that collectively spread the firm's resources too thin, and the pursuit of wrong projects chosen because of corporate politics and/or managers opinions and emotions.

Evidently, sound alliance portfolio management is more than simply increasing a high-tech platform firm's number of R&D alliances in response to the widely acknowledged advantages of flexible organizational forms to steer through turbulent industry environments, high-paced innovation, frequent competitive moves, and value chains too complex for one firm to go it alone (see background literature). Indeed, Deeds and Hill (1996) found an inverted U-shaped relationship between the rate of new product development and the number of R&D alliances entered to access partners' complementary assets in high-tech industries. In addition to the well-known advantages of entering R&D alliances, the scholars found both diminishing returns caused by an increased likelihood of entering new alliances with only marginal contributions, and negative returns caused increased risk of malperformance of alliance formation and management (i.e. alliance capabilities are scarce resources) (see also Keil, 2000). In a sample of 132 biotechnology firms, the study calculated the average "optimal number" of alliances to be 27, while stressing that the number itself is highly dependent on firm specific factors and thus not generalizable. In parallel, Brealey, Myers and Markus (1995) argue that for financial portfolio management, effective risk diversification is typically achieved with investments in 20 different stocks. Moreover, with increasing alliance numbers, the risks of overlapping scopes and partner conflicts also increase. Thus, principles for alliance portfolio management must

enable managers to make consistently good portfolio decisions on which R&D alliances to enter, which R&D alliances to terminate and which R&D alliances to change. Through such principles, ideally, the firm's set of relationships are managed as a portfolio rather than a set of discrete contracts. Resources are allocated strategically according to each alliance's value to the portfolio, and criteria for regular performance reviews of both individual alliance and alliance portfolio performance are established (Deloitte, 2001).

So how does the alliance portfolio management framework create value for managers in developing such sound principles and procedures? Firstly, the framework must be placed within the high-tech platform firms strategic planning process to ensure overall strategic alignment. Traditionally, top management periodically formulates a firm's overall competitive strategy (e.g. Grant, 2003) and in high-tech and turbulent industries, technology is a major driving force the competitive strategy. The strategically crucial accumulation and management of technology assets is managed through the firm's technology strategy. Thus, Burgelman and Rosenbloom (1989) advance the core argument that a firm's technology strategy is formulated against the background of two analytical pillars; (1) the firm's competitive strategy in terms of the necessary enhancement and augmentation of *existing* technical capabilities and radical development of *new* technical capabilities, and (2) the evolution of the firm's technology capabilities, which to a large degree is determined by the exogenous technological development. The technology strategy materializes into innovation targets that set direction and priorities for the firm's technology portfolio development, which is pursued through product and process R&D projects (Leonard-Barton, 1992; Iansiti, 2000). Following R&D project portfolio management considerations (Chien, 2002; Cooper et al, 2001), make-or-buy choices are made for each R&D project on whether to execute it through internal R&D, M&A or a R&D alliance. Increasingly, for high-tech platform firms, these make-or-buy decisions favour R&D alliances, making them a key vehicle to pursue the innovation targets set in the technology strategy, and thereby support the firm's competitive strategy (Hagedoorn and Duysters, 1999; Narula, 2001; Vanhaverbeke, Duysters and Noorderhaven, 2002). At this point in the top-down planning process, the alliance portfolio management framework applies to all R&D projects executed through R&D alliances. Clearly, it is and should be highly interdependent on the preceding planning stages. However, to simplify the analysis, the framework assumes that the considered R&D activities are exclusively carried out through R&D alliances, because integration with internal or acquired R&D is left for future research. Thereby, the framework ignores e.g. diversification of three risk classes jointly by internal and external R&D projects, and e.g.

internally accrued portfolio synergies. Early evidence on such integration suggests that R&D project portfolio management across all make-or-buy modes requires the ability to coordinate competencies and combine knowledge across corporate boundaries (Loronconi and Lipparini, 1999). Especially in high-tech industries, it also requires the ability to manage multiple time scales such as the partners' individual product and technology life-cycles, the R&D project's life-cycle and the alliance's life-cycle to ensure that the alliance is ripe to perform the planned joint activities (Vilkamo and Keil, 2003).

Having placed the framework within the strategic planning process, the paper concludes by explicating the two managerial levers', risk diversification and portfolio synergies, managerial value. The below table contrasts the objectives pursuable through individual R&D alliances and R&D alliance portfolios based on the empirical illustrations from NTT DoCoMo presented previously. Thereby, the complementarity of the two managerial layers (i.e. individual vs. portfolio) and the need to manage R&D alliances as portfolios to reach alliances' full potential is sustained.

