ASYMMETRICAL JOINT ACTION EXPECTATIONS AND PRODUCT INNOVATION PERFORMANCE IN THE SUPPLY CHAIN

By

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ABSTRACT

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Using three essays, this dissertation establishes a case for asymmetrical joint action expectations (AJAE) as a valid phenomenon in interfirm relations and as relevant to innovation performance in the supply chain. Essay one lays the theoretical foundation of understanding how differing marginal cost and benefit curves associated with joint action between two firms can lead to differing optimal levels and therefore differing expectations regarding the desired level of joint action across those firms. Essay two investigates this phenomenon in the context of six case studies of interfirm new product development projects and finds that indeed, gaps between actual and desired levels of joint action do exist and are relevant to innovation performance. Further, the case studies reveal that not only is the size of the gap in AJAE relevant, but so also is the clarity of those expectations. Essay three places AJAE within the context of supply chain interoperability and tests the hypothesized model using an empirical secondary data set of R&D powertrain projects in the automotive industry. Findings support hypothesized relationships between AJAE, behavioral interoperability and innovation performance.

Dedicated to my beautiful wife, Kirsten Reynolds DeCampos

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1.1 Introduction

Increasingly, the locus of innovation is shifting upstream from OEMs in the supply chain towards first tier suppliers (Rothenberg & Ettlie, 2011). For example, as noted by Mosquet, Russo, Wagner, Zablit, and Arora (2014), since 2008 there has been a 37 percent increase in the number of patents filed (an indication of innovation) by first tier suppliers in the auto industry, as compared to a 28 percent increase in patent filings by automotive OEMs. OEM's seeking to capitalize on the innovation potential and investments taking place in the supply chain must therefore view innovation activity differently than they have in the past; namely as a supply-chain rather than as a single-firm activity. Critical to this consideration is management of the relationship between the participating firms in the value chain, specifically between the customer and the supplier. For the innovation to take place, the relationship must first be established, and then managed strategically and purposefully.

This change in the locus of innovation has affected not only how firms in these relationships work with each other, but it also puts into question the relevance of past management practices employed when the locus of innovation was more heavily weighted towards the OEM. For OEMs, supplier management strategies that worked in the past are increasingly less effective in this new environment. For suppliers, rules of customer engagement are being rewritten as suppliers are increasingly choosing with whom to partner with, especially for those suppliers seen as innovation leaders (Chew & Whitbread, 2002). In short, the rules of how interfirm relationships emerge and are managed may not be the same in an environment where the OEM

dominates innovation versus the environment where this innovation activity is shared, or even dominated, by the OEM's tier-one suppliers.

Past research has sought to predict where and when interfirm relationships are organized by focusing primarily on economic considerations (Lampel & Giachetti, 2013; Luzzini, Caniato, Ronchi, & Spina, 2012; McIvor, 2009). For example, transaction cost economics (TCE) draws on economically based frameworks to predict when a firm should make a product/service in-house, buy it in the marketplace, or ally with another firm to produce the product/service in partnership (Williamson, 1979, 2008). Yet, there is strong anecdotal evidence that economic considerations are not sufficient to explain whether or not such relationships emerge. In some cases, relationships that should have been established based on strictly economic grounds were not launched. As an example, consider the failed GM/Renault-Nissan alliance talks of 2006 as described by Langley, White, and Boudette (2006) and LaReau (2006). At the heart of this potential strategic alliance was recognition of the strong potential economic benefits that could be generated. One estimate was that by sharing certain platform developments and purchasing costs, there were over $10 billion USD in potential synergies to be gleaned. Yet, ultimately, this relationship failed to even be established because of differences in expectations of how the benefits would be distributed. Specifically, GM perceived itself as receiving fewer benefits than Renault-Nissan; consequently, it asked for a significant equalization payment upfront – a request that was rejected by Renault-Nissan.

While this is an obvious example of an interfirm relationship that should have been established but was not, it is not unique. There are other examples of failed relationships. It has been reported that over 50% of all alliances fail (Nidumolu, Ellison, Whalen, & Billman, 2014; Parise & Casher, 2003). Research is replete with attempts to explain why so many B2B alliances

fail (Park & Ungson, 2001; Stuart, 1997). Annual buyer/supplier relationship quality surveys tell a similar story – that of numerous failures, even with some of the largest and most mature firms in industry (Zhang, Henke, & Griffith, 2009; Zhang, Viswanathan, & Henke Jr, 2011). It is evident that economic issues, while important, are not enough to explain success and failure in innovation-orientated partnerships. Other behavioral issues must be considered – issues such as trust (Moldoveanu & Baum, 2011; Zaheer & Venkatraman, 1995), top management commitment (Adobor & McMullen, 2007), and corporate culture (McAfee, Glassman, & Honeycutt Jr, 2002).

In this study, we introduce an additional issue – an issue with its roots in behavioral economics – that of differences in expectations between the parties involved in the potential relationship. Implicit in past research has been the assumption that the parties involved in such relationships approach the relationship with identical expectations or that the expectations (or differences) are not critical, compared to the economic considerations. Yet, as can be seen from the previously cited example involving GM and Renault-Nissan, expectations can and do differ and these differences do affect the resulting ability of the relationship to first launch and then succeed. We regard these differences in expectations ultimately as part of a broader set of issues dealing with interoperability.

1.2 Innovation and Relationships

In the context of the shifting locus of innovation, where innovation success resides more and more across firm boundaries, focus on behavioral variables that define the relationships may be a more appropriate paradigm for explaining innovation success as opposed to a purely economic paradigm. While this study does focus on the role of joint action expectations, a behavioral element of the relationship, it does so by building upon traditional economic models of marginal cost and marginal benefit analysis commonly used in economic literature (Olson, 1965, pg.24).

As such, we integrate both behavioral and economic considerations into a single framework that we posit is relevant in understanding differential performance for interfirm innovation initiatives (Hirsch, Friedman, & Koza, 1990).

1.2.1 Joint Action

In interfirm relationships, both firms engage in joint action in order to solve problems related to the value creation process, be it in operations, strategy formulation or new product development. Joint action is defined by Heide and John (1990) as "the degree of interpenetration of organizational boundaries" and by Gulati and Sytch (2007) as "the degree of dyadic cooperation and coordination across a wide array of organizational activities, such as design, cost control, and quality improvement" (Gulati & Sytch, 2007, pg.40; Heide & John, 1990, pg.25). Interpenetration can take place when buyers and their suppliers participate in each other's day-to-day activities in an effort to jointly improve new product development performance. The level of joint action firms engage in can extend from very basic exchanges such as phone calls, to much more complex initiatives such as alliances and joint ventures.

Various other forms of joint action exist that fall between the extremes of this continuum. Some of these include constructs oft studied in academic research including communication (Prahinski & Benton, 2004), coordination (Sanders, 2008), cooperation (Kee-hung, 2009), integration (Frohlich & Westbrook, 2001) and collaboration (Allred, Fawcett, Wallin, & Magnan, 2011), to name a few. While these constructs have been investigated in supply chain research, a lack of clarity exists regarding exact definitions and consistent measures of operationalization that clearly demarcate one construct from the other. Where does the scope of collaboration begin and end? What overlap and distinction exists between collaboration and cooperation, for example? Our intent in this paper is not necessarily to delineate these overlaps

and distinctions, but to investigate the relevance of higher and lower levels of interfirm joint action to explain differential new product development project performance. We therefore focus on the more general construct of joint action in our research, thus capturing the essence of the wide spectrum of interfirm activities while avoiding the unnecessary confusion in delineating these constructs from each other.

Engaging in joint action and deciding what level of joint action to engage in, requires firms to share risk, investments, and benefits. Risk sharing takes place along numerous dimensions, such as risk of intellectual property leakage (Chopra & Sodhi, 2004), risk of disintermediation (Mills & Camek, 2004) and risk of conceding internal data that the other party can leverage in pricing or other rent-sharing negotiations. Further, joint action can also create shared operational risk be it in a jointly owned manufacturing facility or in the market risk associated with a particular new product development initiative. While both firms engage in some level of risk, there is no assumption or requirement that joint action creates risk equally across both firms. Engaging in joint action also requires some level of investment by both parties. Firms can invest cash, time, capital equipment or other resources such as human capital and intellectual property. Similar to risk, investments across both firms for a given level of joint action are not necessarily equal. The purpose of joint action ultimately is to achieve some level of benefit to each of the two firms involved in the joint action. Negotiation is the tool used to distribute both the costs and the rents created through the joint action. The distribution of rents also need not be equal and in fact is a topic of much research in the interfirm relationship literature.

Many different lenses have been applied to the study of interfirm relationships. The relational view of the firm (Dyer & Singh, 1998), a subset of the resource-based view of the firm, and transaction cost economics (Williamson, 2008) are research lenses commonly applied.

Other studies, however, have focused on behavioral issues such as trust (Zaheer & Venkatraman, 1995) and culture (McAfee et al., 2002), and how these constructs are relevant in explaining differential performance in interfirm relationships. These behavioral issues are critical because it recognizes that relationships are driven and maintained by not only economic considerations but also by behavioral considerations (Hirsch et al., 1990).

1.2.2 Relationships and Interoperability

When we talk about interfirm relationships, we also must focus on how organizations develop interfaces between themselves. This focus of building interfaces falls under the category of interoperability. While numerous definitions for interoperability have been provided, the most commonly accepted definition views interoperability as: "The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together" (Ford, Colombi, Graham, & Jacques, 2007, pg.6).

Past research in supply chain management has focused on material, process, and informational flows where the focus is getting the right product to the right place at the right time and at the right cost (Fisher, 1997; Lee, 2004). These are the building blocks of interfirm interoperability. While much research focuses on synchronizing resources and process across differing entities, less research has been devoted to exploring the behavioral aspects of interoperability in the supply chain: a focus that is beginning to gain traction under the banner of behavioral operations (Agarwal, Croson, & Mahoney, 2010; Siemsen, 2011). We posit that joint action expectations are one of the behavioral variables that need to be considered in establishing business-to-business interoperability in the supply chain.

1.2.3 Asymmetrical Joint Action Expectations

Extant research on the benefits of joint action has typically taken a focal firm approach (Bercovitz, 2006). As such, an implicit assumption that arises from such research is that the optimal desired level of interfirm joint action for the focal firm is also "optimal" for the partner firm. We relax this assumption and explore the implications of doing so. When we treat partnering firms as distinct actors, there is no guarantee that the two firms, even though they are interdependent supply chain partners, will share the exact same theoretical optimal level of joint action. In fact, we would expect that this would rarely be the case given the differing marginal costs and marginal benefits associated with each firm's engagement in joint action projects (Nyaga, Whipple, & Lynch, 2010). For example, it has been shown in the bullwhip effect research stream that the benefits of sharing point of sales data across a supply chain accrue to upstream firms more so than to downstream firms (Croson & Donohue, 2003), despite the fact that it is the downstream firm that must contribute much of the investment in sharing point of sales data.

As long as the marginal benefits of joint action exceed the marginal costs for a given firm, then that firm will most likely desire to engage in joint action. The existence of differing marginal benefits and marginal costs associated with shared joint action renders likely that two interdependent supply chain partners will in fact *differ* in their respective theoretical optimal levels of joint action. By definition, however, both firms can only engage in one level of joint action at a given point in time. We assume that each firms desires to operate at their respective theoretical optimal level of joint action, and that these differing desires result in differing expectations in the relationship. We label these differences as *asymmetrical joint action expectations*. While studies have shown that the *absolute* level of joint action between two firms

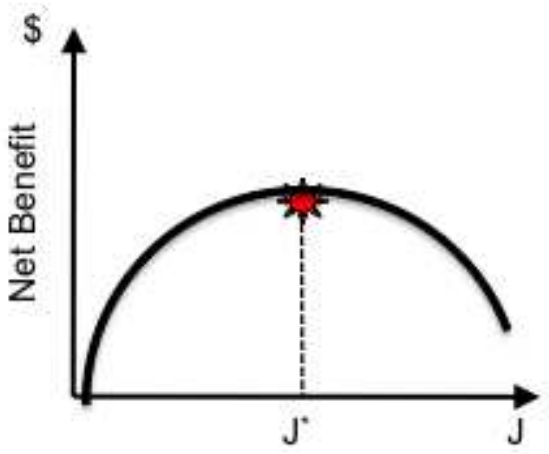
has a direct impact on product innovation performance in the supply chain, this dissertation explores the relationship that the *asymmetry* of joint action expectations has on behavioral interoperability and on innovation performance in the supply chain.

1.3 Towards a Theoretical Framework of Asymmetrical Joint Action Expectations

While we have conceptually argued the existence of asymmetrical joint action expectations, there is further utility in modeling graphically this phenomenon. Doing so establishes a common analytical framework that future research can build upon in investigating the variables that contribute to the existence and size of gaps in joint action expectations. As highlighted previously, we can model the choice of joint action engagement as a trade-off between marginal costs and marginal benefits. In the figure below, we label the x-axis as the intensity of overall joint action (J) between two firms for a given project, spanning from low intensity to high intensity. We make no distinction in this model between the various forms of joint action, but rather recognize that moving from low levels of overall joint action to higher levels of joint action may in fact require the addition of different forms of joint action for that project. For example, two firms engaged in a new product development project may have low levels of joint action that only include infrequent face-to-face meetings, thus yielding a low J-score on the x-axis. Alternately, the two firms could engage in not only face-to-face meetings, but they could also establish a resident engineer program where the supplier assigns one of their developers to assume residence at the OEM's engineering facility in order to expedite and facilitate communication regarding the program. Additionally, the two firms could also jointly invest in software and equipment related to the project where the costs for such investments are shared. In this case, the resulting J-score would be higher on the scale and would be the result of numerous forms of joint action initiatives simultaneously pursued.

We assume that all costs and benefits associated with a given level of joint action can be monetarily expressed. As such, for each level of J, there is a net benefit curve (total benefit minus total cost) that can be plotted against a y-axis expressed in $. In our base model, we initially assume that both firms share the same net benefit curve, an assumption that we will later relax. As argued in prior literature, we assert a curvilinear relationship where increasing overall joint action intensity in a relationship initially increases net benefits, but at a decreasing rate such that there is an optimal level of J where net benefits are maximized (Das, Narasimhan, & Talluri, 2006; Hoegl & Wagner, 2005; Uzzi, 1997; Villena, 2011). After this point, the curve slopes downward where high levels of joint action may expose the "dark side" referred to earlier where costs exceed benefits, thus moving the curve towards zero. While the overall benefits of joint action are still positive when surpassing the point of optimality, they decrease to levels lower than what could be achieved with lower levels of joint action, thus creating an undesired state of joint action.

Figure 1.1: Net Benefit Curve



We now decompose the net benefit curve into its two components of costs and benefits where net benefits (NB) are equal to the total benefits (B) minus the total cost (C):

$$NB = B - C$$ **Equation 1**

Next we take the first derivative of NB with respect to J in order to define the relationship of marginal costs and marginal benefits:

$$\frac{d(NB)}{dJ} = \frac{dB}{dJ} - \frac{dC}{dJ}$$ **Equation 2**

NB is maximized when its slope equals zero. We therefore set the first derivative of net benefits equal to zero and solve for the point of optimality:

$$0 = \frac{dB}{dJ} - \frac{dC}{dJ}$$ **Equation 3**

$$\frac{dB}{dJ} = \frac{dC}{dJ}$$ **Equation 4**

As a result, net benefits are maximized when the marginal benefits of joint action equal the marginal costs of the same. The level of joint action where this occurs is defined as J^*.

1.3.1 Model 1 – Simplifying Assumptions: Shared MB and MC curves

Marginal costs (MC) incurred along the curve could include incremental hardware and software investments, personnel investments, time investments, financial capital investments,

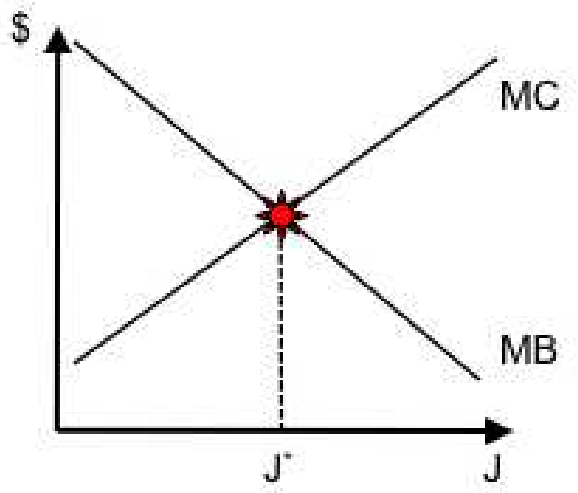
assumed risks such as IP leakage risk (product, process and strategy plans), risk of dependency or risk of decreased power balance/pricing power, to name a few examples. The marginal costs associated with moving from the left-hand side of the joint action spectrum to the right-hand side generally increase with J. This can be interpreted as stating that a one-unit increase in J at higher levels of J results in a larger increase in C as compared to a one-unit increase in J at lower levels of J. In practical terms, the incremental costs for engaging in increased lower levels of joint action are less than the incremental costs for engaging in increased higher levels of joint action. If two firms are not engaged in any joint action (J=0), then the incremental cost to begin basic communications is minimal. On the other hand, if those firms are already engaged in high levels of joint action, then to make the next incremental step in joint action could require that the firms establish a formal joint venture business entity, for example. The incremental cost of doing so could be significantly higher than the incremental costs of establishing basic communications as highlighted previously.

Mirroring this relationship, the marginal benefits associated with moving from the left-hand side of the joint action spectrum to the right-hand side generally decrease. In other words, firms can reap large incremental benefits by engaging in lower-levels of joint action, however those incremental benefits generally decrease as joint action levels increase. The concept of harvesting low-hanging fruit applies here. We assume that high levels of joint action intensity approach a saturation point in terms of marginal benefits. Marginal benefits could include quick notification of disruptions, lower operating costs, improved market opportunities, reduced waste, etc.

We make another simplifying assumption that both marginal cost and marginal benefit curves are linear. As shown earlier, the optimal level of joint action (J^*) for a firm is the point at which the marginal benefit and marginal cost curves intersect. Left of this point the marginal

benefits exceed the marginal costs thus justifying the investment to increase joint action. Right of this point, the marginal costs exceed the marginal benefits thus discouraging further investment to increase joint action. As a result, if we assume that both firms, whom we will call alpha and beta, share identical marginal cost and marginal benefit curves, then we can conclude that both alpha and beta will search for and desire to operate at the same optimal level of joint action, J^*.

Figure 1.2: Alpha and Beta with shared MC and MB curves



1.3.2 Model 2 – Relaxed Assumptions: Differing MC and MB Curves

We now relax the assumption of shared marginal cost (MC) and shared marginal benefit (MB) curves allowing alpha and beta to have their own unique curves. Differing curves will also introduce unique terms for optimal joint action for each firm. While it is possible for the differing curves to converge on the same optimal level of joint action for both firms, such an occurrence would likely be a product of chance rather than strategic intent. We define optimal joint action for alpha as the point J^{*A} where alpha's marginal benefit curve intersects its respective cost curve, where:

$$\frac{dB^A}{dJ} = \frac{dC^A}{dJ}$$ **Equation 5**

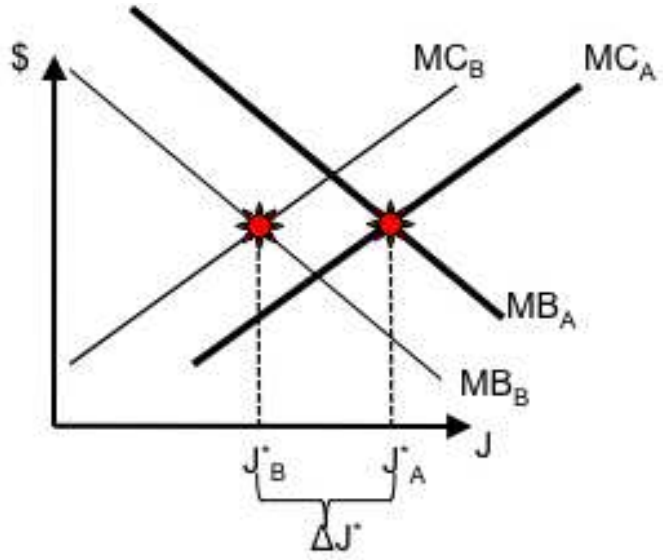
Similarly, the level of optimal joint action for beta is the point J^{*B} where beta's marginal benefit curve intersects its respective cost curve, where:

$$\frac{dB^B}{dJ} = \frac{dC^B}{dJ}$$ **Equation 6**

By nature of interfirm joint action, both parties share the same level of J since joint action is a two-party endeavor. As a result, both alpha and beta may *desire and pursue* differing levels of J^* (alpha pursues J^{*A} while beta pursues J^{*B}) yet by definition they can only jointly implement one level of joint action, J.

In the figure below, we represent this very situation where alpha and beta have differing marginal cost and benefit curves and therefore differing optimal levels of joint action.

Figure 1.3: Alpha and Beta with differing MC and MB curves



In this case, both parties will be likely invest in joint action at a minimum up to point J^{*B}. Beyond this point, however, a series of differing situations may arise. The parties could invest in joint action at point J^{*A}, at point J^{*B} or some point between J^{*A} and J^{*B}. It is unlikely that the dyad will invest in joint action beyond point J^{*A} since this would not be desired by any of the two firms. If the dyad invests at point J^{*B}, then beta will be satisfied, having optimized its tradeoffs between marginal costs and marginal benefits. Alpha, however, will be left unsatisfied since opportunity for further gain is forgone. Conversely, if the dyad invests in joint action at level J^{*A}, then alpha will be satisfied, having reached its level of optimality while beta will be in the undesirable situation where its marginal costs surpass the marginal benefits received. If investment is made at a level exactly midway between J^{*A} and J^{*B}, then both alpha and beta will experience a suboptimal state that is equidistant from their respective points of optimality where beta incurs excess marginal costs while alpha is left in a state where more joint action could be

beneficial.

Assuming that firms seek to maximize utility and desire to invest only in optimal levels of joint action, then we can conclude that the resulting gap that emerges due to differing points of optimality creates asymmetrical joint action expectations. We can analytically quantify the size of this asymmetry for firms alpha and beta using the following expression where ΔJ^* is defined as the absolute value of the difference between alpha's and beta's respective levels of optimal joint action.

$$\Delta \boldsymbol{J}^* = \left| \boldsymbol{J}^{*\boldsymbol{A}} - \boldsymbol{J}^{*\boldsymbol{B}} \right| \qquad \textbf{Equation 7}$$

The model above can serve as a framework in future research concerning the causes and nature of asymmetrical joint action expectations. For example, one could investigate to what degree does increased trust influence the variables of the model, and therefore influence joint action expectations? Does increased mutual trust shift the marginal cost curve of both parties equally or differently? If so, in what directions do the curves shift and how does this impact the gap between optimal joint action levels for the two firms? Perhaps increased trust doesn't shift the curves, but merely influences the *slope* of the curves; if so, this could have a different effect on the size of the resulting asymmetry as compared to a simple shift. What if the increase in trust is not mutual, but rather focused on one party versus the other?

In a similar manner, other constructs could be applied to the model investigating what impact, if any, an increase/decrease of that construct has on the marginal cost and benefit curves of each party, and subsequently how they impact asymmetry in joint action optima. Questions to be investigated can include, but are not limited to, 'what constructs contribute to shifts in the marginal cost and benefit curves' and 'what constructs contribute to changes in slope of the marginal cost and benefit curves'. Further, how can changes in these curves be managed to

reduce the asymmetry in joint action optima and ultimately the expectations of joint action by both firms?

1.3.3 Model Limitations and Assumptions

The model above makes a few important simplifying assumptions. First, marginal cost and marginal benefit curves are linear. This assumption supports the curvilinear relationship between joint action and net benefits identified in prior research (Das et al., 2006) and is also an assumption that has been used to model firm behavior in economics literature (Rosen, 2006). Second, it is true that firms live in a dynamic environment and as such the concept of an optimal point of joint action for either or both firms is a concept that can easily be challenged from a dynamic perspective. We make the assumption, however, that such dynamism takes place over a long-enough period of time, or is small enough such as to maintain the relevance of the proposed static model in predicting firm behavior in the context of a single new product development project.

In discussing the tradeoffs of making simplifying assumptions in economic models, Nobel laureate Herbert Simon (1979) stated, "…decision makers can satisfice either by finding optimum solutions for a simplified world, or by finding satisfactory solutions for a more realistic world. Neither approach, in general, dominates the other, and both have continued to co-exist in the world of management science" (Simon, 1979, pg.350). Our proposed model and its simplifying assumptions follow the former category of finding an optimal solution for a simplified world. Extensions of research into asymmetrical joint action expectations may find interest in exploring deviations to these simplifying assumptions. One such deviation may be the existence of an optimal *range* of joint action rather than an optimal *point*. In other words, perhaps there is a tolerated gap in joint action expectations that is equivalent to no gap at all. If

such is the case, perhaps there is a "tipping point" after which the gap size becomes a significant entity in the relationship equation.

Another assumption that this dissertation makes is that gap size in joint action expectations is an appropriate surrogate for behavioral interoperability. Smaller gap sizes are a manifestation of higher levels of behavioral interoperability. Conversely, larger gap sizes are a manifestation of lower levels of behavioral interoperability. In short, two firms that share smaller gaps in joint action expectations will share increased harmonizing behavioral norms that support interoperability as compared to two firms that share larger gaps in joint action expectations. As a result, we assume that gap size in joint action expectations serves as an adequate surrogate for behavioral interoperability.

1.4 Research Propositions

My primary interest is in investigating what role behavioral interoperability, as represented by size of gap in joint action expectations, has on innovation performance in a new product development setting. The propositions outlined in this section build upon this basic inquiry. Further research may confirm or disconfirm these propositions. In the course of this research, it is plausible that rival theories may emerge. We may discover that joint action expectation gap *size* isn't the variable of interest, but rather other factor(s) related to gaps may emerge as being more relevant. Such competing factors that the authors could conceive as being relevant are (to name a few), 1) clarity of expectations, and therefore *clarity* of the existing gap, b) rate of investments that one or the other firm typically makes in closing joint action expectation gaps with partner firms and c) incentives associated with the project that may precipitate abnormal attention and investment in the relationship. I begin, however, with a focus on gap size in joint action expectations.

In order for firms to effectively work jointly, a basic level of resource interoperability is required. Therefore, two firms with low levels of resource interoperability that desire to engage in joint action will require varied levels of resource investments. This variation in investments will most likely result in a greater difference in net benefit curves across the two firms for engaging in joint action. Two firms, however, with high levels of resource interoperability have the advantage of approaching the relationship with similar or harmonizing resources that allow those firms to explore joint action from a more similar vantage point, where it is likely that they will share more similar net benefit curves as compared to the two firms with lower levels of resource interoperability. Since similar net benefit curves result in smaller gaps in optimal levels of joint action, I make the following proposition:

PROPOSITION 1: Interfirm resource interoperability is inversely associated with gap size in joint action expectations (higher levels of resource interoperability correlate with smaller gaps in joint action expectations)

Process interoperability is achieved when two firms harmonize not only their resources, but also their processes in order to effectively engage in joint action. In a similar argument to that made for resource interoperability, we posit that firms that have higher levels of process interoperability explore joint action from a more similar vantage point as compared to firms that have lower levels of process interoperability. As a result firms with higher levels of process interoperability most likely share more similar net benefit curves for joint action as compared to firms with lower levels of process interoperability. The similarity in net benefit curves will result in small gaps in optimal levels of joint action. I therefore make the following proposition:

PROPOSITION 2: Interfirm process interoperability is inversely associated with gap size in joint action expectations (higher levels of process interoperability correlate with smaller gaps in joint action expectations)

Interfirm relationships characterized by smaller gaps in joint action expectations will spend less time and concern dealing with this asymmetry as compared to firms that have larger gaps in joint action expectations. As a result, both the ideation and the problem solving processes required during new product development will perform at higher levels as compared to those firms that are constantly second guessing their own level of involvement in the project. I therefore propose:

PROPOSITION 3: Gap size in joint action expectations is inversely associated with innovation performance (smaller gaps in joint action expectations correlate with higher levels of innovation performance)

Interfirm relationships characterized by higher levels of resource interoperability will be able to more quickly and effectively identify opportunities and solutions during a new product development project as compared to relationships characterized by lower levels of resource interoperability. Lower resource interoperability may generate the situation where solutions and opportunities identified by one partner may not be as feasible to execute by the other partner since the solution or opportunity may be resource dependent. I therefore posit that higher interfirm resource interoperability will be correlated with higher levels of innovation performance.

PROPOSITION 4a: Interfirm resource interoperability is directly associated with innovation performance (higher levels of resource interoperability correlate with higher levels of innovation performance)

Further, resource interoperability, as argued in proposition 1, leads to reduced gaps in joint action expectations. Ultimately, innovation performance in joint new product development projects is achieved when firms make the decision to share ideas and invest resources in a timely manner to solve the problems being addressed by the initiative. As such, it is expected that gap size in joint action expectations will mediate the relationship between resource interoperability and innovation performance.

A mediating, rather than a moderating relationship is theoretically asserted in the model. Resource interoperability alone is not expected to be the key lever that drives innovation performance. Rather, higher levels of resource interoperability lead to reduced AJAE gap size, which in turn leads to improved innovation performance. Given the complexities of human interaction involved in achieving innovation performance, it is anticipated that behavioral interoperability (as operationalized by reduced AJAE gap size) is the key factor of success and fully mediates the positive relationship between resource interoperability and innovation performance. Arguing for a moderating relationship would place behavioral interoperability as a secondary factor that simply amplifies or attenuates the direct relationship between resource interoperability and innovation performance. This is clearly not the case since it is humans, not resources that ultimately generate innovations.

PROPOSITION 4b: Gap size in joint action expectations mediates the relationship between resource interoperability and innovation performance

Interfirm relationships characterized by higher levels of process interoperability will be able to more quickly and effectively implement solutions during a new product development project as compared to relationships characterized by lower levels of process interoperability. Lower process interoperability may generate the situation where solutions and opportunities identified by one partner may not be as efficiently or effectively implemented by the other partner given the challenges that arise with coupling differing processes that may work against each other. I therefore posit that higher interfirm process interoperability will be correlated with higher levels of innovation performance.

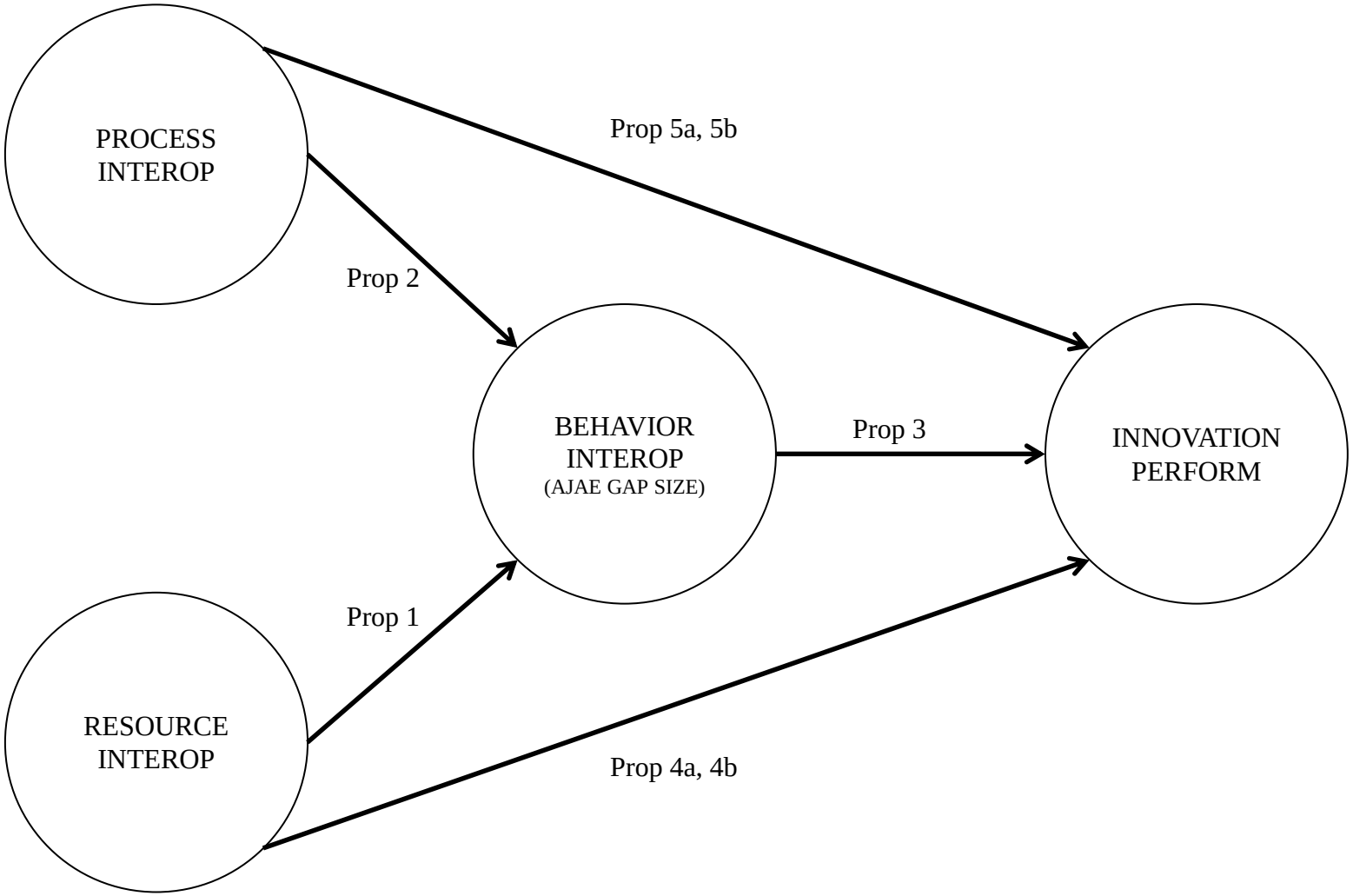
PROPOSITION 5a: Interfirm process interoperability is directly associated with innovation performance (higher levels of process interoperability correlate with higher levels of innovation performance)

In a similar manner that AJAE gap size is expected to mediate the relationship between resource interoperability and innovation performance, we also expect AJAE gap size to mediate the relationship between process interoperability and innovation performance. The same argument for mediation rather than moderation holds here as well. Both resource and process interoperability are proposed to be 'failure preventers' while behavioral interoperability (AJAE gap size) is proposed to be 'success producers' (Varadarajan, 1985). In short, the failure

preventers, resource and process interoperability are both necessary to start the relationship but are not sufficient to assure success. The success producer is behavioral interoperability.

PROPOSITION 5b: Gap size in joint action expectations mediates the relationship between process interoperability and innovation performance

Figure 1.4: Posited Model



1.5 Conclusions and next steps

This paper has both theoretically and analytically argued that firms engaged or attempting to engage in joint action will most likely differ in the optimal level of joint action for that relationship. Assuming firms desire to operate at an optimal level of joint action, asymmetrical joint action expectations will exist in the relationship, albeit the gaps between levels of optimality may greatly differ across different relationships. This nature of this asymmetry is the subject of interest in our research, in particular with its relation to innovation performance during new product development projects. Further, we introduced the construct of interoperability and extended it to the domain of interfirm relationships. We recognize that behavioral interoperability is a broad construct impacted by numerous factors, however, our research takes a focal approach on gaps in joint action expectations as a proxy for behavioral interoperability. In particular we argue that the size of the gap is relevant to innovation performance.

While some prior research has recognized that firms may differ in expectations of the net benefits associated with a resource (Barney, 1986), this paper is the first, to our knowledge, to offer an analytical model of asymmetrical joint action expectations and to investigate more fully the nature and impact that this gap has on innovation performance. Given the nascent nature of this research, a qualitative study can both substantiate the key elements of the posited model, and provide further insights to refine the model and its constructs. The next step of this dissertation is to conduct this qualitative research in the form of a multi-case study (Eisenhardt, 1989). This multi-case study will be the subject of essay two and will focus on identifying real-world examples of gaps in joint action expectations and will seek to answer the following questions: 1) are these gaps real? 2) if so, are they relevant? 3) does size of the gap in joint action expectations really matter? 4) how do such gaps emerge? 5) in what ways do they impact performance . The

final and third essay in this dissertation will be a larger-scale investigation of the refined model that results from essay two.

2 ESSAY TWO – ASYMMETRICAL JOINT ACTION EXPECTATIONS AND INNOVATION PERFORMANCE: A CASE STUDY ANALYSIS

2.1 Introduction

Essay one in this dissertation posited that gap size in joint action expectations has an inverse relationship with innovation performance: in other words, smaller sized gaps are correlated with increased innovation performance. Further, we placed the construct of asymmetrical joint action expectations (AJAE) into the greater context of establishing behavioral interoperabi2lity between two firms. We developed in essay one a theoretical framework based on past research. The past research, however, does not adequately deal with the issue of asymmetrical joint action expectations. Consequently, before proceeding to further empirical evaluation of the framework and its associated propositions, this current essay seeks to verify and evaluate the existence of AJAE and improve understanding of its nature and its relationship to interfirm innovation performance in the supply chain.

Given the nascent nature of research on AJAE, we employ a qualitative research methodology to help explore this construct and to better refine the a priori theoretical model posited in essay one (Corbin & Strauss, 2008, pg. 12). The use of detailed case study data allows us to determine the extent to which the posited theoretical framework can adequately explain observed results and, if not, will help us identify appropriate refinements to the current framework so that it provides a more accurate explanation of what is observed in actual complex business situations (Yin, 2009, pg. 4). We conducted a multi-case study (Eisenhardt, 1989) of six interfirm product development projects using a purposeful sample that spans both high/low levels of success and high/low levels of product complexity.

Our findings from these case studies confirm the existence of AJAE and suggest that they do have an impact on interfirm relationships. However, whereas we initially posited that the *size* of the gap of AJAE was the key variable of interest, our case studies revealed another, potentially more critical construct: that of the *clarity* of the gap. Clarity bespeaks an understanding that one firm has of not only their own costs and benefits associated with varying levels of joint action, but also an understanding of the costs and benefits associated with the partner firm's engagement in those same levels of joint action and the ensuing joint action expectation gaps that result. Therefore, when clarity exists, a firm understands not only what level of joint action is beneficial to their own firm, but also to that of their partner firm. Alternately, a lack of clarity is the result of a firm only concerned with it's own costs and benefits associated with joint action and thus that firm lacks an awareness and appreciation of any asymmetry in joint action expectations that may exist with its partner firm.

One observation we found interesting was that firms that had an established level of clarity of AJAE still decided to enter or maintain existing business-to-business relationships with a partner firm despite the existence of AJAE. Those firms appear willing to live with and accept some level of asymmetry (gap) in joint action expectations. This is an important consideration for managers who may be either hesitant to share with a partner firm their own costs and benefits associated with a desired level of joint action, or may not be interested in what factors contribute to their partner's firm desired level of joint action. Further, this study suggests that alignment between the respective optimal levels of joint action for both firms need not necessarily exist in order for those two firms to succeed in joint innovation initiatives. On the contrary, it may be that the existence of AJAE is an impetus for firms to establish clarity and therefore enhance performance.

We next discuss the methodology used to conduct the qualitative research on AJAE. We then present overviews of each of the six case studies conducted in the context of within-case analyses. We then follow with a cross-case analysis identifying the themes and findings that emerged across the six case studies. We lastly present a refined theoretical model that takes into account our case study findings and present propositions that can be investigated with a future confirmatory study.

2.2 Methodology

2.2.1 Analytic induction

Given the exploratory nature of this research, we apply an inductive theory-building methodology using multiple case studies (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) as opposed to a single, deep case study (Dyer & Wilkins, 1991; Eisenhardt, 1991). A key characteristic of a case study is that it "attempts to examine a contemporary phenomenon in its real-life context…" (Yin, 1981, pg. 59) Our goal in this research is to verify and evaluate the relevance of the theoretical model established in essay one using real-life cases involving innovation in interfirm new product development projects. What we are doing is asking a simple question: 'to what extent does the data generated in the case study align with the model posited in essay one?' If it does not, why not and what changes need to be made? Investigating multiple case studies enables the research to refine the theoretical model in preparation for a future confirmatory study where deductive theory building can further establish the theories being developed.

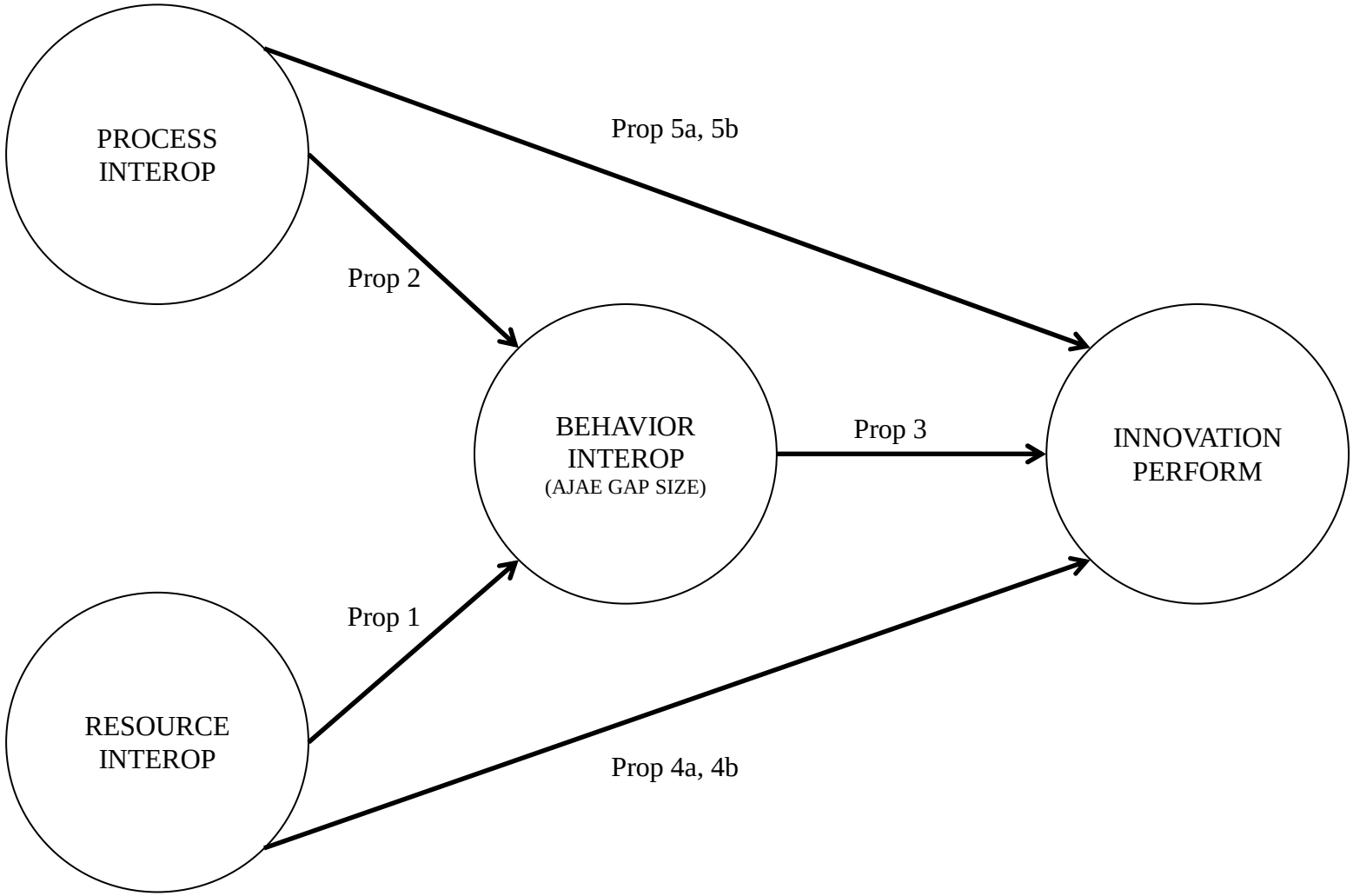
Inductive theory-building methodologies are categorized into two major groupings: grounded theory or analytic induction (Bansal & Roth, 2000, pg. 719). Whereas grounded theory requires researchers to explore case and field studies with little to no a priori hypothesized model

established, analytic induction allows for such. In particular, analytic induction requires researchers to conduct case studies in search for disconfirming evidence that informs further refinement of the model (Katz, 2001; Manning, 1982). Our study follows the analytic induction approach and uses findings from the six case studies to refine the a priori model developed in essay one.