Managerial lever	Individual R&D alliance	R&D alliance portfolios	Case
Risk diversification			
1. Market risks			
- New service development	Jointly develop one new service	Develop multiple and different-type services, hedge market risks and end with killer applications	11 service types: graphics, video tech, video app, portal, gaming, corporate, physical, advertising, car, e-payment, identify
2. Technology risks			
- Wireless transmission standard	Jointly develop a wireless transmission standard combining more initial trajectories into one trajectory	Access and/or participate in competing transmission standards, hedge technology risks and end with dominant technology	DoCoMo: W-CDMA. SK Telecom: W-CDMA and cdma2000. Ericsson: W-CDMA and cdma2000.
3. R&D/Capability risks			
- New service development	Jointly develop one new service	Develop multiple similar-typed services, hedge R&D/Capability risks and end with at least one service of the desired kind	8 service types each with between 2 and 83 different partners. Multimedia tech: IBM, HP and Packet Video. Corporate: 83 partners
Portfolio synergies			
1. Alliances with same partner			
- New ideas and opportunities	Jointly pursue one business idea	Through successful collaboration build relational capital, expand scope of collaboration and launch new alliances.	DoCoMo and HP: multimedia distribution platform and preferred server vendor contract

- Interfirm routines	Establish interfirm routines for one R&D project	Leverage established interfirm routines for new R&D projects	DoCoMo and handset/network vendors: joint product development routines
- Economic hostages	Invest equity in R&D alliance performing one R&D project	Leverage initial equity investment across subsequent alliances.	DoCoMo and KPN mobile: 1 initial equity JV and 5 subsequent non-equity alliances
2. Same-type R&D alliances			
- Critical mass for technology standard proliferation	Obtain one supporting partner for technology standard	Obtain multiple supporting partners for technology standard	DoCoMo formed 11 alliances with operators to create critical mass for W-CDMA
- Complementary products and services	Develop one new service	Develop complementary products and services constituting unique package	Within mobile gaming DoCoMo with Sony for consoles and Sega for arcades
- Best practice transfers	Develop practice for one R&D alliance	Leverage best practices across subsequent similar-type alliances	I-mode overlay for GPRS developed with first overseas I-mode partners leverages for subsequent alliances
3. Across subset of alliance types			
- Fill multiple innovation gaps	Pursue one innovation target	Pursue multiple, diverse and complementary innovation targets	Synergies between application platform development and (1) content provision, and (2) handsets. Handset partners leveraged for overseas market alliances.
- International leverage of strategic network assets	No leverage across geographical markets	Leverage network assets across multiple geographical markets	DoCoMo leverages economies of scale from global handset sales, experience to build infrastructure and wireless market in Japan, business models, and established technology standards
4. Across entire portfolio			
- Alliance capabilities	Partner-specific alliance know-how acquired	Accumulation of alliance management best practices across multiple and diverse alliances	DoCoMo renowned for alliance capabilities build on comprehensive alliance portfolio
Source: own creation			

Lastly, guidelines on how to implement the managerial levers are presented. Based on interviews with 30 leading companies and a questionnaire with 205 respondents, Cooper et al (2001) found that for product development portfolio management firms use financial methods such as NPV (77,3%), business strategy based prioritizing (64,8%), bubble diagrams or portfolio maps (40,6%), scoring models (37,9%), and checklists (20%). However, the choice among these valuation methods and the like highly depends on the analytical tools used for individual alliance management, because these determine information available for alliance portfolio

management. Best practice studies suggest that such existing individual alliance analytical tools at best include business case studies, cash flow analysis, partner assessments, and alliance assessments based on real options (Kale et al, 2001; Reuters, 2003; McKinsey, 2002; Williamson, 1999; Luehrman, 1998).

A simple but disciplined approach to implement the alliance portfolio management framework would be to first list all potential candidates for both risk diversification and portfolio synergies in a table like the above, to secondly value and prioritize all potential candidates, and lastly implement chosen candidates. To map candidates for risk diversification, each of the three risk classes are analyzed separately. For market risks, the corporate strategy defines which product and service fields the company wish to compete in, and detailed external analysis of existing and future product and service categories and configurations yield a list of potential candidates. For technology risks, the external technology environment is analyzed for competing technology trajectories, which yields a list of potential candidates. For R&D/capability risks, the associated uncertainty of R&D is estimated and alternative partners identified. Similarly, for portfolio synergies, each of the four portfolio levels are systematically scanned synergy opportunities yielding a long list of potential synergy candidates. The second step involves prioritizing of the list of alliance portfolio management initiatives. For risk diversification, the risk's severity (i.e. value), likelihood, ease to implement and ease to recover from are estimated e.g. on a numerical scale. Similarly, for portfolio synergies, each potential candidate's value, likelihood, ease to implement now and ease to implement later are estimated also on a simple numerical scale. Lastly, the most promising and valuable candidates are chosen based on a weighing of the above dimensions and implementation programmes are crafted to achieve the promises of alliance portfolio analysis (inspired by Williamson, 1999; Goold and Campbell, 1998).