2.2.2 A priori model

Essay one posits that the size of gaps in joint action expectations are directly and inversely related with innovation performance (proposition 3). Specifically, smaller gaps correlate with higher levels of innovation performance. Further, Essay one proposes three distinct levels of interoperability (resource, process and behavior) between two firms and argues that gap size in joint action expectations serves as a proxy for behavioral interoperability. While we posit that higher levels of both resource and process interoperability are related with high levels of innovation performance (propositions 5a and 5b) and higher levels of behavior interoperability (propositions 1 and 2), we expect these relations to be mediated by behavioral interoperability, as proxied by gap size in joint action expectations (propositions 4b and 5b). In this study, however, we narrow the focus of our case studies to proposition 3. We do so in order to allow the research to more deeply investigate the construct of AJAE and its relation to innovation performance in the interfirm new product development setting.

Figure 2.1: Posited Model from Essay 1



2.2.3 Multi-Case Sampling

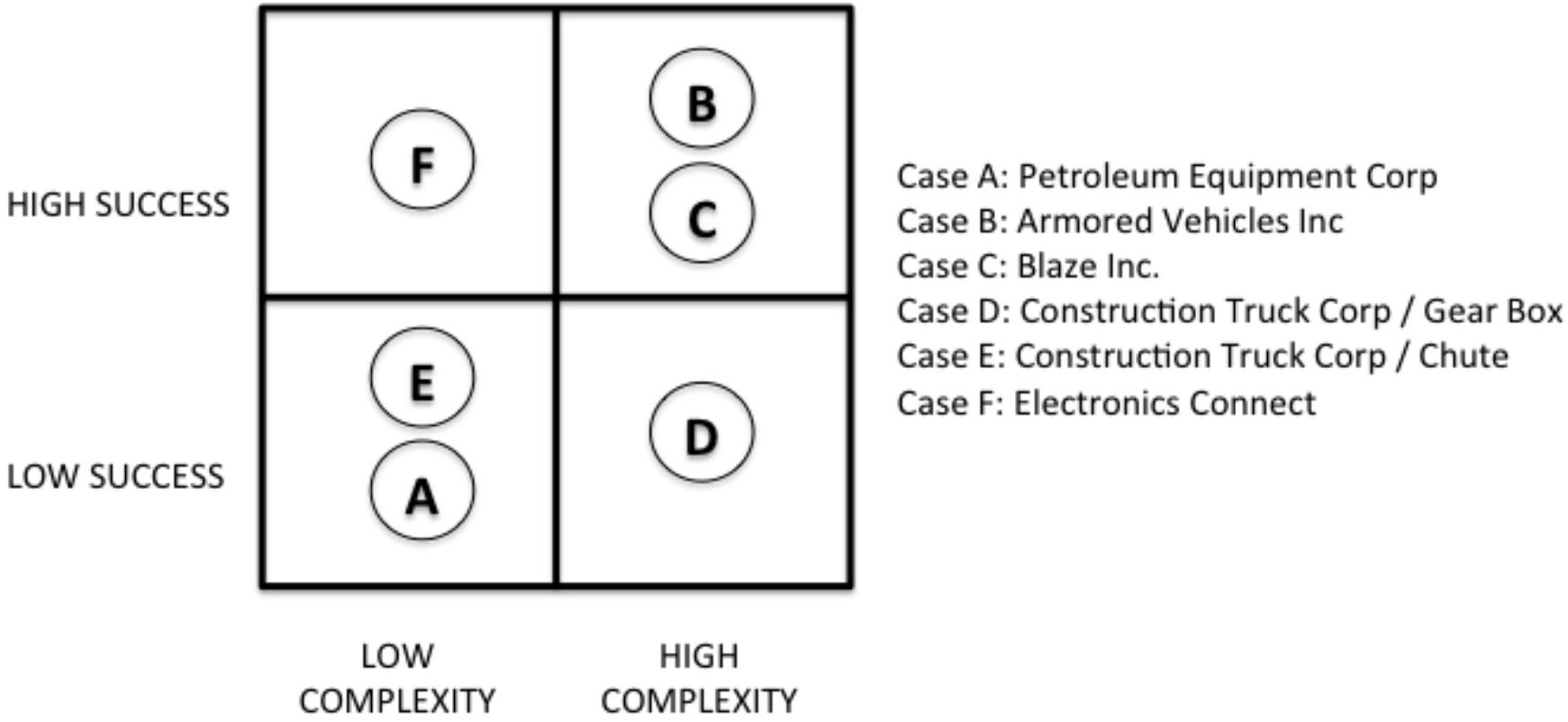
Eisenhardt (1989) provides a framework for conducting multi-case study analysis that supports analytic induction. This framework includes conducting both within-case and cross-case analyses using a purposeful sample of cases that adequately inform the researcher on the phenomenon of interest. We followed this framework and conducted six case studies of innovation in new product development initiatives involving both high and low levels of project success across varying degrees of product complexity. While the data was collected from organizations, the unit of analysis was the project.

Project success was initially categorized by the lead contact at the company that identified what case would be included in the research at the company. Performance data were also gathered during the actual interview process and was used to verify the performance rating initially provided by the lead contacts. We also included product complexity as a dimension of interest given prior research that has empirically validated a significant positive relationship between product complexity and propensity for vertical integration (Novak & Eppinger, 2001). If such a relationship does exist, then we wanted to ensure that our study included cases involving both low and high levels of product complexity so as to diversify our exposure to AJAE across both dimensions.

Novak and Eppinger (2001) operationalized product complexity as a multi-dimensional measure of design complexity that varied according to the product. In one example, Novak and Eppinger (2001) identified the relevant dimensions as 1) the newness of the technology being used, 2) the number of moving parts in the product and 3) whether the system was active or passive. We likewise identify the level of complexity of the products involved in each case study (figure 2) using the three dimensions listed in Novak and Eppinger (2001).

While our hypothesized model does not necessarily focus on product complexity as a construct of interest, we did want to control for this variable in our case selection criteria. As can be seen in figure 2, our six case studies provide a sampling across all four quadrants of the sampling matrix. Further, the six cases represent three distinct industries: the oil and gas industry (Case A), the heavy vehicle manufacturing industry (Cases B, C, D and E) and the telecommunications industry (Case F).

Figure 2.2: Case Sampling



The case studies explored in this paper come from a convenience sample generated from the authors' industry contacts of chief procurement officers and other executive-level supply chain leaders across various industries (oil/gas, heavy vehicle manufacturing and telecommunications). These industries were targeted due to the increased importance that innovation plays in establishing a sustainable competitive advantage in their respective business environments. Approximately 20 companies were contacted and sent one-page overviews of the research being conducted and the type of case studies that would help further the research. Six companies responded with interest yet only five were able to obtain company approval to proceed with the studies.

Firms are generally hesitant to allow outside access to sensitive innovation projects. The relatively low rate of participation, given that those invited already had previous contact with the researcher, underscores the challenge of studying innovation in the supply chain. Confidentiality agreements were required by all but one of the companies prior to allowing access to key informants. Therefore, all names of companies, products or individuals in this paper are pseudonyms in order to maintain the agreed to confidentiality. Table 1 provides an overview of the six cases studied. A single case study was conducted at each company with the exception of Construction Truck Corp where two separate projects were investigated with differing products and suppliers (Cases D and E). Three of the companies, Armored Vehicles Inc., Blaze Inc. and Construction Truck Corp (Cases B, C, D and E) are separate companies that reside under a common parent company.

Table 2.1: Case Demographics

	Company	Supplier	Industry	Project Focus	Project Length at Time of Interview (Years)	Total Length of Relationship (Years)
Case A	Petroleum Equipment Corp (PEC)	Metal Frame Corp (MFC)	Oil and gas	Liquid dispenser	2	6
Case B	Armored Vehicles Inc (AVI)	Shield-all Technologies (SAT)	Heavy vehicle manufacturing	Small armored vehicle	4	13
Case C	Blaze Inc. (BI)	Super Motors Corp (SMC)	Heavy vehicle manufacturing	Fire truck	3	30+
Case D	Construction Truck Corp (CTC)	Gearbox Corp (GBC)	Heavy vehicle manufacturing	Mixer gearbox & motor	3	20+
Case E	Construction Truck Corp (CTC)	Composite Manufacturing Incorporated (CMI)	Heavy vehicle manufacturing	Material chute	5	5
Case F	Electronics Connect (EC)	Design Service Corp (DSC)	Telecom	Fiber optic connection system	4	4

2.2.4 Interview protocol

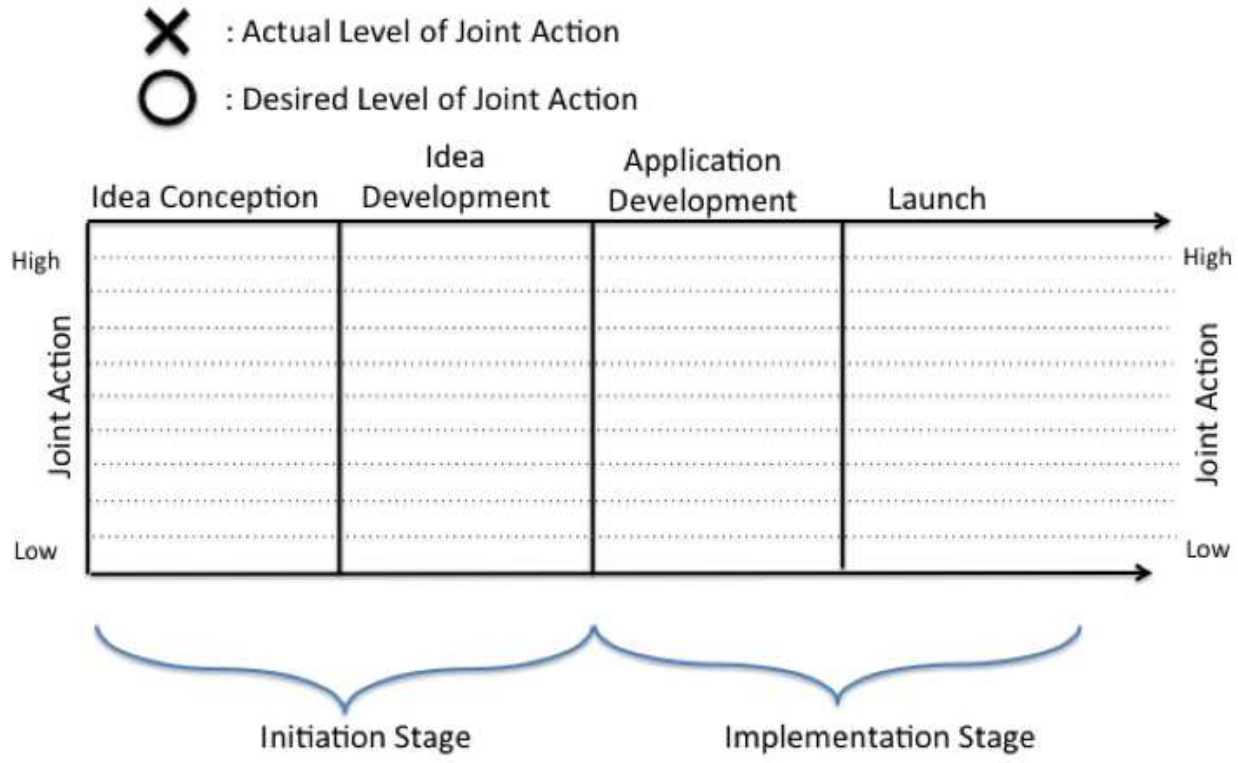
The interview protocol was designed in accordance with established guidelines for a multi-case study (Yin, 2009, pg.81) and was pre-tested with two supplier chain managers. Feedback from those managers was used to clarify terms and other questions that otherwise might have been confusing to the respondents. In addition to open-ended questions and Likert scale items, the protocol also included graphical figures for respondents to use in quantifying responses related to joint action in the relationship. A copy of this protocol instrument is included in the appendix.

In this research, the project is the unit of analysis. Given the varied activities associated with new product development, we asked respondents to describe the different stages of the development project including ideation, idea development, application development, and launch. After an overview of the different stages of the project was given, the interview then focused on understanding both the actual joint action that took place as compared to the desired joint action that existed for each stage. The respondents used figure 3 below to help them talk through these items and to express any differences between expected and actual levels of joint action. A circle represents a desired level of joint action while an X represents the actual level of joint action. A circle and an X are then plotted for each of the four stages of the product development timeline. In the case that the focal firm was not at all engaged in a specific phase, then that section was left blank.

Whenever the respondent identified a gap, we asked for an explanation of why the gap existed and what it would have taken to close the gap. While the data generated in this study is used for inductive rather than deductive theory development, use of this assessment tool can also be employed in future empirical studies with a large enough statistical sample in order to draw

deductive conclusions. Thus, this study not only helps shed light on the nature of AJAE, but it also provides researchers with a common assessment tool that can be used for future confirmatory studies.

Figure 2.3: Blank Assessment Tool



The final part of the interview focused on ascertaining project performance including dimensions of innovation success. We asked respondents to identify performance using a 7-point Likert scale across seven different dimensions including both innovation and project performance criteria (financial and timing) as outlined in figure 4. The 7-point scale has been shown to yield similar mean scores, once adjusted for scale, as compare to the 5-point scale (Dawes, 2008). Since description, rather than statistical properties of the performance scores were of primary interest, we chose the 7-point scale in order to provide the respondent with the

opportunity to better differentiate performance across the numerous dimensions. In sum, the interview protocol was carefully designed with the objective of providing a rich description of each case that could uncover any inconsistencies in the a priori model, thus enabling the research team to apply the analytic induction methodology in refining the model.

Figure 2.4: Performance Assessment Survey

Did not challenge existing ideas	1	2	3	4	5	6	7	Challenged existing ideas
Did not offer new ideas	1	2	3	4	5	6	7	Offered new ideas
Not Creative	1	2	3	4	5	6	7	Creative
Did not offer superior value to the customer	1	2	3	4	5	6	7	Offered superior value to the customer
Late	1	2	3	4	5	6	7	Ahead of Schedule
Over Budget	1	2	3	4	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	2	3	4	5	6	7	Market Acceptance Stronger than Expected

2.3 Data collection and analysis

Initial contact with each of the five companies was made with a supply chain executive, who identified both the new product development projects and the respondents that could best speak to the topics outlined in the interview protocol. Respondents needed to be knowledgeable of the events surrounding the chosen project, party to the interfirm relationship and able to provide insights and informed comments on the processes and outcomes of the project. Further, it was requested that at least two respondents be identified per case where one respondent could provide a technical perspective while the other provide a financial perspective. All twelve of the key respondents across the six case studies had job titles of manager or above: manager (N=6),

director (N=5) and vice president (N=1). The twelve respondents had a median seven years with the company that employed them. The minimum was a purchasing manager with four years and the maximum was an engineering manager with eighteen years. Where possible, respondents were interviewed alone with the researcher and not in the presence of others in order to encourage openness in the interview.

Copies of the semi-structured interview protocol, along with consent forms were sent to the respondents beforehand in order to expedite the interview process. However, we did not request that the protocol be completed beforehand; rather, we provided the protocol as a preparatory tool so that the respondent would know what questions and topics would be discussed in the face-to-face interview. The signed consent forms were collected at the time of the face-to-face interview and are stored in a locked and protected file storage system per IRB standards.

Interviews for five out of the six case studies were conducted on-site and included tours of manufacturing and engineering facilities. The interview for Case F, however, was conducted over an international teleconference link and an on-site tour was not feasible. A hard copy of the interview guide was used to direct the interviews and to capture responses to the two figures above. Respondents were encouraged to elaborate or deviate from the protocol whenever they felt relevant information on the topic needed to be mentioned. Two respondents were separately interviewed for each case with the exception of cases E and F, where only one interview was conducted yet with multiple respondents participating in the interview. All questions were discussed with both participants simultaneously until a consensus was made on the response to the topic at hand.

Interviews were conducted by a single researcher and were audio recorded with permission from the respondents so that the researcher could focus on conducting the interview. Audio files

were subsequently transcribed and transcripts were emailed to the respondents to provide an opportunity for correction. The transcripts were then edited to replace any actual names of persons or companies mentioned with alternate names in order to maintain anonymity of both participants and the companies involved. Given the competitive and sensitive nature of strategic new product development projects, the research team assured the respondents and their companies of anonymity in order to encourage openness in the interview and data gathering process. Additionally, once the transcription and name replacement process was completed, the original audio files were destroyed.

Sanitized transcripts were then imported into a qualitative analysis tool. For this project, we used QSR International's NVivo 9 qualitative data analysis software to manage and analyze the data collected. The imported transcripts were coded according to themes that emerged, such as joint action expectations, gaps in expectations, and project performance. The case studies were conducted over a 9-month period of time starting late 2012. Coding protocols and results were reviewed with the research team as the case studies progressed and new constructs were added to the coding protocols as new themes emerged that were relevant to the study. Whenever new themes emerged and were coded, prior cases were re-examined in search for the same new themes. The codings were then used to conduct both within-case and cross-case analyses. We first present the within-case analyses and then synthesize our findings in the cross-case analysis.

2.4 Within-Case Analysis

2.4.1 Case A: Petroleum Equipment Corp

Petroleum Equipment Corp (PEC) is a US-based company that provides fuel-dispensing equipment to the petroleum industry. The company has over 3500 employees and annual revenues of over US$1 billion. Products produced at PEC are exported around the globe.

Metal Frame Corp. (MFC) is a US-based company that provides metal-based components, subassemblies and finished products to various industries including agriculture, heavy construction, automotive and petroleum. The company has over 400 employees and annual revenues of approximately US$150 million. MFC's customer base resides mostly in the US.

2.4.1.1 Idea Conception

In 2010, PEC approached MFC, one of PEC's key suppliers from a purchase value standpoint, and invited them to participate in an on-site Kaizen[1] event at PEC to analyze the sheet metal body and design of a key fuel-dispensing product supplied by MFC.

MFC sent an engineer to participate in the kaizen event at the PEC facility. The MFC engineer, together with personnel from PEC brainstormed ideas for design improvement that could yield cost reductions in the products supplied by MFC. Multiple ideas were generated and analyzed for both design and economic viability. The team converged on one idea that reduced the amount of sheet metal used and simplified the overall design from both a manufacturing and assembly standpoint.

The overall time spent in this idea conception phase lasted about one week. Both teams were satisfied with the results. In particular PEC was pleased with the estimated pricing that MFC quoted during the Kaizen event for the redesign.

2.4.1.2 Idea and Application Development

The idea development and application development stages are one in the same in this particular project. While the idea conception phase was completed in a one-week time frame,

[1] A Kaizen event is a continuous improvement initiative focused on a product or process. Generally, individuals responsible for different parts of the product or process convene to identify opportunities for improvement and to plan a process of implementation for those improvements.

the development of that idea and ultimately the specific application design took over 1.5 years to finalize. The key challenge the firms encountered in the development stage was determining the appropriate manufacturing process to be used in implementing the new design. Prototypes of the new design were fabricated using competing variations and manufacturing processes related to conjoining the sheet metal assembly. Through this iterative learning process a final design and process was decided upon. At this point in time revised quotations for the redesign were presented at price levels much higher than what was originally quoted at the kaizen event. Additionally, ownership of the tooling had not yet been determined. After further negotiation including an agreement to a multi-your contract, MFC agreed to pay for and own the tooling. While the tooling agreement removed some of the financial uncertainty for both sides, it also created a situation where changes requested by PEC were often met with skepticism by MFC since MFC was carrying the financial burden associated with change requests. PEC engineers were focused on maximizing the technical performance of the redesigned component, while MFC engineers pushed back on those items they felt were not necessary to achieve compliance with the specifications. Disagreements, for example, arose regarding the number of joining points needed between the two mating parts. Such design disagreements would be settled through the production and testing of prototype samples.

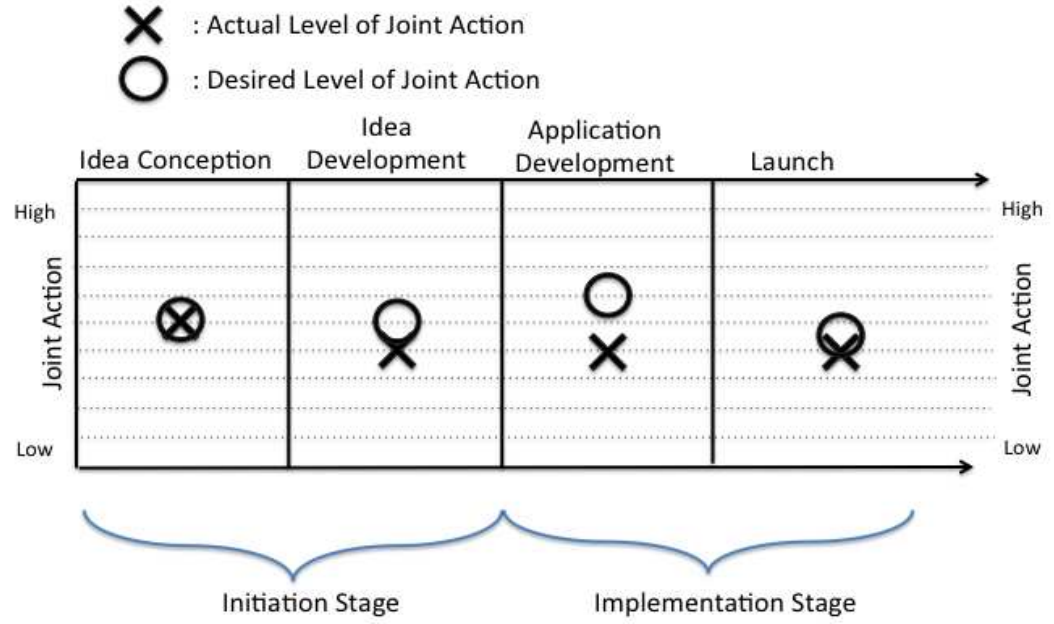
Additional complications arose with respect to the speed of communication between the two teams. What had initially been a shared sense of urgency amongst the two teams quickly turned into a one-sided focus where MFC would respond in a slow, careful and well-measured cadence that left PEC frustrated from a timing standpoint. The delayed implementation timeline, combined with the decreased promise of savings became a point of consternation for PEC.

2.4.1.3 Launch

The redesigned product finally launched two years after the initial Kaizen event. The launch itself could have taken place slightly sooner, however there were delays due to managing excess raw material specific to the older design that was already committed to. While this issue could have caused an even greater launch delay, PEC purchasing and engineering identified an alternate application that could consume the obsolete material and committed to purchase the material from MFC accordingly.

Figure 2.5: Actual vs. Desired Joint Action - Case A

Respondent 1



Respondent 2

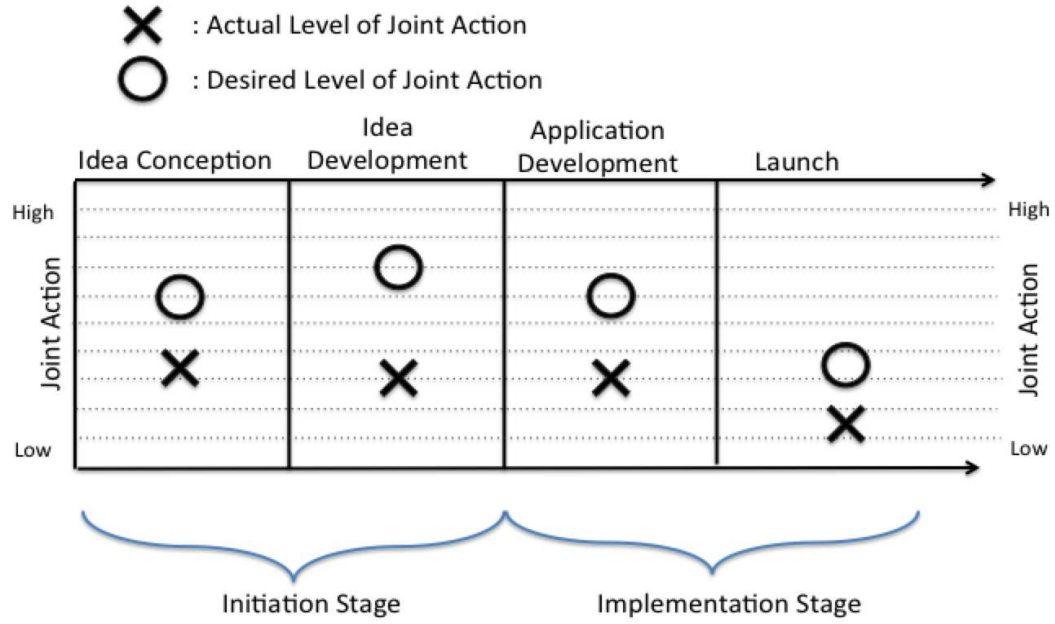


Table 2.2: Respondent Quotes Regarding Actual vs. Desired Joint Action - Case A

	Respondent 1	Respondent 2
Idea conception	"They were very actively participating, they sent three different people to come participate with us, they were varying engaged with us. I would say that the expectation was definitely met"	"The guy that was here for the Kaizen event… that was a really good event… but he was here only for the event. But once we got out of the event the idea seemed to stall."
Idea development	NA	NA
Application development	"I think it would've been more helpful had they been more on-site, because many of the things that we were coming into, where the actual idea needed to be adjusted was because of something that one of the engineers here observed on the line that they can't really see when they are not interacting completely"	"It felt like they were always wanting to push us towards what they wanted to do in stamping and with their processes in stamping rather than taking an open box approach… and so that idea development seemed to fall into just one area, where they wanted it to go. So I felt like we got boxed in with some of the ideas we had. So we could have had a better joint effort to develop whatever works…"
Launch	"…they got better again… and I think that was because that new project manager kind of came on board and was the one that helped get this pushed through to completion… he's here a lot more often, and is a lot more participative. So I would say that that definitely helped during the implementation phase"	"I would have wanted them to be a little bit more involved in the field in trials and in production runs here. I think the guy came here maybe one time, or maybe two times. We ran field trials for probably a month, and it would have been good to have him here for a couple of those"

Figure 2.6: Performance - Case A

Respondent 1

Performance of the Innovation Project

- How did this project perform along the following dimensions?

Did not challenge existing ideas	1	2	3	4	**5**	6	7	Challenged existing ideas
Did not offer new ideas	1	2	**3**	4	5	6	7	Offered new ideas
Not Creative	1	2	3	4	**5**	6	7	Creative
Did not offer superior value to the customer	1	2	3	**4**	5	6	7	Offered superior value to the customer
Late	**1**	2	3	4	5	6	7	Ahead of Schedule
Over Budget	1	2	**3**	4	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	2	**3**	4	5	6	7	Market Acceptance Stronger than Expected

Respondent 2

Performance of the Innovation Project

- How did this project perform along the following dimensions?

Did not challenge existing ideas	1	**2**	3	4	5	6	7	Challenged existing ideas
Did not offer new ideas	1	2	3	**4**	5	6	7	Offered new ideas
Not Creative	1	2	**3**	4	5	6	7	Creative
Did not offer superior value to the customer	1	2	**3**	4	5	6	7	Offered superior value to the customer
Late	**1**	2	3	4	5	6	7	Ahead of Schedule
Over Budget	1	**2**	3	4	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	2	3	**4**	5	6	7	Market Acceptance Stronger than Expected

2.4.1.4 Performance

It can be noted in the performance scores that both respondents appeared to agree that the project did not achieve the highest scores of either 6 or 7 with respect to innovation (the first four categories). Both were in agreement on the lowest score possible on timing and slightly below average financial (budget performance) and market acceptance. We categorize this case as one with an overall lower level of performance.

2.4.1.5 Key points

While both firms shared an initial vision of what would be achieved, execution during the idea and application development phases slowed down significantly due to lapses on communication. Both respondents suggested a lack of trust contributed to the slow and measured rate of response to communications and to problems that arose.

2.4.2 Case B: Armored Vehicles Inc.

Armored Vehicles Inc. (AVI) is a US manufacturer of medium and heavy-duty vehicles used for military logistics. While AVI's key customer is the US military, it also sells its transportation solutions to other local and national governments around the globe. AVI's vehicles are often used for transporting military personnel and equipment in both on-road and off-road environments.

Shield-All Technologies (SAT) is an armor solutions company that is headquartered in the Asian continent. Its key engineering and manufacturing facilities are located near its headquarters facility. SAT also has a business presence, including manufacturing, on the North American and European continents and market their armor solutions to companies and governments across the globe.

2.4.2.1 Idea Conception / Idea Development

SAT approached AVI in 2008 with a business proposition. SAT had identified a medium-duty chassis made by a large US OEM that could be used to integrate an SAT armor solution in order to produce an armored vehicle larger than a typical SUV but smaller than a Hummer-sized vehicle. This unique-sized armored vehicle segment had not yet been exploited. The chassis is similar in size to those used by tow trucks.

SAT had already produced a concept-evaluation prototype to prove the concept. What SAT needed was a vehicle manufacturer that could commercialize and produce the vehicle in larger quantities than what it had ability to produce. While it was able to make a prototype concept vehicle, SAT did not have the vehicle manufacturing skills needed to handle the project themselves. AVI could provide the necessary skills to make the project succeed. The project was named Desert Fox and the target market was local governments and border patrol agencies as opposed to the main branches of national military groups.

2.4.2.2 Application Development

Executives from both companies recognized the potential that existed in the new segment and agreed to purse the Desert Fox project. SAT agreed to relinquish all vehicle and vehicle/armor integration responsibilities to AVI and SAT became solely responsible for the armor solution. In fact, any changes to the armor solution would need to be agreed to by AVI before implementation since any changes could impact the integration of the armor solution. In effect, AVI became the gatekeeper of the project. In return AVI agreed to use SAT as the sole supplier for the armor.

AVI and SAT had an already established executive steering committee that met regularly to discuss joint projects and to provide assistance where needed. One respondent described the steering committees as:

> '…anyone would anticipate there's going to be some conflict. So there was a mechanism built into this to have an executive level steering committee, because there was a desire to have a close working relationship tween the two organizations, Shield-All Technologies and Armored Vehicles Inc; it had existed before Desert Fox came along. There was an interest in continuing that relationship… and not just for this one product but for lots of different product initiatives'

Application development for this project required AVI to learn how the concept vehicle was made and to establish a supply chain and manufacturing process that could repeat the design in an economically feasible and reliable manner. Doing so was no small task and required much coordination between SAT, AVI and BuildSmith, a chassis modifier located near the OEM chassis manufacturing location. SAT and BuildSmith had established a business relationship before AVI came into the picture. Their sole purpose was to help SAT build vehicle prototypes that SAT would use in marketing their product.

While BuildSmith was initially engaged by SAT for the initial concept vehicle build, they were only guaranteed work for an initial 10-vehicle pilot build and did not have a business relationship with AVI. The uncertainty surrounding BuildSmith's future involvement with AVI was a complicating factor in this three-party initiative for the pilot build. On the one hand, they were desirous for the future business and wanted to put their best foot forward in order to showcase their capabilities to AVI. On the other hand, the risk existed that their efforts would yield no returns. AVI ultimately decided to use the in-house manufacturing facility of a sister business group to manufacture the vehicle, leaving BuildSmith without any portion of the business.

2.4.2.3 Launch

This case was interesting in that the idea creation and development stages were done 100% by SAT, the upstream supplier, with no input from AVI, the downstream customer. AVI, however, took over the application development and launch stages and quickly assumed approximately 90% of the workload required to execute these last stages. According to an AVI manager,

> '…the basic product we were not involved at all (sic), but now the sustainment of the product and the adaptation of it to meet customer requirements in the US and our international markets, we control the lion share of that. So I would say that is 90%… We are 100% leading it, but we do have to farm work back to Shield-All Technologies.'

Frequent communication between the two firms was cited as a key ingredient in enabling the success of this project. Regular meetings were held at both executive and working levels. The executive-level meetings were established prior and independent to the Desert Fox project and were attended by presidents of both companies. This executive steering committee discussed issues pertaining to any of the joint projects, including the Desert Fox project and would resolve issues that bubbled up from the working level.

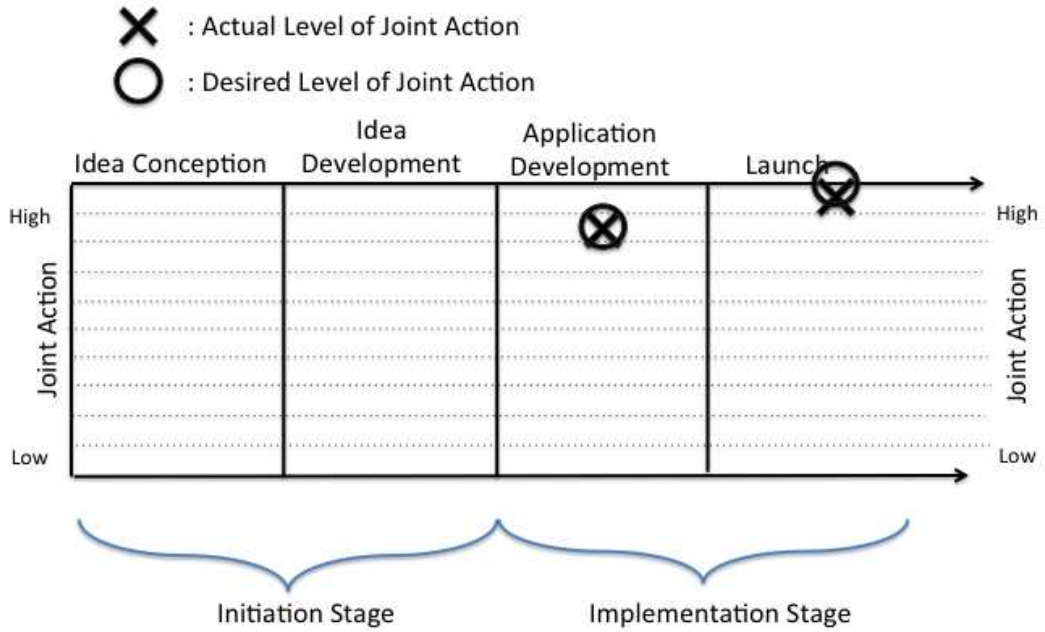
At the working level, employees from both companies engaged in weekly meetings that took place whether or not there was much content to cover. In the words of an AVI manager,

> '…we had to set up a regularly scheduled time, a weekly team meeting whether or not anybody thought that we had something to talk about, we were going to have a weekly event where people from both sides got together on the phone and talk through a project agenda… This is what's going on, this is what's going to need to happen from an Armored Vehicles Inc perspective, this is what support we need from Shield-All Technologies, this is when we need it. And once we got that going on a formal schedule things really worked well. So solving the communication problem, getting the right people talking from both sides to each other was really the key, for my judgment, to the success of the project.'

In addition to the manufacturing and supply chain design and setup work that was done, both companies also engaged in global marketing efforts. These efforts, however, were not as well coordinated as were the manufacturing and supply chain aspects of the project. Situations occurred where AVI marketing personnel contacted a government organization to only find out that SAT marketing personnel were already in talks with that same government entity. While there seemed to lack an overall coordination in marketing, this was not viewed as a key roadblock to the success of the project. In fact, AVI admitted that SAT was able to bring customers to the table that AVI did not have access to and that the joint coverage of the two marketing teams yielded strong success.

Figure 2.7: Actual vs. Desired Joint Action - Case B

Respondent 1



Respondent 2

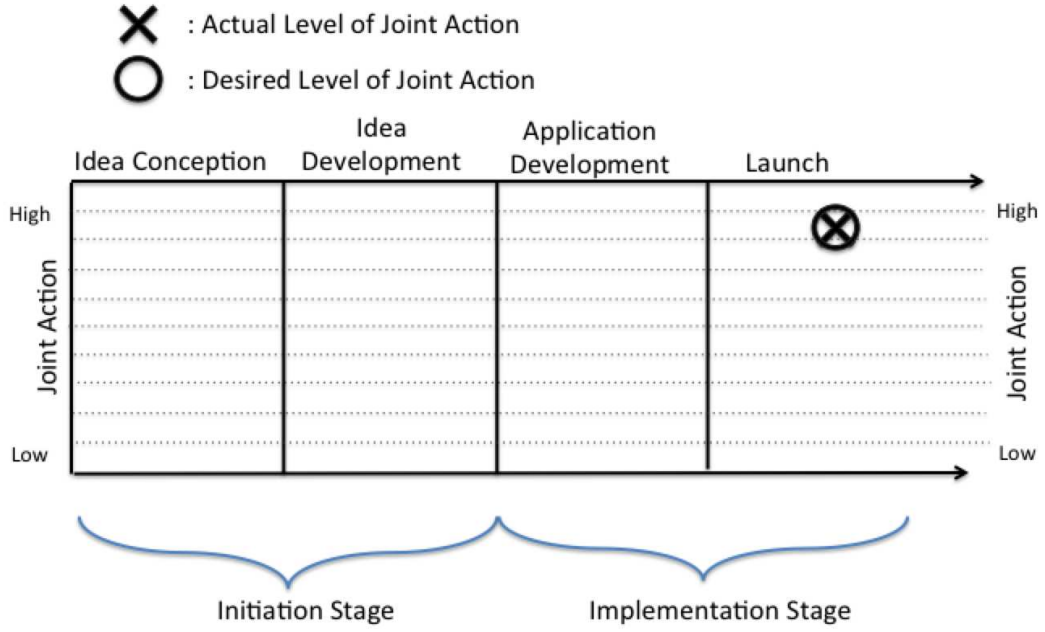


Table 2.3: Respondent Quotes Regarding Actual vs. Desired Joint Action - Case B

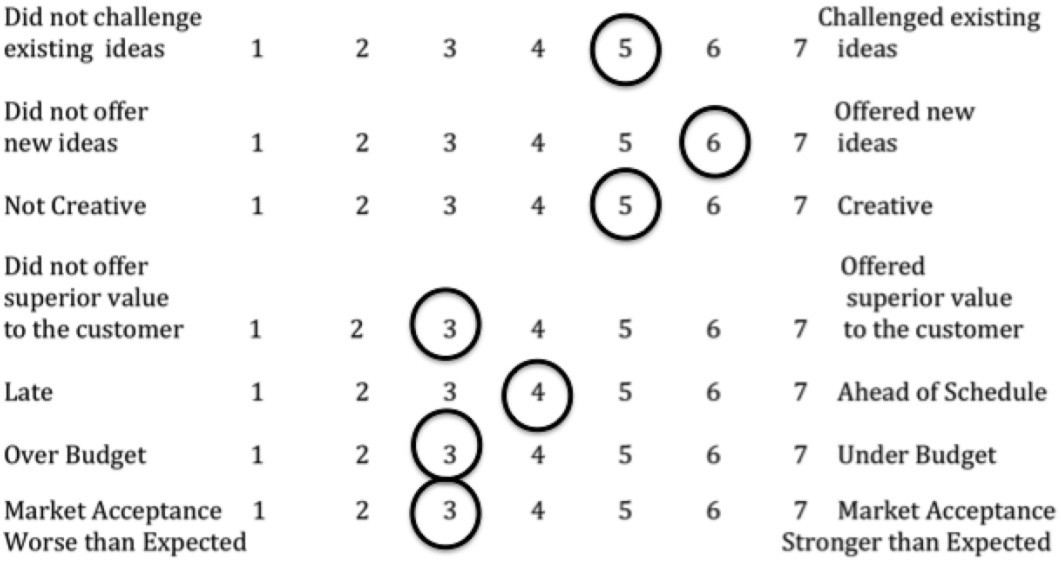
	Respondent 1	Respondent 2
Idea conception	NA	NA
Idea development	NA	NA
Application development	“There was cooperation with regard to customer development… the communication was frequent and regular… both parties were motivated to see the program succeed.”	NA
Launch	“When we needed Shield-All Technologies to send people here, they did. You know, they stepped up to that. Again our expectation for how far along they probably should've been, or where we would have liked them to have been with documentation may or may not have been realistic… maybe the people to sign the agreement didn't realize how much work needed to be done when they stepped into this thing, but they really did step up"	“… I think they did an outstanding job supporting us…they met our expectations”

Figure 2.8: Performance - Case B

Respondent 1

Performance of the Innovation Project

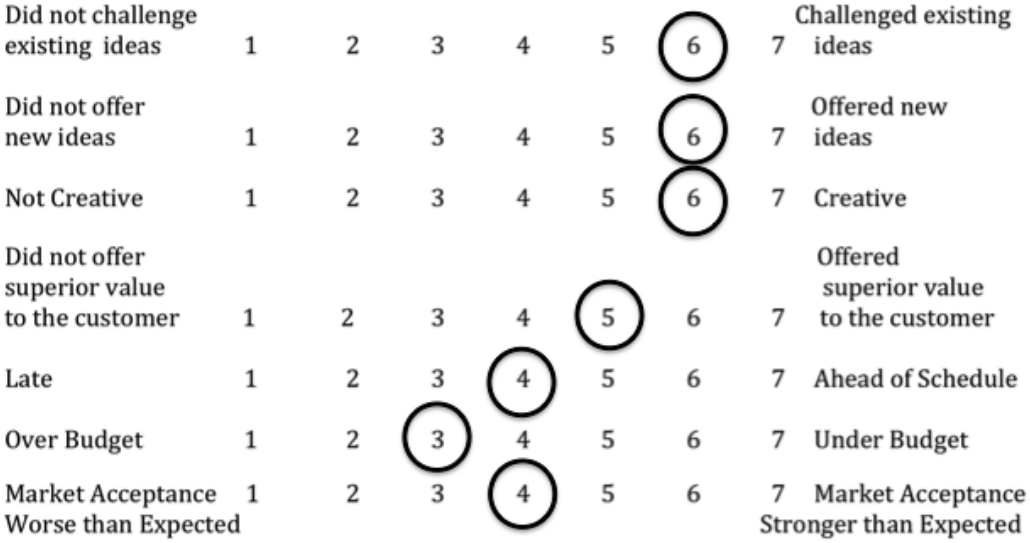
- How did this project perform along the following dimensions?



Respondent 2

Performance of the Innovation Project

- How did this project perform along the following dimensions?



2.4.2.4 Performance

Overall, the Desert Fox project was deemed a success. This case scored above average scores on the innovation performance dimensions of challenging existing ideas, offering new ideas and creativity. Scores were in the average range for value creation, market acceptance and project execution dimensions of timing and cost. We categorize this case as one with an overall higher level of success.

2.4.2.5 Key points

This is an interesting case where two supply chain partners engage partway through an existing product development project rather than at the idea conception phase. This added the complication of melding two existing supply chains where BuildSmith eventually needed to be disintermediated for the new relationship to work. Carefully managing this process was important to the success of the project.

2.4.3 Case C: Blaze Inc.

Blaze Inc. is a US manufacturer of fire trucks. Their customer base comprises mostly of local governments, in particular, fire departments that are established and controlled at the city or township level. Fire trucks are expensive investments for these fire departments and are highly customized in terms of fire fighting accessories and capabilities. Often the fire chiefs that run these fire departments have significant input into the customization of the order. Blaze Inc. purchases heavy-duty engines from engine suppliers and assembles the engines to the chassis. They then install the required optional equipment (water tanks, pumps, auxiliary power units, etc.) and then paint and finish the trucks in preparation for final delivery to the customer.

Super Motors Corp. (SMC) is a heavy-duty diesel engine manufacturer. SMC designs engines for multiple applications including light-duty, medium-duty and heavy-duty trucks.

SMC sells their engines across the globe and to numerous industries. In fact, SMC engines are one of the leading choices of engine options in fire truck manufacturing. While SMC is a leading engine supplier for fire trucks, they are not without competition. Orion and Cruzada are both strong competitors with similar global reach and technical capabilities that are considered viable options to SMC.

The performance of an engine in a fire truck has a significant impact on the performance of a fire fighting team. Not only must the engine reliably and quickly move the heavy fire truck from the station to the point of need, it must also provide the electrical and hydraulic needs of the life-saving accessories installed on the fire truck. For example, many fire trucks carry a water reservoir and pump that can be used on a limited basis until a fire fighter is able to tap into the water supply and pressure of a nearby fire hydrant. Additionally, the engine must reliably provide the power used to lift a rescue ladder to its needed position. It is no understatement to highlight the fact that lives often depend on the performance of the fire truck engine.

2.4.3.1 Idea Conception

SMC's position as one of the leading fire truck engine suppliers was not sufficient enough to keep them from attempting to leave the business. The highly fragmented fire truck market meant that SMC needed to deal with numerous different customers, each attempting to differentiate their product from that of their competition, thus driving complexity into the application phase of engine manufacturing. This complexity, coupled with low order volumes made the fire truck market an unattractive business to operate in. New emissions standards, set to become effective in 2010, would necessitate that most engines be redesigned in order to ensure compliance. When the global financial crises of 2007 began to take shape, SMC evaluated the multiple market forces at play and decided to exit the business altogether.