5. Conclusions

This paper's primary objective is to enhance managerial guidance available on the emergent discipline of alliance portfolio management that plays an increasingly crucial role in high-tech platform firms' simultaneous management of their substantial, diverse and often interdependent single-partner and multi-partner R&D alliances. A managerial framework is proposed to this end based on analogue reasoning from Modern Portfolio Theory, early contributions to alliance portfolio management research, and empirical evidence from the leading Japanese wireless operator NTT DoCoMo. In particular, it is argued that two managerial levers are valuable principles at the portfolio level of alliance management to complement the parallel individual

management of the focal firm's R&D alliances. Risk diversification is developed and illustrated as means to diversify and thereby reduce an alliance portfolio's total risks in terms of three critical risk classes associated with R&D alliances; market risks, technology risks, and R&D/capability risks. Likewise, portfolio synergies are developed and illustrated as means to increase an alliance portfolio's total returns by exploring synergies at four distinct portfolio levels. The proposed framework is integrated with the focal high-tech platform firm's overall competitive strategy and technology strategy formulation processes by linking the firm's innovation targets with the two managerial levers. While initial steps are made to integrate the framework with individual alliance management best practices, future research should aim to combine the complementary managerial disciplines further.

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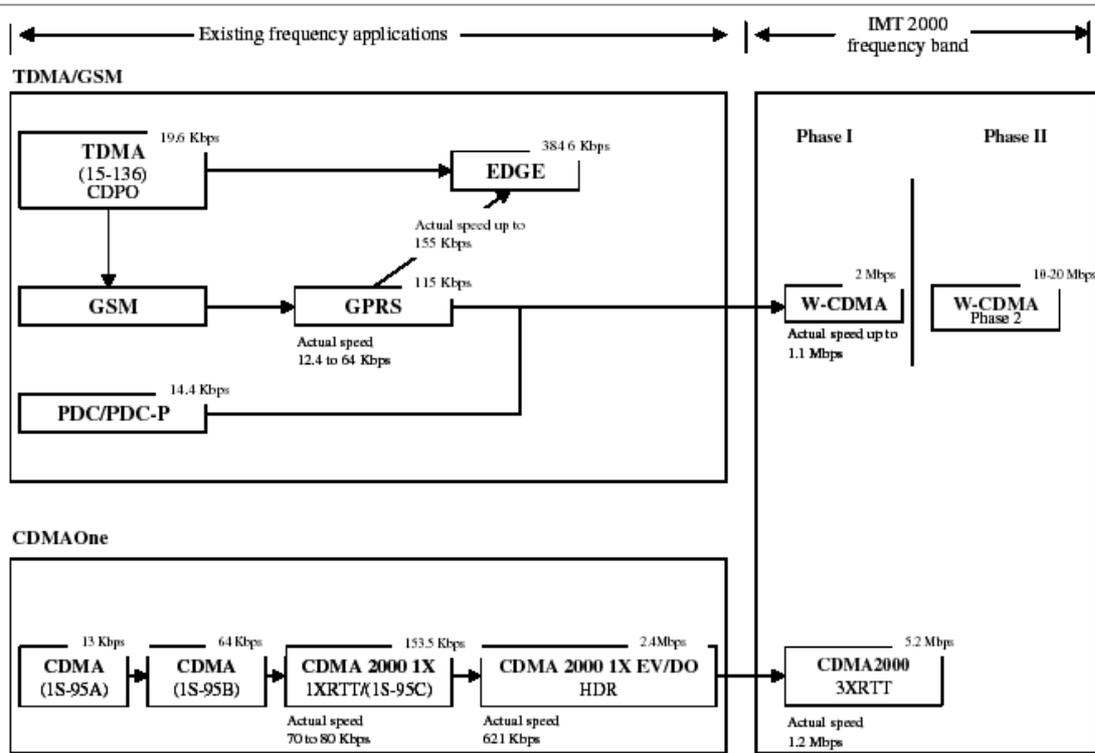
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APPENDIX

Figure 67: Standard evolution chart



Source: Credit Swiss First Boston (2002)