SMC's announcement to exit the market sent shockwaves throughout the industry and manufacturers quickly began aligning future business with the two remaining engine manufacturing giants in the industry: Orion and Cruzada. In the midst of this situation, Blaze Inc. conceived a strategic alternative involving SMC in an attempt to keep SMC in the business. Blaze Inc. proposed an exclusivity agreement with SMC for the supply of fire truck engines. Blaze Inc. would agree to use only SMC engines for 100% of their fire truck sales, and SMC in turn would sell their engines only to Blaze Inc. It was Blaze Inc.'s hope that providing SMC with a combination of their entire volume coupled with a single customer interface would present an attractive business proposition to SMC. Further, Blaze Inc. anticipated that the risks inherent with any single-source agreement would be outweighed by the strategic positioning that Blaze Inc. would have in the marketplace as the sole source of fire engines using SMC diesel engines. The value that customers placed on SMC engines was key to the potential success of the strategy.

2.4.3.2 Idea Development

Convincing Blaze Inc. to sign up to the exclusivity agreement was not an easy task. For one, the two companies, despite having a history of cooperation, were going through a rough patch in their relationship. A few years previous there had been a falling out amongst the two firms' leadership. While those same leaders were no longer in their same positions, the pall of mistrust they had cast over the relationship remained. However, what also remained was the recollection by employees at both companies regarding how strong the relationship was prior to the falling out. Ironically, the combination of these recollections with the current situation served as an impetus to leverage the opportunity as a means to repair the relationship. In the words of a manager close to the situation:

> ‘There was interest on both sides in figuring out how to get back to working well together. We had some key individuals and some emotions that had gotten in the way and it had pushed us apart. We recognized it, our customers recognized it and we wanted to bring it back together, because we know that there was an opportunity. A lot of people saw this as a stepping-stone in getting us back into the right direction. So having the history, and having the incentive of ‘this is where we want to get back to’, I think helped us plow through this agreement. Even though we had a lot of skeptics and weren’t quite sure if we were going to be able to pull it off, there was that incentive to get back to where we once used to be. That has carried us through.’

SMC and Blaze Inc. eventually penned the exclusivity agreement; this created a significant win for both sides. Blaze Inc. would be the sole distributor of fire trucks using SMC diesel engines. SMC, in turn was able to reduce the complexity in part proliferation by dealing with just one customer while ensuring their volume forecast by aligning with one of the top fire truck manufacturers in the nation. It was anticipated that the net sales impact of this strategic move would be positive, where increased sales through Blaze Inc. would offset and surpass the sales they had anticipated with other smaller players in the market.

SMC thus began designing the new engine that would meet the 2010 regulatory requirements. Blaze Inc. participated in the idea development phase mainly by providing input to the engine performance specifications from a functionality, durability and regulation compliance standpoint. The electronics interface between the fire truck’s many electrical accessories and components and the engine itself was particularly complex. Blaze Inc. acknowledged that most of the effort and contribution of the idea development stage was born by SMC.

2.4.3.3 Application Development

Once the engine design was developed, the next stage in the project was to finalize the physical integration of the engine onto the truck and to validate the integrated truck. By all

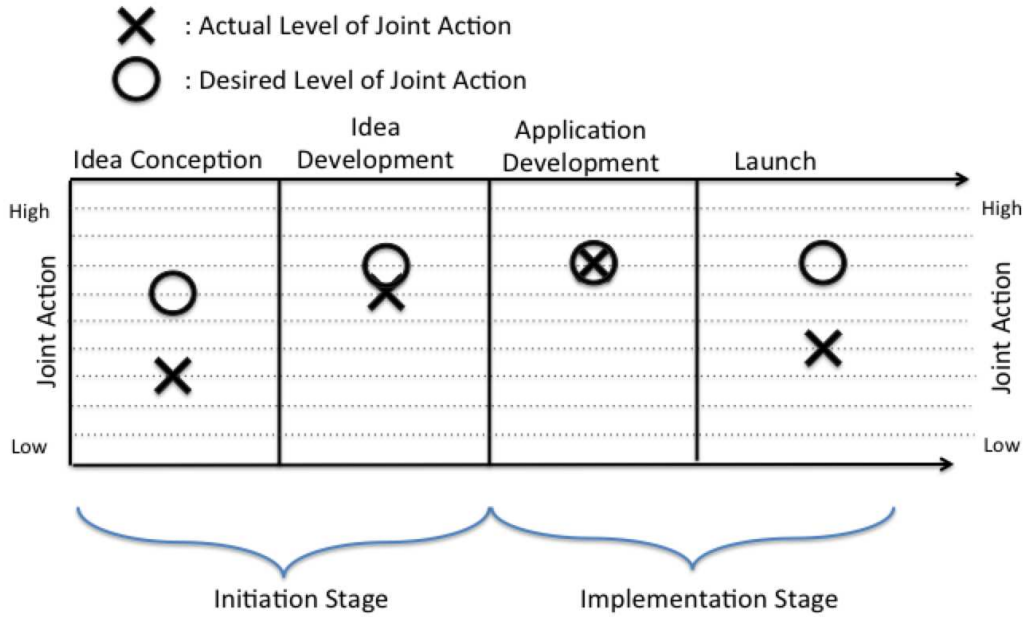
accounts, this process ran smoothly and Blaze Inc. was satisfied with the degree of joint action engaged by both parties.

2.4.3.4 Launch

One area that could have seen better alignment with joint action expectations on launch was joint marketing efforts. One respondent cited missed opportunities for using the engine in adjacent truck products made by a sister company (not necessarily fire truck applications) while another respondent cited the need for SMC to have more strongly defended and marketed their technological approach to engine design when another competitor announced to the public that it was pursuing a different technology for future engines. Despite these identified shortcomings, however, the Blaze launched on time, on budget and with strong sales.

Figure 2.9: Actual vs. Desired Joint Action - Case C

Respondent 1



Respondent 2

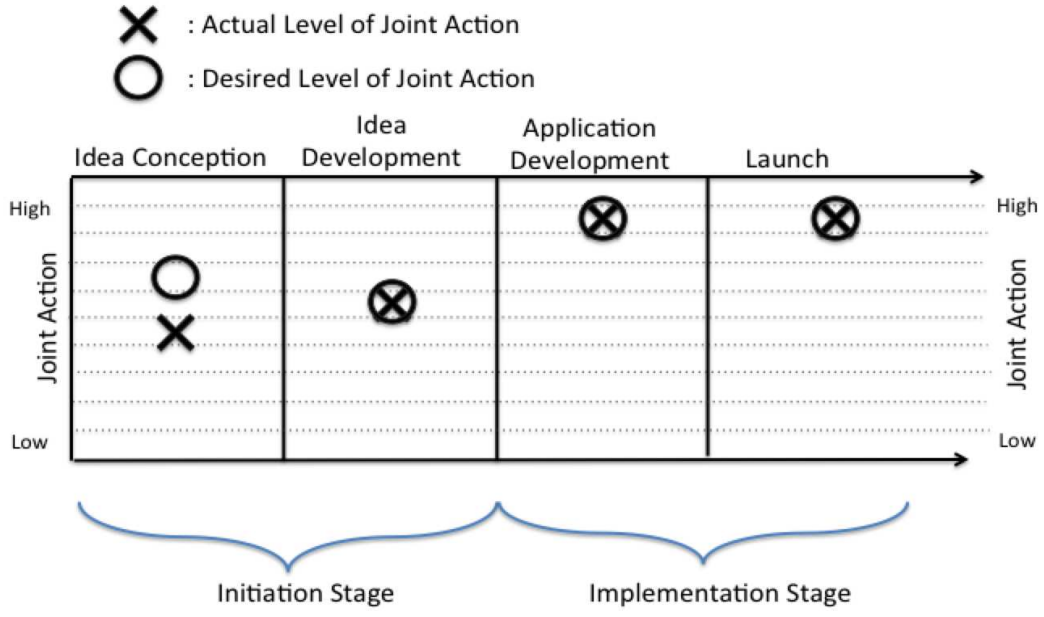


Table 2.4: Respondent Quotes Regarding Actual vs. Desired Joint Action - Case C

	Respondent 1	Respondent 2
Idea conception	"I would say in the idea conception, we were probably pushing Super Motors Corp. more than maybe what they wanted. They had just made the announcement that they were not selling to any OEMs, and here we come and say, 'come be our partner'…"	"…in the idea conception, we would have liked to have more input; we had higher expectations than what we actually got… we felt that there was more opportunity than what Super Motors Corp. actually wanted to support"
Idea development	"I think it took a little time for them to warm up to the idea. But once they got on board, like I said here during the idea development, we got pretty close to our expectations versus their involvement"	"…in the idea development, we did a lot of joint testing to ensure that their actual design was robust."
Application development	"…the application development, I would say we were in lockstep"	"…we worked quite well together… getting those programs together and then actually developing a main application, developing the programming so that it would support the pump and interface with our systems"
Launch	"…at the launch I would separate us again a little bit. I think we would have liked to have had more of their involvement and resources to market the product, and to really push the fire industry and make this a little more of a marketing splash and a joint development."	"… the production launch delivering on time and everything else, but actually spending time out in the market together, marketing and selling the product together"

Figure 2.10: Performance - Case C

Respondent 1

Performance of the Innovation Project

- How did this project perform along the following dimensions?

Did not challenge existing ideas	1	2	3	4	5	6	(7)	Challenged existing ideas
Did not offer new ideas	1	2	3	4	(5)	6	7	Offered new ideas
Not Creative	1	2	3	4	5	6	(7)	Creative
Did not offer superior value to the customer	1	2	3	4	5	6	(7)	Offered superior value to the customer
Late	1	2	3	(4)	5	6	7	Ahead of Schedule
Over Budget	1	2	3	(4)	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	2	3	4	5	6	(7)	Market Acceptance Stronger than Expected

Respondent 2

Performance of the Innovation Project

- How did this project perform along the following dimensions?

Did not challenge existing ideas	1	2	3	4	5	(6)	7	Challenged existing ideas
Did not offer new ideas	1	2	3	4	5	(6)	7	Offered new ideas
Not Creative	1	2	3	4	(5)	6	7	Creative
Did not offer superior value to the customer	1	2	3	4	5	6	(7)	Offered superior value to the customer
Late	1	2	3	(4)	5	6	7	Ahead of Schedule
Over Budget	1	2	(3)	4	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	2	3	4	5	(6)	7	Market Acceptance Stronger than Expected

2.4.3.5 Performance

We categorized this case as one with a high level of success. The market reception to the redesigned fire truck using SMC's diesel engine was very positive, with sales surpassing initial expectations. The product launched on time and on budget. Both respondents considered the project an innovation success from not only a product standpoint, but from a business strategy standpoint as well, where the new exclusivity agreement with SMS provided both firms with a sustainable competitive advantage that will be difficult for competitors to challenge into the future. Not only was the project itself successful, but the overall relationship between the two companies improved as a result.

> "Given some of the difficult history that both companies experienced in the past with each other, I think initially both sides thought that this was something that would never happen. But when we did pull it off, it served as a catalyst. Almost overnight the relationship switched. So now we are to the point where our relationship with Super Motors Corp. is one of the least contentious. Things are pretty easy going in that relationship. Other than occasionally they are not really responsive, they're very supportive, they are really easy to work with on commercial terms that are typically a challenge with other suppliers: vending agreements, material cost price adjustments, exclusivity… they are pretty easy-going."

2.4.3.6 Key points

This is a case where the value added innovation was not only in the product development initiative, but also in the innovation of the business model. The shared vision of the new business model became the foundation and driving force behind the success of the new product development initiative.

2.4.4 Case D: Construction Truck Corp. and Gear Box Corp.

Construction Truck Corporation (CTC) is a North America-based company that assembles mixer trucks for the construction industry. CTC assembles the truck chassis to the mixer barrel and other required accessories and then sells the completed truck through a dealership network.

Gearbox Corporation (GBC) is a European-based company that designs and manufactures driveline systems for the vehicle industry. Their products span both commercial and consumer vehicles. GBC for many years was the sole supplier of the gearbox used by CTC trucks on their mixer barrels. CTC combines the GBC gearbox with one of two different motors supplied by other suppliers. This combined gearbox/motor system is responsible for turning the barrel while the mixed product is being transported for use at a construction site.

2.4.4.1 Idea Conception

In 2009, GBC notified CTC that it was developing a new generation design that would integrate the gearbox and motor into one assembly using a MasterMotors Inc. (MMI) designed and built engine. Despite the brand recognition that MMI carries in other industries for designing and building motors, this would be MMI's first time building motors for CTC mixer trucks. The Gen-2 design, as the integrated design was called by GBC, would be approximately 350 pounds lighter than the prior gearbox + motor system. It would reduce the overall package size and would also reduce operating noise with the use of an isolation barrier between the assembly and the chassis mount. While these achievements were considered definite improvements, they came at a cost from both a purchase price and a serviceability standpoint. The price for the integrated system was significantly more than the combined stand-alone prices of the original gearbox and motor. Additionally, the integrated system offered less warranty than what was being offered with the original system and would cost more to repair and service.

2.4.4.2 Idea Development

GBC did not solicit CTC's input or approval prior to proceeding with the redesign and assumed all development costs and risks associated. The initial reaction by CTC when notified of the development project was guarded; nevertheless GBC forged forward with idea development and did not involve CTC at all in the development process. As the project developed and more details of the design emerged, CTC became greatly concerned regarding both the serviceability and cost aspect of the redesign. If the motor failed on the newly integrated design, the entire module would need to be replaced: gearbox and motor included. In the original system, if the motor failed, then just the motor itself could be repaired or replaced. The service infrastructure and know-how to manage the current system was well established and would be deemed irrelevant with the Gen-2 system. All repairs for the Gen-2 system would need to be handled by GBC, and not by the existing service infrastructure.

2.4.4.3 Application Development

Despite objections from CTC regarding serviceability, GBC proceeded with developing the Gen-2 system. Given GBC's lack of alignment with CTC's expectations on this product, CTC realized that maintaining GBC as a sole supplier for the gearbox was not in the best long-term interest of the company. They therefore resolved to introduce competition for this product and began working with an alternate gearbox supplier who would not only manufacture gearboxes with the desired warranty level, but would also brand the product with CTC's private label.

CTC resolved to attempt once more to realign the GBC relationship. They assembled their entire leadership team of not only CTC leaders involved with GBC, but also those leaders of other businesses under their parent company that also did business with GBC. This combined

leadership contingency traveled to GBC's European headquarters and communicated their concerns to the GBC leadership team.

Pricing and warranty were key topics of negotiation, however warranty was the overriding concern. The warranty terms offered for the Gen-2 system were actually *less* than what GBC was currently providing on their existing stand-alone gearbox. The constraining factor on the Gen-2 system warranty terms was MMI's motor. Since MMI was not willing to match the more generous warranty terms of the gearbox, GBC could only warrant the Gen-2 system at the level provided by MMI. In the meantime, the alternate supplier that CTC developed offered an improved warranty on the private label gearbox, even beyond that which was currently being provided by GBC.

Only marginal improvements to warranty terms and pricing were achieved through the CTC leadership contingency visit to GBC's European headquarters. The team therefore resolved to push forward with launching the alternative supplier's gearbox with the CTC private label in addition to the Gen-2 system provided by GBC.

From an application development standpoint, CTC needed to make alterations to their existing truck pedestal that holds the mixer in order to accommodate the Gen-2 system design. CTC proceeded with this redesign and tested the new product. In essence, CTC proliferated the number of pedestal designs in order to accommodate not only the new Gen-2 system, but also the new alternative supplier's gearbox design so that the final customer could choose between the available options.

2.4.4.4 Launch

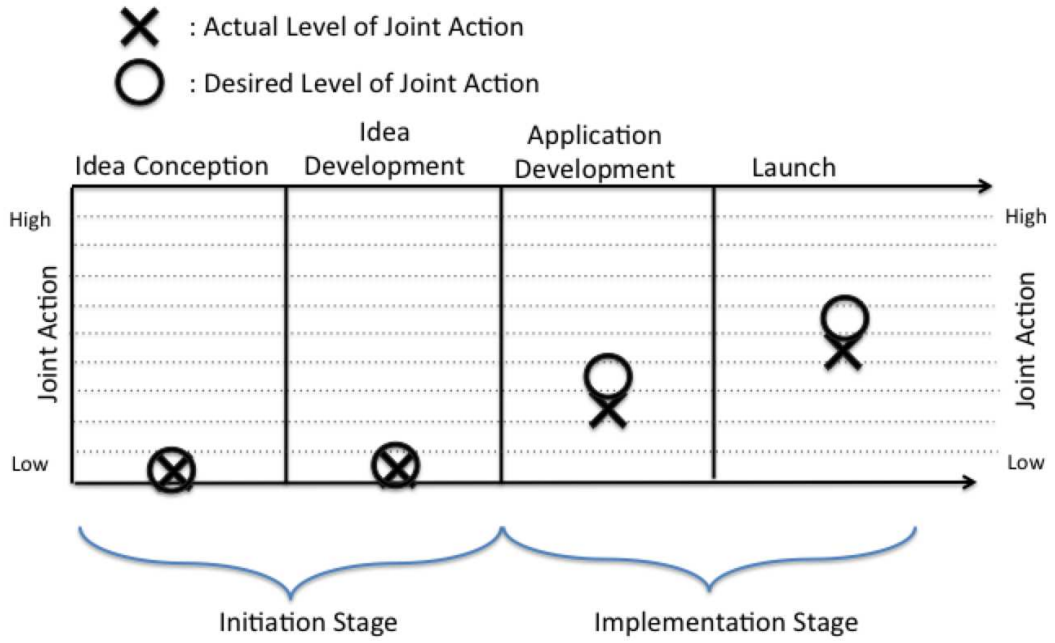
CTC has a customer catalogue that details what options are available for order. Customers use this catalogue in customizing their truck orders. Flexibility, however, exists for customers to

request adaptations not specifically detailed in the catalogue. One key consequence of CTC's dissatisfaction with GBC's Gen-2 system was that the Gen-2 system was not included in the customer catalogue. If customer's wanted the Gen-2 system, they would need to specifically request the product. CTC instead included in the catalogue the new private label gearbox that provides a lower price and greater warranty than even the current GBC system. The updated catalogue offered customers the option to either order the new private label option or the traditional GBC option, but did not explicitly advertise the Gen-2 system. If a customer, however, was aware of and desired to specify GBC's new Gen-2 system, they could do so and CTC would be able to accommodate the request into the order.

Since CTC did not include the Gen-2 system in their catalogue, GBC embarked on a marketing campaign of their own in order to market the new product directly to end-users. GBC's marketing campaign was done on their own and was not planned nor executed jointly with CTC. CTC forecasts projected no more than 10% -20% market penetration for the new Gen-2 system (as a percent of CTC total sales) – a far cry from the previously held 100% market penetration that GBC previously held with CTC assembled trucks.

Figure 2.11: Actual vs. Desired Joint Action - Case D

Respondent 1



Respondent 2

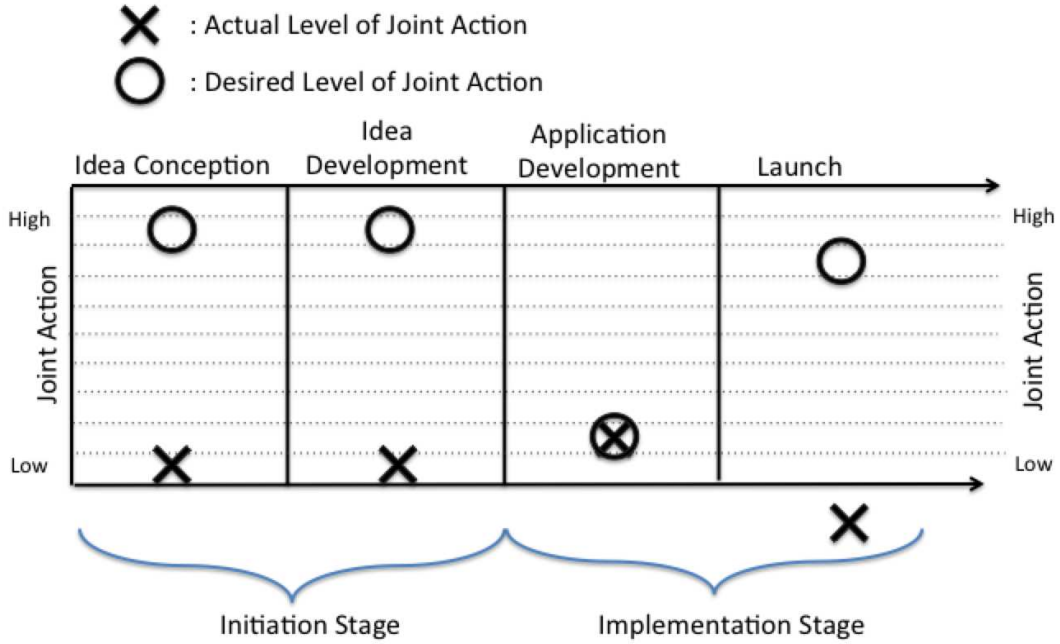


Table 2.5: Respondent Quotes Regarding Actual vs. Desired Joint Action - Case D

	Respondent 1	Respondent 2
Idea conception	"Idea conception was theirs…I'm kind of satisfied with how it went… we're not going to start designing our own mixer drives"	"…early on during the concept development phase we would have liked to have done joint development. We would have liked to have sat down with them and said, 'look, your current product is good, but we struggle with bearing issues and leaks and seals. So there are areas of opportunity, and if we could get it smaller, lighter… So we would have liked to have been part of it, instead of them developing a solution that was actually counterintuitive to a solution that we would have asked for."
Idea development	NA	NA
Application development	"Application development… there was some interaction where they sent us a few and we tested them. We do this every day, not a big deal"	"…they provided the required information for the vehicle application development"
Launch	"…and then a little more communication as we got closer to launch to make sure parts were available"	"…on the launch, if there were negative numbers I would give it to them because they are undermining everything we are doing. They are trying to go to the end customer and incent the product and everything else… Their actions are going to force us to deal with the product that we don't want to. They are making matters worse for us."

Figure 2.12: Performance - Case D

Respondent 1

Performance of the Innovation Project

- How did this project perform along the following dimensions?

Did not challenge existing ideas	1	2	3	4	**5**	6	7	Challenged existing ideas
Did not offer new ideas	1	2	3	4	5	**6**	7	Offered new ideas
Not Creative	1	2	3	4	5	**6**	7	Creative
Did not offer superior value to the customer	1	2	3	4	**5**	6	7	Offered superior value to the customer
Late	**1**	2	3	4	5	6	7	Ahead of Schedule
Over Budget	1	**2**	3	4	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	2	**3**	4	5	6	7	Market Acceptance Stronger than Expected

Respondent 2

Performance of the Innovation Project

- How did this project perform along the following dimensions?

Did not challenge existing ideas	1	2	3	4	5	6	**7**	Challenged existing ideas
Did not offer new ideas	1	2	3	4	5	6	**7**	Offered new ideas
Not Creative	1	2	3	4	5	6	**7**	Creative
Did not offer superior value to the customer	**1**	2	3	4	5	6	7	Offered superior value to the customer
Late	**1**	2	3	4	5	6	7	Ahead of Schedule
Over Budget	**1**	2	3	4	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	**2**	3	4	5	6	7	Market Acceptance Stronger than Expected

2.4.4.5 Performance

We note that the respondents interviewed offered markedly differing views on expected levels of joint action across the different stages of the project while generally agreeing on the actual levels of joint action experienced. This difference highlights that gaps in joint action expectations can exist even within a single firm. While our research focuses on the firm as a single actor and seeks informed participants that can speak for the firm regarding a specific project, divergence as we observed is a real possibility and can provide rich insights into the dynamics of the relationship-building process. In this particular case, inspection of the interview transcript reveals that respondent 1 was pleased with the outcome of introducing a competing supplier for the component. In fact, little was mentioned regarding the reduced serviceability of the module while much was mentioned regarding the positive outcome of having two competing suppliers for the product. The two respondents viewed the same events through different lenses.

2.4.4.6 Key points

What provide interesting insight into this case is the performance scores assigned by both respondents. Scores across all dimensions match within two units on the Likert scale with the exception of 'offering superior value to the customer'. Respondent 1, who reported small gaps in AJAE, assigned a '5' to this performance dimension while respondent 2, who reported very large gaps in AJAE, assigned a '1'. Both respondents agree that the product developed was innovative from the perspective of challenging existing ideas, offering new ideas, and being creative, yet in the context of the supply chain, the product was late, over budget and market acceptance was below average. Due to these ratings, we categorize this case as one with an overall lower level of success.

2.4.5 Case E: Construction Truck Corp. and Composite Manufacturing

Construction Truck Corporation (CTC) is a North America-based company that assembles mixer trucks for the construction industry. CTC assembles the truck chassis to the mixer barrel and other required accessories and then sells the completed truck through a dealership network.

Composite Manufacturing Incorporated (CMI) is a North America-based company that deals in rubber and composite components for the construction, defense, agriculture and recreational vehicle industries.

2.4.5.1 Idea Conception

A key product on the CTC mixer truck is the chute used to pour construction material from the barrel on the truck to the desired location of use. This chute is comprised of three sections, which are all manually hung separately on the side of the truck and are subsequently assembled into place at point of usage. The chute is traditionally made of steel and each section weighs approximately 50 pounds, dry. After usage throughout the day, however, the construction material that sticks to the surface of the chute can cause the total weight of each section to increase up to 60-70 pounds, each. Given the need to manually assemble and disassemble the chute at the beginning and end of each project, the weight of each section becomes an important design consideration that impacts worker safety.

Aluminum is a more expensive material alternative that saves weight. One drawback of aluminum, however, is its reduced resistance to abrasion. As a result, the lifespan of aluminum is significantly less than that of steel. CTC decided to search for and develop a technical solution that would match the weight of aluminum while also achieving the life-span of steel chutes. CTC found a solution in composite materials. In particular, it identified CMI as one of the few

suppliers in the world that could mass produce a specific type of composite that had the structural strength needed for use in the chute design.

2.4.5.2 Idea Development

A unique aspect of CMI's design was a proprietary manufacturing process where the manufacturing tools moved down the line versus the traditional static molding process. While CMI had never applied this new technology to the chute product line, it was concurrently developing the technology to service not only CTC, but to also service a major recreational vehicle company (RVC) for use in recreational watercraft hulls. RVC was moving from a composite hand lay-up process to the more automated process being developed by CMI. CTC's portion of the business was less than one-tenth of RVC's; however, CMI's new manufacturing line would service both RVC and CTC. From a revenue perspective, CTC and their new composite chute was by far secondary in importance (to CMI) as compared to RVC and their recreational watercraft hull business.

2.4.5.3 Application Development

The overall project took approximately 3.5 years from start to finish and was characterized by the respondents as a successful joint effort throughout the development phase. Given the new technology involved in the project, many surprises and cost overruns were encountered. These issues did not dissuade CTC from the project and price adjustments were agreed to by CTC to help cover the unforeseen costs. Both parties made significant monetary investments into the project. CTC owned the intellectual property of the design while CMI owned the intellectual property of the manufacturing process and the physical tools needed to make the chute components. Both design and manufacturing process were key sources of product value in the project.

Since composites are not abrasion resistant, a special coating was required to protect the chute surface. The initial coating formulation, however, did not perform to expectations and alternative coatings were developed and tested until the team refined an adequate solution. Another issue that arose was related to the hooks used to hang the chute segments on the side of the truck during transport. Initially, the hooks were designed of composite materials like the chute themselves. This design, however, was not robust enough for the application and the team developed a steel hook design that then needed to be integrated with the composite chute. The joint CTC/CMI team eventually developed a solution that integrated these two parts successfully.

2.4.5.4 Launch

After 3.5 years of development, the product launched and thousands of composite chutes were sold in the first year alone. The product was lauded as a success and orders continued to come in. Despite the price premium of the composite chute as compared to the aluminum and steel options, customers were willing to pay for the weight savings that the composite chute provided. The lighter chute not only enabled a larger construction material payload, but also helped reduce workman's comp liability by reducing the lifting forces that employees needed to exert to assemble and disassemble the chute.

The first year of launch was a complete success. The success, however, was short-lived when CMI suddenly notified CTC that it would no longer be able to manufacture the chutes. CMI explained that they needed to focus all their efforts on the RVC business. While they did not provide details to CTC, it became evident that CMI was encountering difficulties with sustaining the business that they had developed with RVC, thus placing their entire operations in jeopardy. CTC was forced to remove the successful composite chute product offering from their catalogue. Later, CTC discovered that RVC pulled out of their agreement with CMI and

abandoned the new technology altogether. While the reasons for RVC's abandonment of the technology were not made know to CTC, it was shared that RVC was reverting to the composite hand lay-up process and that their manufacturing would be shifted to a low labor-cost country. Since a traditional lay-up process was not compatible with the composite technology needed for a construction material chute, the chain of events left CTC with no supply of composite chutes at all and what was initially deemed a strategic breakthrough in composite manufacturing quickly disappeared into the graveyard of unsuccessful innovation projects.

Figure 2.13: Actual vs. Desired Joint Action - Case E

Respondent 1

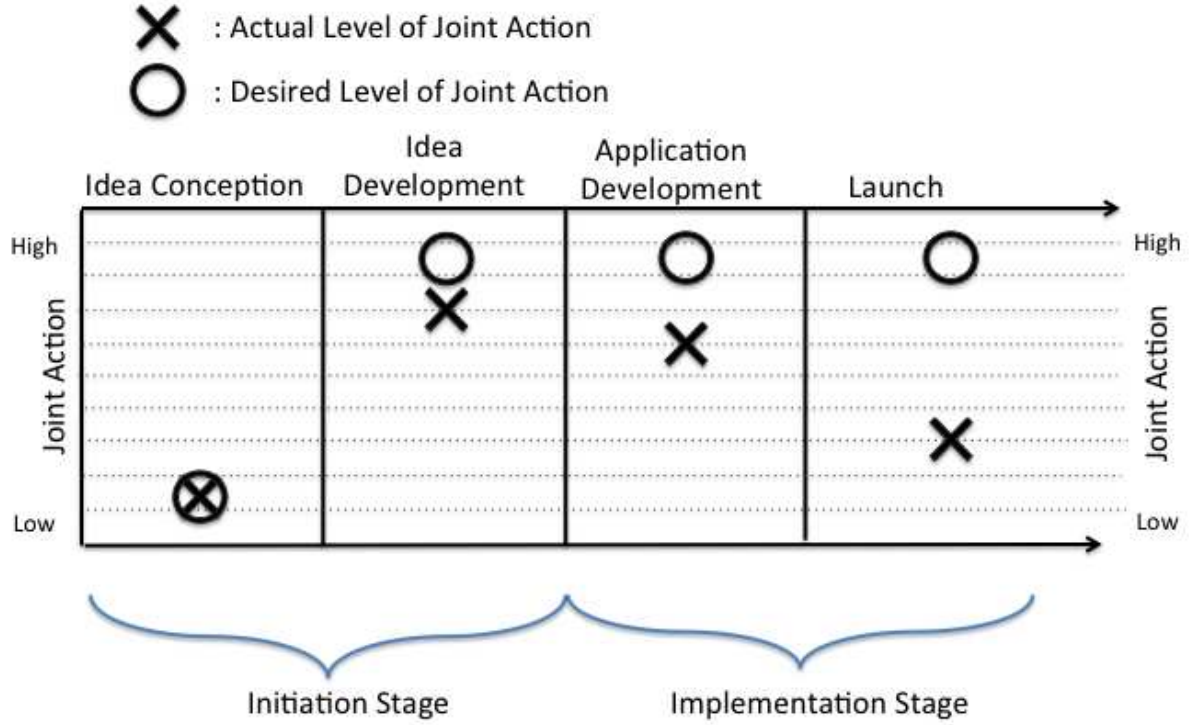


Table 2.6: Respondent Quotes Regarding Actual vs. Desired Joint Action - Case E

	Respondent 1	Respondent 2
Idea conception	"…in the idea conception phase, Construction Truck Corp came up with the idea of the chute. …I would say that that portion of the interaction was pretty low. We had the concept already done when we started our discussions with Composite Manufacturing Inc."	NA
Idea development	NA	NA
Application development	"As we got closer and closer to launch, and as we learned more and more… in terms of joint action along this entire period of time, there were weekly phone calls, multiple site visits from our engineering and supply chain group to their facility…"	NA
Launch	"I think we realized that the quality of the joint action was deteriorating. But I don't think we realized or understood until afterwards… we didn't know why... hindsight being 20 – 20, we now understand much more of what was going on inside Composite Manufacturing Inc., but we didn't know it at the time." "You have tons of communication, doesn't mean you're getting the project any further. It depends on what the actual communication looks like…quantity went up, but quality went down as we got to the end "	NA

Figure 2.14: Performance - Case E

Respondent 1

Performance of the Innovation Project

- How did this project perform along the following dimensions?

Did not challenge existing ideas	1	2	3	4	5	6	(7)	Challenged existing ideas
Did not offer new ideas	1	2	3	4	5	6	(7)	Offered new ideas
Not Creative	1	2	3	4	5	6	(7)	Creative
Did not offer superior value to the customer	1	2	3	(4)	5	6	7	Offered superior value to the customer
Late	(1)	2	3	4	5	6	7	Ahead of Schedule
Over Budget	(1)	2	3	4	5	6	7	Under Budget
Market Acceptance Worse than Expected	1	2	3	4	5	(6)	7	Market Acceptance Stronger than Expected

2.4.5.5 Performance

While the project launched later than originally scheduled and was over budget, it scored very high ratings on creativity and idea quality. Additionally, market acceptance was stronger than anticipated. The respondent hesitated, however, to give the highest marks on 'offered superior value to the customer'. The respondent explained "It does offer superior value to the customer in terms of performance. It is lighter, it does last, but we've got to get the price right though. I couldn't say that that's a seven until we get the price to hit the target".

2.4.5.6 Key points

From a product only standpoint, the project was a success. From an overall new product development standpoint, however, the project failed since the launch never completed and was altogether cancelled. (Yin, 2009, pg.81) operationalize innovation performance as the fraction of revenue at a firm that comes from products that are either new to the world market (radical innovation), or new to that firm (incremental innovation). Implicit in this operationalization is the fact that only projects that result in revenue can be considered a success. We therefore recognize that while CTC and CMI jointly developed an innovative product that the market initially accepted, failure to sustain the launch relegated the project as one with a low-level of success (figure 2).

2.4.6 Case F: Electronics Connect and Design Service Corp

Electronics Connect is a large European-based company that supplies electrical and communication connection and device systems to industrial and commercial applications across various industries. Electronics Connect has a global customer base and competes with some of the world’s largest electrical and communication device manufacturers.

Design Service Corp is a small engineering design company based in Europe that provides design services to companies in the electronics industry. They currently have fewer than 200 employees and follow a business model that is focused solely on engineering services. In other words, Design Service Corp does not produce or manufacture any tangible products, but rather helps firms in their product development initiatives

2.4.6.1 Idea Conception

Electronics Connect developed a concept for a new fiber optics connection system that would enable the customer to assemble the connection system in the field themselves using a special tool set. While Electronics Connect has expertise in both fiber optics and connectors, they didn't have the know-how to develop both the connection assembly protocol and the specialized tools necessary to launch this product. As a result, Electronics Connect initiated a search to find the appropriate supply chain partner with the mechatronics background needed to support the project.

2.4.6.2 Idea Development

Using an external consultant familiar with such type of engineering services companies, Electronics Connect identified a short-list of companies and then pursued a series of audits and site-visits necessary to narrow down the list to two companies. Throughout this search, Electronics Connect made clear to all companies the expectation that they would own 100% of all intellectual property generated with the project. Any company that could not accept these terms was not considered. Ultimately, two companies were chosen that would participate in a six-month competition for the business; Design Corp was one of the two companies. In the words of one respondent,

> "We told both of them that they were competing for the job and that after six months, we would make up our minds with whom we would work together. Basically we would select the one with not only the best ideas, but also the most cooperative one, the most open one, most willing to work together towards a solution".

Given the small size of many of these engineering services companies, Electronics Connect resolved to pay each company for their time in participating in the design competition. At the end of the competition, Design Corp was chosen as the winning partner. Given Design Corp's business model of engineering services, there was no desire on their part to own any intellectual property, thus this topic was not a debate for the two firms.

2.4.6.3 Application Development

Key elements of the application development phase were 1) to define and prove the necessary steps needed to make a fiber-optic connection using the system, and 2) design and develop the necessary tools that the customer would need to make the connection. The majority of the time elapsed during the overall project timeline was dedicated to this application development phase of the project.

Design Corp's CEO was personally involved during the design competition defining the framework of the overall solution and ensuring appropriate support was being provided to the project. Upon securing the business, however, working-level engineers at both companies took over the project. These engineers would meet every two weeks for status update meetings. Additionally, once a month, management from both companies would meet as a steering committee to discuss high level issues, key milestones and budget performance. Given the uncertain nature of the project, a flexible 'time plus material' contract was used as opposed to a 'fixed-price' contract.

Electronics Connect was pleased with the frequency and the openness of communication with Design Corp. In this case, communication was referred to as the timely sharing of

information and feedback relevant to the project. In fact, such communication was cited as a key decision criterion in awarding them the business in the first place. According to an Electronics Connect manager,

> "I think very positively was the openness of that company – that they are willing to share all their successes, but most of all they were also willing to share their failures. The thing that was more the key in getting to the point where we are right now was a really open and honest communication".

Part of the upfront agreement between the two companies recognized the possibility and ability of Electronics Connect to request a personnel change in the project team should lack of individual performance necessitate such a change. The Electronics Connect manager credited success in implementing this contract term with the openness in communication that existed between the two firms, where both firms freely shared feedback with each other. Regarding exercising the personnel change clause in the contract, one Electronics Connect manager explained:

> 'In our country they would say, 'maybe it's good if you leave the room for a moment', because we don't want to have that discussion in front of that guy; but Dutch guys would probably just say, 'this guy is not performing on this and this and this…' and they would have no issue with that at all, which makes it very easy as a customer to discuss performance with them. By the way, they also do it with us and our performance!'

The culture of open communication without offense was a key element in aligning expectations to reality throughout the project.

2.4.6.4 Launch

While Design Corp was brought in for their expertise in designing and developing the connection protocol and related mechatronic tools, they do not have large-scale manufacturing expertise. As a result, Electronics Connect partnered with another firm for the launch phase of

the project. Design Corp was still involved to a small degree, however, ensuring that any ensuing changes to the design did not violate critical performance assumptions.

Electronics Connect initiated and ended the relationship with Design Corp, within the scope of the single project. In other words, there was no attempt to establish a long-term supply chain partnership with expectations of multiple projects into the future. Rather, both firms understood that their efforts, risks and rewards were confined to the context of the single project.

Figure 2.15: Actual vs. Desired Joint Action - Case F

Respondent 1 (group)

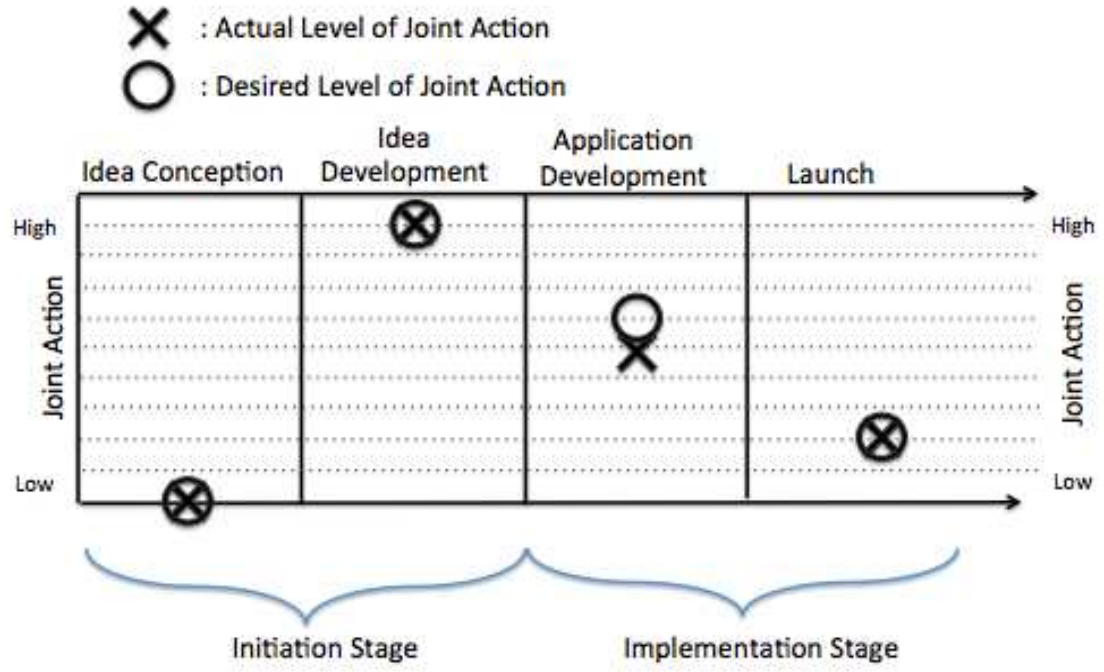
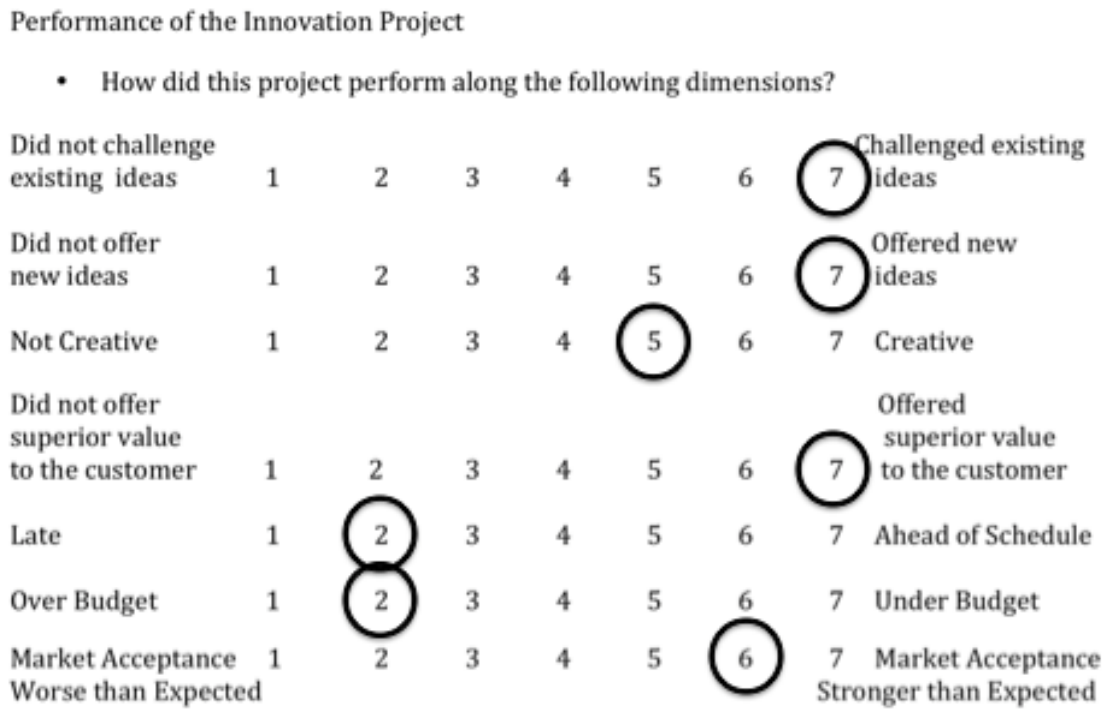


Table 2.7: Respondent Quotes Regarding Actual vs. Desired Joint Action - Case F

	Respondent 1 (group)	Respondent 2
Idea conception	"Idea conception, that was fully on our side. We came up with the idea."	NA
Idea development	"…we meet each other every two weeks where we discuss the results of the past two weeks and where we failed on both sides"… regarding actual and desired joint action, "it was aligned"	NA
Application development	researcher: "OK… what would have closed that gap?" respondent: "Competences on our side. We did not have the resources, nor the competencies to review the part of their work because we stayed too far out of their domain. We should have been more involved in reviews. I think we should have done more from our side. It's not their mistake, I think it is our own, we should have managed this better."	NA
Launch	"For the launch we are going for the mass production sets and designs, and that's not their expertise… we really need to go and partner with somebody else. So they will still be involved to review what we are doing and that we do not break any rules that we established in the past, but the majority of the work will not be executed by them but by someone else."	NA

Figure 2.16: Performance - Case F

Respondent 1 (group)



2.4.6.5 Performance

Overall the project was reported as being highly successful, with 10 patents filed for the tooling portion of the project alone. Electronics Connect made clear in the interview that even though they owned the IP for the product, they included the names of the contributing engineers at Design Corp as co-inventors on the patent. Electronics Connect felt that the project strongly challenged existing ideas, offered new ideas and offered superior value to the customer. While the project was slightly late and over budget, this was reported as relative to the unknown and was not seen as deterioration in performance of the project. We categorize this case in the high level of success category.

2.4.6.6 Key points

This is a unique case where the supply chain relationship is created with an understanding that the relationship will dissolve upon completion of the project. Whereas other supply chain relationships are created with a long-term relationship horizon in mind, this was purposefully designed to be a short-term relationship. This project highlights that successful interfirm innovation performance can occur without the need to commit to a long-term relationship.

2.5 Cross-Case Analysis

2.5.1 AJAE Gap Size

A key objective of this study was to empirically validate the existence of AJAE and investigate its impact on performance. As qualitatively highlighted in the previous section, there in fact does exist a difference between actual levels of JA and desired levels of JA in the interfirm new product development projects investigated in this essay. Further, we observed that the levels of both desired JA and actual JA can vary across the different stages of the project (eg. cases A, C and E). As a result, the degree of the asymmetry (AJAE gap size) between desired

and actual levels of JA also can vary across the different stages of the project (figure 5, figure 9 and figure 13). Given this observation, we recommend future studies control for the stage of the innovation project when studying AJAE since AJAE may be more prominent in some phases of the development project than in others.

While the interview protocol did not have a numeric scale identified on the figure, the figure is depicted with ten equally spaced lines that the respondent used in quantifying the actual versus desired levels of JA from low to high (figure 3). We subsequently assigned a scale of 0 (bottom line) to 100 (top line) to assist in our analysis of the respondent scores. It is interesting to note that in all cases where a gap exists, the respondents reported higher average desired levels of JA as compared to the actual levels achieved. In no case did a respondent identify a level of joint action that was higher than desired. Either the respondent felt that actual and desired levels were aligned, or he felt that a higher level of JA was desired.

It would be of interest to also assess the suppliers' responses to the same instrument and see if a similar pattern persisted or if the reverse pattern is observed where suppliers felt that the actual level of joint action was not necessary and that a lower level would have been more appropriate. This behavior has been noted in prior research where more powerful supply chain members can use their leverage to coerce less powerful partner firms to engage in joint action investments where the net benefit is more favorable to the powerful partner (Hart & Saunders, 1997; Weinstein, 2005). Exploring the supplier view, unfortunately, was not possible in this study since in only three cases were supplier contact information provided for the dyad; of those three supplier contacts, none agreed to participate in the research. In the other three cases where no contact information was provided, the participants hesitated to facilitate supplier participation citing concerns that doing so could adversely impact the ongoing business relationship by

signaling to that supplier that something was wrong and the relationship need to be studied by an academician. This highlights the challenging nature of obtaining dyadic empirical data from informed respondents regarding buyer/supplier relationships. A possible extension, however, to this research could be a replication of this study using supplier respondents rather than OEM respondents that are not matched to the original research.

For sake of comparison in this cross-case analysis we average the scores for a given JA dimension across all stages of the project and across both respondents. For example, respondent one in Case A reported desired levels of JA of 50, 50, 60 and 45 across the respective stages of idea conception, idea development, application development and launch. The average of respondent one's four scores for desired JA is therefore 51.25. For the same stages, respondent 2 reported desired levels of JA of 60, 70, 60 and 35 with an average of 56.25. Averaging the two respondent scores together yields an overall desired JA score of 53.75. The same process applied to actual levels of JA results in a combined average score of 35.00. The difference between the averaged levels of actual JA and desired JA is reported as the average AJAE gap size, and in this case (Case A) equals to 18.75. Table 8 reports these values for all cases and for all respondents. Note that values above both median and average scores are highlighted with an asterisk.

Using both average and median scores, we categorized desired JA, actual JA and AJAE gap size into the three groupings of 'high', 'low' and 'medium' (table 9). A score is categorized as 'high' if it is above both the average and median scores. It is categorized as 'low' if it is below both the average and median scores. It is categorized as 'medium' if it is equal to, or bounded by the average and median scores.

Table 9 also includes two additional columns: ‘AJAE gap clarity’ and ‘management performance assessment’. The scoring methodology for ‘AJAE gap clarity’ was qualitatively derived from the interview transcript codings and is discussed in the following section. The ‘management performance assessment’ is the performance category assigned to the project by the key executive contact at each firm at the onset of the interview process when the original projects were selected for the research study. Later in this essay we conduct a validation analysis (table 10) where the survey performance scores reported by key respondents during the interview process are compared to the a priori management performance assessments listed in table 9.

Table 2.8: AJAE Gap Size

	Respondent 1			Respondent 2			Average		
Project	Desired JA	Actual JA	AJAE Gap Size	Desired JA	Actual JA	AJAE Gap Size	Desired JA	Actual JA	AJAE Gap Size
Case A - PEC	51.3	42.5	8.8	56.3	27.5	28.8	53.8*	35.0	18.8*
Case B - AVI	46.3	45.0	1.3	21.3	21.3	0.0	33.8	33.1	0.6
Case C - BI	67.5	50.0	17.5	72.5	67.5	5.0	70.0*	58.8*	11.3
Case D - CTC/GBC	25.0	20.0	5.0	65.0	3.8	61.3	45.0	11.9	33.1*
Case E - CTC/CM	67.5	43.8	23.8	NA	NA	NA	67.5*	43.8*	23.8*
Case F - EC	42.5	40.0	2.5	NA	NA	NA	42.5	40.0*	2.5
Median							49.4	37.5	15.0
Average							52.1	37.1	15.0

* Score is above both the median and the average for that dimension

Table 2.9: AJAE Gap Size, Gap Clarity and Performance

Project	Desired JA	Actual JA	AJAE Gap Size	AJAE Gap Clarity	Management Performance Assessment
Case A - PEC	High	Low	High	Low	Low
Case B - AVI	Low	Low	Low	High	High
Case C - BI	High	High	Low	High	High
Case D - CTC/GBC	Low	Low	High	Low	Low
Case E - CTC/CM	High	High	High	Low	Low
Case F - EC	Low	High	Low	High	High

Table 2.10: Performance Score Validation

	Challenged Existing Ideas	Offered New Ideas	Creative	Value to the Customer	Market Acceptance	Timing	Budget	Total Average	Survey Performance Score	Management Performance Assessment
Case A - PEC	3.5	3.5	4.0	3.5	3.5	1.0	2.5	3.1	Low	Low
Case B - AVI	5.5	6.0	5.5	4.0	3.5	4.0*	3.0*	4.5	Med	High
Case C - BI	6.5*	5.5	6.0*	7.0*	6.5*	4.0*	3.5*	5.6*	High	High
Case D - CTC/GBC	6.0	6.5*	6.5*	3.0	2.5	1.0	1.5	3.9	Low	Low
Case E - CTC/CM	7.0*	7.0*	7.0*	4.0	6.0*	1.0	1.0	4.7*	High	Low
Case F - EC	7.0*	7.0*	5.0	7.0*	6.0*	2.0	2.0	5.1*	High	High
Average	5.9	5.9	5.7	4.8	4.7	2.2	2.3	4.5		
Median	6.3	6.3	5.8	4.0	4.8	1.5	2.3	4.6		

* Score is above both the median and the average for that dimension

2.5.2 AJAE Gap Clarity

Despite the challenge to obtain the dyadic view on a single innovation project, we were still able to qualitatively identify asymmetry between desired and actual levels of joint action for a focal firm through the descriptions obtained and reported previously. Another construct that emerged in the course of this research related to AJAE was the *clarity* of the gap. As highlighted in essay one of this dissertation, AJAE arise when two firms engage in joint action and those two firms bring with them differing marginal cost and benefit curves associated with varying levels of shared joint action. This results in those two firms most likely differing in the optimal level of joint action desired, thus leading to asymmetrical joint action expectations (AJAE).

As researchers, we can graphically conceptualize the gap between the respective optimal levels of joint action when we plot both firms' marginal cost and benefit curves; thus for the researcher the gap can be clearly comprehended from a theoretical perspective. Applied in a managerial context, however, the gap may not be as readily clear to those involved. A manager with limited information may not be able to identify the existence of such gaps to the extent that the marginal costs and benefits for engaging in joint action are unclear from either his own firm's perspective or from the partner firm's perspective. If a manager has a high level of knowledge of his own firm's marginal cost and benefit curves yet for various reasons has little to know knowledge of the partner firm's marginal cost and benefit curves, then gap clarity will be low and the manager may be unaware that the partner firm desires a differing level of joint action as compared to what the manager's firm desires. The greater the knowledge a manager has of these factors, the greater the gap clarity will exist. If a manager is informed of both his own firm's marginal cost and benefit curves and that of the partner firm, then gap clarity can exist for that manager.

We observed the construct of gap clarity in our transcripts. In some cases, it was evident that the respondent was interested in understanding the viewpoint of the partner firm. In other cases, lack of clarity was also evident. In case A (PEC), for example, the respondent demonstrated frustration in his inability to establish clarity when he stated "I just wish that they would have been a little more forthright about it and just been direct. I just felt like there was an elephant in the room at all times, and they would still come together with us and still be nice and still talk and still work together and still go forward… but there was still this underlying feeling of 'we don't trust you… we don't know what you're doing' ". Conversely, case B (AVI) exhibited evidence of establishing clarity in their relationship through regular meetings at both the operational level and at the leadership level where an executive steering committee convened to discuss issues and opportunities. In this environment of communication, both sides were able to help each other understand and appreciate their respective marginal costs and benefits associated with joint action, thus establishing clarity in AJAE.

In case C (BI), the entire premise of the joint project was based on Blaze Inc's willingness to think out of the box and identify a business arrangement (exclusivity contract) that would be beneficial not just to them, but also to Super Motors Corp. Much of the effort that went into establishing the project built upon this foundation of clarity. Case D is another example with a lack of clarity in the relationship. One respondent summarized this lack of clarity when he stated,

> 'They went off on their own to develop the new technology for that market and they get a little bullish assuming that they… dictate the technology because they owned it, they owned the market. They developed some unique technology that would be beneficial to increase their revenue stream, to increase their business case and quite a few benefits for them. They failed to think of the impact to Construction Truck Corp. and to the customer… assumed that that would just be necessary pains for us because we didn't have any other options, so we went out and found options.'

Case E appeared in all aspects to have a high degree of clarity and success associated with it until Composite Mfg (CM) left the business after one year of production with little to no warning leaving CTC with no option but to revert to the old technology. It became apparent to CTC that there had been much more to the story they were not aware of pertaining to the true costs and benefits that CM incurred for their joint product development project. In short, CM assumed clarity existed when in fact it did not. Case F exhibited a high degree of clarity in the relationship, partly due to the level of openness in communication referred to in the within-case analysis of the case. We summarize in table 9 the level of gap clarity associated with each case along with the gap size previously reported and performance for all six cases.

A gap clarity score of 'high' was assigned to those cases with statements coded in NVivo 9 under the category of gap clarity. A gap clarity score of 'low' was assigned to those cases with no evidence of gap clarity in the coding. The overview in the preceding paragraphs summarizes this analysis. In summary, while desired JA, actual JA and AJAE gap size were categorized as high/low using *graphical* feedback generated by the respondents, 'AJAE gap clarity' and 'management performance assessment' were categorized using coded verbal evidence from the transcripts.

2.5.3 Performance

How innovation performance is operationalized varies greatly across innovation research literature. Some studies measure innovation performance at the firm level (Ahuja & Katila, 2001; Laursen & Salter, 2006; Luca & Atuahene-Gima, 2007) while others measure it at the product or project level (Arora, Gambardella, Magazzini, & Pammolli, 2009; Wagner, 2012). Studies also vary in the items used to measure innovation performance. Performance can be measured by percent of revenue attributed to innovative products (Laursen & Salter, 2006), the

number of patents produced (Ahuja & Katila, 2001), or financial performance derived from innovative products (Luca & Atuahene-Gima, 2007). Goodale, Kuratko, Hornsby, and Covin (2011) used a multi-dimensional approach that combined multiple factors into a single importance-weighted score.

In a like manner, we measure innovation performance across three key dimensions relevant to the innovation project: 1) innovativeness (challenged existing ideas, offered new ideas and creative), 2) market performance (value to the customer, market acceptance) and 3) project execution (timing, budget). We average the scores across all seven items into a single composite score for innovation performance. Whereas Goodale et al. (2011) employed a weighting scheme using respondent-provided weights, we assume equal weighting for all items and average the scores for each case (table 10). Additionally, those scores above both median and average are highlighted with an asterisk. Finally, the 'total average' scores are categorized as either high or low given the respective score's position as either above or below both average and median scores. In the one case (Case B) where the 'total average' score is exactly equal to the overall average, we categorized it as 'medium'.

Given the qualitative nature of this research, we do not assert any statistical significance to this analysis but use the scoring mechanism simply to assist the research team to identify both themes across cases and outliers that emerge. In particular, we were interested to establish some level of validation to the a priori qualitative assessment of performance provided by the executive contact when cases were initially identified. This a priori assessment is reported in the column titled 'management performance assessment'.

We now compare this a priori assessment to the performance scores collected from the key informants during the interviews. Cases A, C, D and F all align in the two respective

performance assessments (table 10); namely cases A and D are considered as low-performing while cases D and F are considered as high-performing. Case B average survey performance score matches the overall average, thus we assign it a 'medium' rating for performance. This is not a concern for validity since the project still scores above both average and median scores on the execution dimensions of timing and budget while scoring near the average/median scores for the remaining dimensions.

The performance data from Case E, however, does provide us initial cause for concern. The project was identified by the executive contact as a lower-performing example while the survey responses state otherwise (table 10). Review of the transcripts for this case highlights that the project did, in fact, develop and launch as a success. Had the research team conducted the interview within the first few months after the initial launch, most likely the executive contact would have categorized case E as a high-performing example of success. Yet the subsequent collapse of the supply chain for the product after the first year of production rendered the overall project a lower performance category.

It is important to note that the measures used in the survey instrument focus only on the project development and initial launch stages of case E and capture the higher degree of success achieved during this time. The measures do not, however, capture the persistence of performance beyond launch. Our research specifically bounded the domain of applicability to the project development and initial launch phase. In fact, the initial request for participation stated that the research team was interested in studying projects that had recently launched. However, given this discrepancy observed in case E, follow-up emails were sent to all other firms that participated in the study to ascertain if any material differences in performance

emerged over the previous 12 to 21 months since the interviews were conducted. No notable discrepancies were reported.

Another limitation in this study is potential common method bias of the reported performance dimensions. Unfortunately, due to the limited nature of published performance data at the project level, our study relied solely on self-reported measures of project performance. Ideally, one would want to verify project performance against an independent data source, but this was not possible with the cases and performance dimensions studied in this project. At a minimum, however, we relied on multiple sources within the firms in order to generate an acceptable level of reliability on the data gathered. Also, the two methods of collecting performance data as just discussed previously provided an increased level of reliability as opposed to only using the initial management assessment or relying solely on the survey response scores from the interview protocol.

2.6 Propositions and Refined Model

Inspection of table 9 reveals a few important patterns across the constructs. First, as expected, gap size appears to be inversely related to performance. Large gaps are associated with lower levels of performance (cases A, D and E) while smaller gaps are associated with higher levels of performance (cases B, C and F). This relationship was conceptually predicted in the a-priori theoretical model and is supported by this qualitative empirical study. Second, gap clarity appears to be positively related to overall performance. When interfirm relationships establish clarity of AJAE, they appear to achieve higher levels of performance (cases B, C and F) as compared to relationships that have lower levels of clarity (cases A, D and E). This finding was not predicted in the original conceptual model and is subsequently added as an additional dimension relevant to establishing behavioral interoperability. Third, absolute JA level also

appears to be weakly related to overall performance. Cases A, B, C and D exhibit matching levels of performance with absolute levels of JA. Cases E and F, however, are the exceptions where an inverse relationship exists between absolute level of JA and the level of performance. In case E, both firms engaged in very high levels of JA yet the project ultimately failed. Case F, on the other hand, had lower levels of JA yet was seen as a highly successful joint development project. This finding is interesting in that it supports the premise that while JA in interfirm relationships (as often operationalized as the level of collaboration, integration or cooperation between two firms) is an import factor of success, perhaps even more relevant to predicting performance success are the behavioral factors related to expectations that give context to the relationship engaged in JA. In this research we identify both AJAE gap size and AJAE gap clarity as import behavioral factors. This leads us to modify the original proposition 3 as follows:

Original Proposition

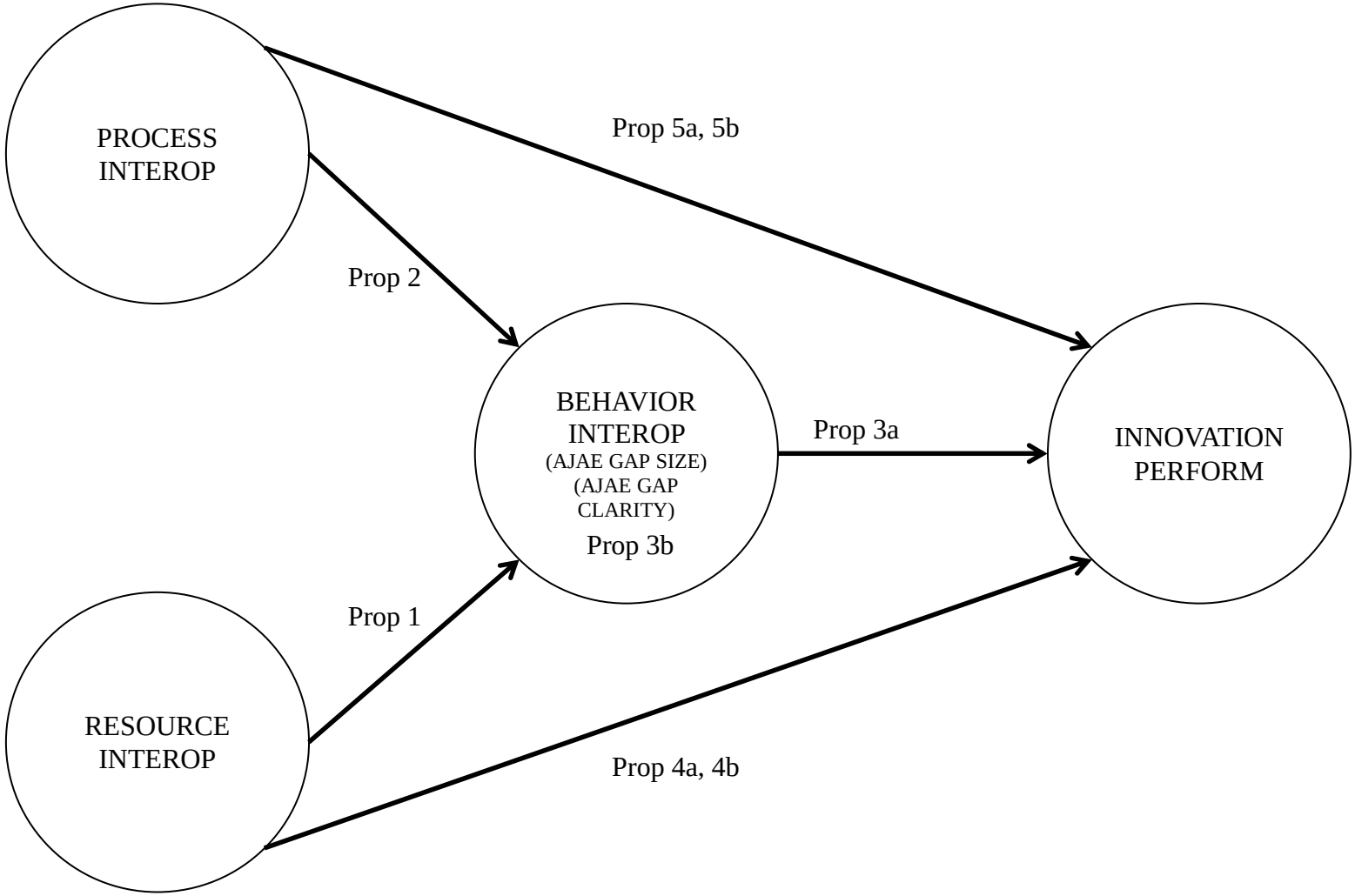
Proposition 3: Gap size in joint action expectations is inversely associated with innovation performance (smaller gaps in joint action expectations correlate with higher levels of innovation performance)

Revised Proposition

Proposition 3a: Interfirm behavioral interoperability is significantly and directly associated with innovation performance. (higher levels of behavioral interoperability are directly associated with higher levels of innovation performance)

Proposition 3b: Both AJAE gap size and AJAE gap clarity are reflective indicators of the behavioral interoperability construct

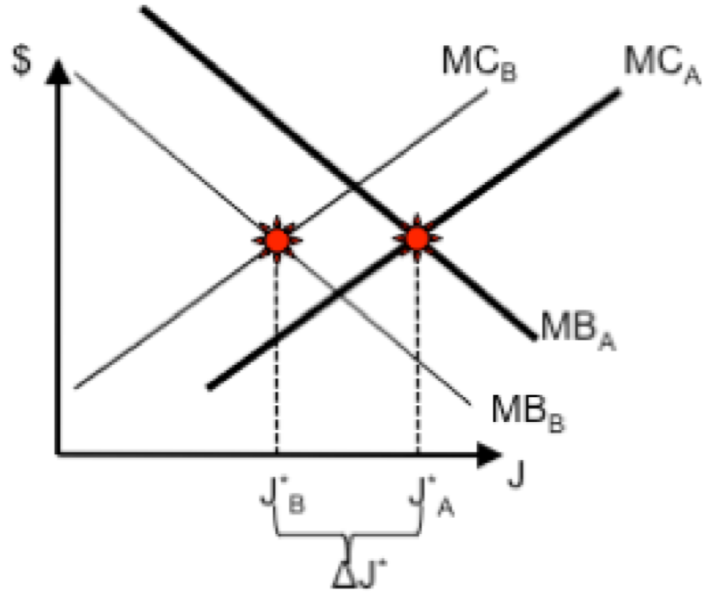
Figure 2.17: Revised Model



2.7 Limitations and Conclusions

It is important to note that the size of the gaps identified in this study may or may not be similar to the size of the theoretical gaps between the two firms' optimal levels of JA as depicted by ΔJ^* in figure 18.

Figure 2.18: Graphical Model of Asymmetrical Joint Action Expectations



MC - marginal cost curve

MB - marginal benefit curve

J - Level of joint action

J^* - Optimal level of joint action where marginal costs equal marginal benefits for a given firm

In this study, we observe gaps between actual and desired levels of JA from a focal firm/OEM perspective. We make the assumption that these firms seek to maximize utility and therefore engage in a level of joint action that is either equal to, or bounded by the respective

theoretically optimal levels of joint action (J^*_B and J^*_A). Referring to figure 18, we expect the firms to engage in a level of joint action (J) that is defined by:

$$\mathbf{J^*_B \leq J \leq J^*_A} \qquad \textbf{Equation 8}$$

Further, since all gaps identified in the case studies reported a desired level of joint action (J*) that is higher than the actual level of joint action experienced, we can assume that the focal firm interviewed is represented by firm 'A' (figure 18), whose marginal cost and benefit curves intersect at a higher level of joint action (J*A) than that for firm 'B' (J*B). The challenge, however, is that we have only uncovered the gap from a single perspective. Two alternative situations therefore exist if we were to obtain the dyadic perspective: 1) the actual level of joint action engaged in is in fact optimal for the supplier and the supplier is not willing to engage in any higher levels of JA, in other words:

$$\mathbf{J = J^*_B} \qquad \textbf{Equation 9}$$

or 2) the actual level of joint action engaged in is greater than the optimal and desired level of JA for the supplier and that the actual level of JA engaged in is somewhere between the two optimal levels of JA for the two firms:

$$\mathbf{J^*_B < J < J^*_A} \qquad \textbf{Equation 10}$$

Either case is feasible and while we know a gap exists from the perspective of one firm, we don't yet have the complete picture that allows us to accurately assign a graphical representation of the gap in each case.

One could argue that it is possible that two firms report AJAE gaps where both parties desire higher levels of JA. This situation could arise in the case that both firms share differing views on the forms of higher levels of JA. For example, one firm could desire a greater number of resident engineers assigned by both firms to the project while the other firm desires an increase in joint marketing efforts by both firms. Each firm desires their form of joint action while possibly not being aware of the other form desired by their partner. This hypothetical case is a clear example of a relationship that has not yet achieved consensus on the forms of joint action available to their partnership; in short, the definition of the J axis in figure 18 has not yet been clearly established. The graphical model, therefore helps us identify another important aspect to understanding clarity in AJAE: namely, firms need to establish a mutual understanding of what forms of JA are possible and feasible in the relationship in order to better establish clarity in joint action expectations.

The construct of asymmetrical joint action expectations (AJAE) clarity captures the extent to which both firms have visibility and understanding of each others' respective costs and benefits for the shared joint action. Establishing clarity is not an easy endeavor, especially if the two firms do not share key underlying assumptions that guide day-to-day decision-making that define their respective corporate culture (Schein, 1985). In the presence of clarity, however, firms will be more likely to identify and embrace forms of joint action that are beneficial to both firms, rather than to simply maximize benefits to itself. Additionally, gap clarity will enable a firm to more easily identify investment opportunities that may beneficially shift the cost and benefit

curves of both partners, or allow the partners to increase the overall level of JA to a more economically optimal level for both parties.

A further study of AJAE can be aided by a few extant constructs already researched in the supply chain literature. Team orientation is one such construct that seeks to capture the extent that a team spirit pervades, commonality of purpose exists and visions are shared (Hult, Ketchen Jr, & Nichols Jr, 2003). Additionally, supply chain orientation is another similar construct that emphasizes the need for a firm to reach beyond its own paradigm (Mentzer et al., 2001) and adopt a systemic/holistic view of the supply chain (Esper, Defee, & Mentzer, 2010). Another consideration for future studies is to control for the length and history of the relationship. Such a control variable can help segregate any potential variance in performance due to established relationships.

This qualitative research has uncovered numerous apparently relevant aspects of buyer supplier relationships that impact innovation performance in joint new product development initiatives. Whereas prior research focused on the absolute level of joint action engaged between firms, this essay elevates the importance of the behavioral dimension and role that joint action expectations have on performance. In particular we identified AJAE gap size and AJAE gap clarity as relevant. We have only begun to understand the role that understanding and managing joint action expectations has in establishing effective interfirm relations. Whether or not a gap exists, whether or not that gap is transparent to both parties, and whether or not (and *how*) firms seek to close such gaps are all separate, yet important concepts that can influence the performance of joint action efforts. These questions offer excellent opportunities for further research that will enrich our understanding of effective supply chain management.

3 ESSAY THREE - ASYMMETRICAL JOINT ACTION EXPECTATIONS, SUPPLY CHAIN INTEROPERABILITY AND INNOVATION PERFORMANCE: AN EMPIRICAL ANALYSIS OF INTERFIRM NPD POWERTRAIN PROJECTS IN THE AUTOMOTIVE INDUSTRY

3.1 Introduction

Using literature review and case study research, the first two essays of this dissertation have established a case for asymmetrical joint action expectations (AJAE) as a valid phenomenon in inter firm relations and as relevant to innovation performance in the supply chain. Essay one laid the theoretical foundation of understanding how differing marginal cost and benefit curves associated with joint action between two firms can lead to differing optimal levels and therefore differing expectations regarding the desired level of joint action across those firms. Essay two investigated this phenomenon in the context of six case studies of interfirm new product development projects and found that indeed, gaps between actual and desired levels of joint action do exist. The case studies support the premise that AJAE exist and are relevant to project innovation performance from a financial, design and timing perspective. Further, the case studies reveal that not only is the size of the gap in AJAE relevant, but so also is the *clarity* of those expectations.

While research has already been done on how firms can successfully integrate in interdependent supply chain relationships, the research has mostly focused on the effective management of resources and processes across supply chain members (Frohlic and Westbrook, 2001). This research, however, highlights that behavioral considerations, in particular joint action expectations, are also relevant in establishing effective supply chain relationships in the context of innovation performance.

Firms have the choice to go it alone (make), outsource completely (buy), or engage in a partnership (ally) in pursing innovation initiatives. Transaction cost economics broaches the question of how firms define their boundaries and associated governance structures in terms of the make/buy/ally decision (Coase, 1937; Williamson, 1979). The choice between these options is largely dependent on the respective costs and benefits a firm could derive by pursuing each of the three options. The ability (or inability) a firm has to effectively manage an ally relationship has a critical bearing on the strategic options that firm can pursue. Lack of ability to manage interfirm relationships effectively renders the ally option unavailable and limits the strategic toolbox available to that firm. Worse yet, firms could overestimate their ability to pursue an ally option, invest time and resources accordingly to only come up empty handed.

Research has reported that approximately 50% of alliances do not achieve desired outcomes (Parise & Casher, 2003; Park & Ungson, 2001). This high incidence rate of failed alliances is a testament to the prevalence of this strategic fallacy. Alternately, competence in managing interfirm ally relationships can expand the strategic toolbox available to a firm and provide that firm with options and strategic avenues not easily accessible by its competitors, thus creating a potential competitive advantage. This research focuses on the ally scenario where a firm engages an external business partner that is directly associated with the focal firm in the supply chain (Williamson, 2008). The research question driving this inquiry is: what role does AJAE play in achieving innovation performance within supply chain partnerships (ally)?

Interoperability was previously introduced as a construct to describe the ability of entities to effectively interface with each other over time. Originally explored in both military and IT literature, interoperability is extended in this dissertation to the field of supply chain management in order to examine the research question. This dissertation categorizes supply chain

interoperability into three categories: resource interoperability, process interoperability and behavioral interoperability, and hypothesizes that managing AJAE is both relevant to establishing behavioral interoperability within supply chain relationships and impacts innovation performance.

In this third essay of the dissertation, I empirically evaluate the hypothesized model, as presented at the end of Essay Two, using a secondary data set collected on 67 powertrain product R&D development projects. The model posits that all three categories of interoperability are relevant to innovation performance and that behavioral interoperability mediates the influence of resource and process interoperability on innovation performance. Using structural equation modeling, we find statistical support for the hypothesis that behavioral interoperability (as operationalized by AJAE gap size and clarity) has a statistically significant positive relationship with innovation performance. In particular, smaller sized gaps in AJAE and higher levels of AJAE clarity are both associated with increased levels of innovation performance.

Clarity, a construct not originally considered in Essay One, emerged in Essay Two as a relevant dimension of AJAE; it is confirmed in this study as having a statistical relationship with innovation performance. While the analysis in this Essay does not confirm the hypothesized mediating relationship of behavioral interoperability, it does open the possibility that these distinct dimensions of interoperability may not be as interdependent as originally hypothesized. This finding is significant in that it suggest that firms can invest in behavioral interoperability independent of the state of the other dimensions of interoperability. The analysis also finds that resource interoperability has a statistically significant positive relationship with behavioral interoperability.

These results are relevant to firms and managers seeking to maximize the innovation potential that resides within their supply chain. Analysis of the secondary data set supports the argument that firms that invest time and effort in establishing clarity of expectations by explicating the costs and benefits of joint action from both their own point of view and from that of the partner firm can achieve a higher level of interoperability and therefore an improved level innovation performance as compared to those firms that don't. These findings support the notion that effective supply chain management for innovation requires that firms invest in synchronizing not only resources and processes, but also expectations. Doing so enhances the feasibility of the ally option and expands the strategic innovation toolbox available to a firm.

This research contributes to both the interfirm relationship literature and the innovation literature. While much of the current R&D literature explores innovation performance at the firm level (Calantone, Harmancioglu, & Droge, 2010), this dissertation approaches innovation performance at the interfirm supply chain dyad level. Given the significant pressures that exist in the automotive industry to improve fuel economy, the use of powertrain-related R&D project data provides a salient context from which these hypotheses can be tested. Additionally, the trend of R&D intensity shifting from OEM's to Tier 1 suppliers increases the impetus to understand effective interfirm innovation performance management.

The following section expands on the theoretical construct of interoperability and its relation with AJAE. First, a summary of the hypothesized model developed in the first two essays is presented. Then the statistical analysis of the secondary data set used for this study is summarized. Finally, this essay concludes with a results discussion section and highlights both limitations to the study and opportunities for extension.

3.2 Interoperability

Firms that engage in innovation have a strategic choice to keep the work in-house, leveraging their own resources, or to leverage the resources of external entities in what is sometimes called open innovation (Chesbrough, 2003). These external sources can be single or multiple entities and can be found as either existing members of the supply chain, or as non-supply chain related entities such as a universities or government agencies. Our study centers on the configuration of two interdependent partner firms (buyer-supplier dyad) that share a common supply chain for which the innovation is intended. Understanding the nature of how such firms can successfully position themselves to interact in order to achieve the desired innovation outcomes is of critical importance to managers. Interoperability is an existing construct already used in other fields of study (military and IT) that addresses the effectiveness of how interdependent entities prepare themselves to successfully interact over time (Ford, Colombi, Jacques, & Graham, 2009; LaVean, 1980; Otjacques, Hitzelberger, & Fernand, 2007). We adopt this concept as a starting point and extend it to the field of supply chain management. To the best of our knowledge, this is the first study to extend the concept of interoperability to predict innovative outcomes in buyer-supplier supply chain relationships.

3.2.1 Interoperability in military and IT fields of research

The discussion on interoperability first emerged in the military after experiencing coordination failures between branches of the armed services during the Vietnam War (Ford et al., 2007; LaVean, 1980). The discussion continued over the ensuing decades as a key topic of planning and strategy in military organizations around the world (Ford et al., 2009). While numerous definitions for interoperability emerged over this time, the most common definition that researchers converged on defines interoperability as: “The ability of systems, units, or forces

to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together" (Ford et al., 2007, pg.6). In military applications, interoperability is concerned with enabling different groups (e.g. branches of the military) to effectively combine efforts in achieving specific military objectives. Such efforts require a focus on both the resources (physical systems) and the procedures used to integrate those resources. In fact, these two dimensions, resources and processes are a common theme across much of the extant literature on interoperability. In recent military research, interoperability is operationalized using a measure of sameness across both friendly and hostile interactions (Ford et al., 2009). This concept of sameness underscores the importance of considering the matching qualities of the respective sides' systems and processes.

Interoperability subsequently emerged in the IT literature where the ability for commercial IT systems across firms to 'provide services to and accept services from other systems' is a fundamental determinant of success (Mouzakitis, Sourouni, & Askounis, 2009; Otjacques et al., 2007). The establishment of clearly defined and adopted communication protocols such as Transmission Control Protocol (TCP), Internet Protocol (IP) and HypterText Markup Language (HTML) has been instrumental in the establishment of the Internet as an agent of IT interoperability and the ensuing fundamental changes that emerged from a global society linked by the Internet (Friedman, 2005). This example alone underscores the transformative power that resides within the construct of interoperability.

IT interoperability emerges when both resource and process dimensions are purposefully designed and implemented to allow two or more firms to interact effectively from an information technology standpoint. Again, the dimensions of both resources and processes are instrumental in establishing IT interoperability. The resource dimension includes computing and

communication hardware and software while the process dimension relates to business processes needed to allow those hardware and software systems to interact with the systems of other entities. Not only must firms use compatible files and software to exchange electronic data, but they must also know when to send what information and how that information needs to be used for decision-making.

3.2.2 Interoperability in supply chain management

Supply chain management also is concerned with effectively managing resources and processes across entity boundaries in order to achieve operational success (Frohlich & Westbrook, 2001). IT interoperability plays a critical role in establishing interoperability across firms in the supply chain (communication, scheduling and tracking systems) (Mouzakitis et al., 2009). However IT interoperability alone is not sufficient to ensure that parts and data arrive at the right place, at the right time and at the right price. Effective operational integration with supply chain partners requires the interoperability of other resource categories including transportation equipment and infrastructure, packaging design and material, testing equipment and compatible part interface designs. With respect to the process dimension of interoperability, supply chain management needs to synchronize long-term capacity planning, sales forecasting, production scheduling, materials requirement planning, supply chain risk contingency planning, and new product development (NPD) initiatives. Achieving resource and process interoperability, even amongst a buyer-supplier dyad in a supply chain, is no small feat!

The importance of the resource and process dimensions is further highlighted by Frohlic and Westbrook (2001), who operationalized supply chain integration with eight key activities (Frohlich & Westbrook, 2001). Referring to the listed integration activities, Frohlic and Westbrook (2001, p. 197) asked informants to rate “to what extent do you organizationally

integrate activities with your suppliers and customers?" The eight factors are listed below in Table 1 along with the relevant interoperability dimension. Upon inspection of Table 1, it can be seen that these eight factors reflect both resource and process interoperability. The resource interoperability dimension is reflected in the activities of integrating joint EDI access/networks, packaging customization, using common logistical equipment/containers and common third-party logistics services; while the process dimension is reflected in the activities of integrating shared access to planning systems, sharing production plans, integrating knowledge of inventory mix/levels and integrating delivery frequencies.

Table 3.1: Supply Chain Interoperability

Frohlic and Westbrook (2001) Integration Activity	Relevant Interoperabiity Dimension
Access to planning systems	Process
Sharing production plans	Process
Joint EDI access/networks	Resource
Knowledge of inventory mix/levels	Process
Packaging customization	Resource
Delivery frequencies	Process
Common logistical equipment/containers	Resource
Common use of third-party logistics	Resource

First, we note that integration and interoperability are distinct, yet related constructs. Interoperability refers to the *ability* of systems to interact with other systems (Ford et al., 2007, pg.6), while integration, however, refers to the extent that firms actually coordinate with each other in order to act as a single company (Frohlich & Westbrook, 2001, pg. 187). Two firms that have established a high degree of interoperability simply have the potential to achieve a high level of integration; in essence interoperability refers to the latent integration capacity of two systems. Firms that invest in integration, it can be argued, should first address interoperability before they engage in integration activities; otherwise, those integration efforts may not yield the desired results. As such, the categories relevant to interoperability are also relevant to integration.

The activities explored in Frohlic and Westbrook (2001) relate mostly to a product manufacturing setting where the product has already launched and is in a state of ongoing production. In the context of the Supply Chain Operations Reference (SCOR®) model (Council,

2008), a widely used framework that organizes key supply chain activities (Zhou, Benton, Schilling, & Milligan, 2011), the Frohlic and Westbrook (2001) activities relate mostly to the "make" and "deliver" categories. Yet, effective supply chain management also calls for interfirm participation in the "source" and "plan" categories, both of which are not addressed by Frohlic and Westbrook (2001).

If the interfirm relationship is strategically limited to only an operational context, then the Frohlic and Westbrook (2001) framework may be sufficient. However, if the context of the interfirm relationship extends into the strategic realm of interfirm joint action involving new product development, then a richer model of interoperability is needed that accounts for the complex *human* interactions involved in the ideation and problem-solving activities involved in the work of innovation (Mohr & Spekman, 1994). Behavioral interoperability, we posit, is a third interoperability dimension that should be considered in establishing a more complete model of the effective supply chain interoperability needed to achieve innovation performance.

The question that then arises is 'what entails behavioral interoperability'? In other words, what behavioral aspects of the interfirm relationship either enhance or hinder performance? Are there basic beliefs and norms of doing business that, when matched together across two firms, facilitate the efficient and effective flow of ideas, information and solutions? Behavioral interoperability may in fact require the blending of a broad set of beliefs and norms as opposed to any single dimension. Research already exists regarding specific behavioral aspects of B2B relationships that can be synthesized and built upon in order to investigate the question of 'what entails behavioral interoperability'. These potential areas of research are listed in Table 2.

Table 3.2: Research Streams Potentially Related to Interoperability

Research Streams	Citation(s)
Shared understanding of procedural and distributive justice	(Griffith, Harvey, & Lusch, 2006; Hofer, Knemeyer, & Murphy, 2012)
Shared vision of the desired outcomes of the relationship	(Melnyk, Davis, Spekman, & Sandor, 2010)
Financial transparency in the relationship	(Lipparini, Lorenzoni, & Ferriani, 2014)
Corporate culture	(Ettlie, 2007; Oliver, 1997; Schein, 1985)
Risk profile	(Lee & Johnson, 2010)
Trust	(Fawcett, Jones, & Fawcett, 2012; Moldoveanu & Baum, 2011)
Joint action	(Gulati & Sytch, 2007; Heide & John, 1990)

Each of the items listed above merits extensive discussion and research in the context of interfirm relations and may be considered as potential indicators of behavioral interoperability as a reflective construct. However, for this study we narrow our focus to that of the final item: the role of joint action expectations and its relation to innovation performance.

3.3 Hypothesized model

Essay One of this dissertation established a theoretical model for understanding how joint action expectations emerge in interfirm relationships given the costs and benefits associated with that joint action. Since each firm brings with it a unique history of past investments, resources and capabilities, it is likely that those firms have different marginal cost and benefit curves associated with various levels of joint action within the partnership. This is likely to result in two differing optimal levels of joint action for the two firms thus leading to asymmetrical joint action expectations (AJAE). The distance between the respective desired levels of joint action

across two firms is labeled as the AJAE *gap size*. Essay One posited that AJAE gap size is relevant to predicting innovation performance in interfirm NPD projects.

Essay Two confirmed the existence and relevance of AJAE gap size in the context of six case studies of NPD projects involving a buyer-supplier relationship. In addition to AJAE gap size, the case studies also revealed the construct of *clarity* as relevant to understanding AJAE. In short, some cases exhibited a higher level of clarity of joint action expectations as compared to others. The firms involved with higher levels of clarity appeared to understand not only their own company's costs and benefits associated with joint action, but they also sought to understand the partner firm's costs and benefits as well, thus raising an awareness of the existence of AJAE in the relationship. Partnerships where clarity was evident exhibited higher levels of performance as opposed to those that did not. We place AJAE in the broader context of behavioral interoperability and hypothesize that AJAE gap size and AJAE gap clarity are both reflective indicators of the broader behavioral interoperability construct.

HYPOTHESIS 1: Both AJAE gap size and AJAE gap clarity are reflective indicators of the interfirm behavioral interoperability construct

As reflective indicators of behavioral interoperability, we posit that AJAE gap size will be inversely related to performance. In other words, smaller gap size is expected to correlate with higher innovation performance. AJAE gap clarity, however, is expected to correlate directly with innovation performance. Given that these two measures are reflective indicators of behavioral interoperability, we anticipate that higher levels of behavioral interoperability will be positively related to improved innovation performance.

Buyer-supplier partnerships that engage in joint NPD initiatives take their business relationship to a higher level of human interaction as compared to an operationally-focused relationship where make and deliver are the sole focus of activity. Operational activities generally focus on the effective and efficient production and delivery of goods and services, where roles, responsibilities and the sharing of rents are contractually defined. Joint NPD initiatives, however, require numerous additional problem-solving activities that are not so readily anticipated and therefore not contractually defined. Navigating successfully through this oft times ambiguous process requires a higher degree of assumptions and trust regarding the roles, responsibilities and behavior of the other partner firm. Partner firms that establish higher levels of behavioral interoperability are those that have aligned assumptions and behavioral norms that facilitate effective and efficient problem solving so that the supply chain can offer products and services that satisfy customer needs profitably.

HYPOTHESIS 2: Interfirm behavioral interoperability is significantly and directly associated with innovation performance. (higher levels of behavioral interoperability are directly associated with higher levels of innovation performance)

Resource interoperability is achieved when the resources of both firms enable those firms to successfully interact. In the absence of resource interoperability, there is less likelihood that a supply chain partnership can generate rents sufficient to justify the relationship. The relational view of the firm (Dyer & Singh, 1998), a theory related to the resource-based view of the firm (Barney, 1991; Wernerfelt, 1984), argues that supply chain partners can jointly create or manage rent-generating resources across firm boundaries thus creating an interorganizational competitive

advantage. We posit that resource interoperability therefore has a positive impact on interfirm innovation performance.

HYPOTHESIS 3: Interfirm resource interoperability is significantly and directly associated with innovation performance (higher levels of resource interoperability are directly associated with higher levels of innovation performance)

Firms that invest in interoperable resources have a foundation on which more complex interactions can take place. As stated previously, behavioral considerations become a more prominent determinant of success as complexity of interactions increase. We therefore postulate that interfirm relationships that share interoperable resources are also more likely to share interoperable behavioral norms as well.

HYPOTHESIS 4: Interfirm resource interoperability is significantly and directly associated with behavioral interoperability (higher levels of resource interoperability are directly associated with higher levels of behavioral interoperability)

Process interoperability reflects the ability for interfirm relationships to successfully integrate processes across firm boundaries. Prior research has supported the premise that interfirm relations that so do, generally achieve improved performance (Das & Narasimhan, 2001; Das et al., 2006; Perols, Zimmermann, & Kortmann, 2013) including improved innovation performance (Perols et al., 2013). We therefore hypothesize that increased process interoperability will be associated with increased levels of innovation performance.

HYPOTHESIS 5: Interfirm process interoperability is significantly and directly associated with innovation performance (higher levels of process interoperability are directly associated with higher levels of innovation performance)

In a similar manner to firms with higher levels of resource interoperability, firms that have a higher level of process interoperability also have a stronger foundation upon which more complex interactions can build upon. Firms that achieve higher levels of process interoperability can focus further relationship enhancing initiatives on behavioral dimensions of the relationship, rather than focusing on operational short falls.

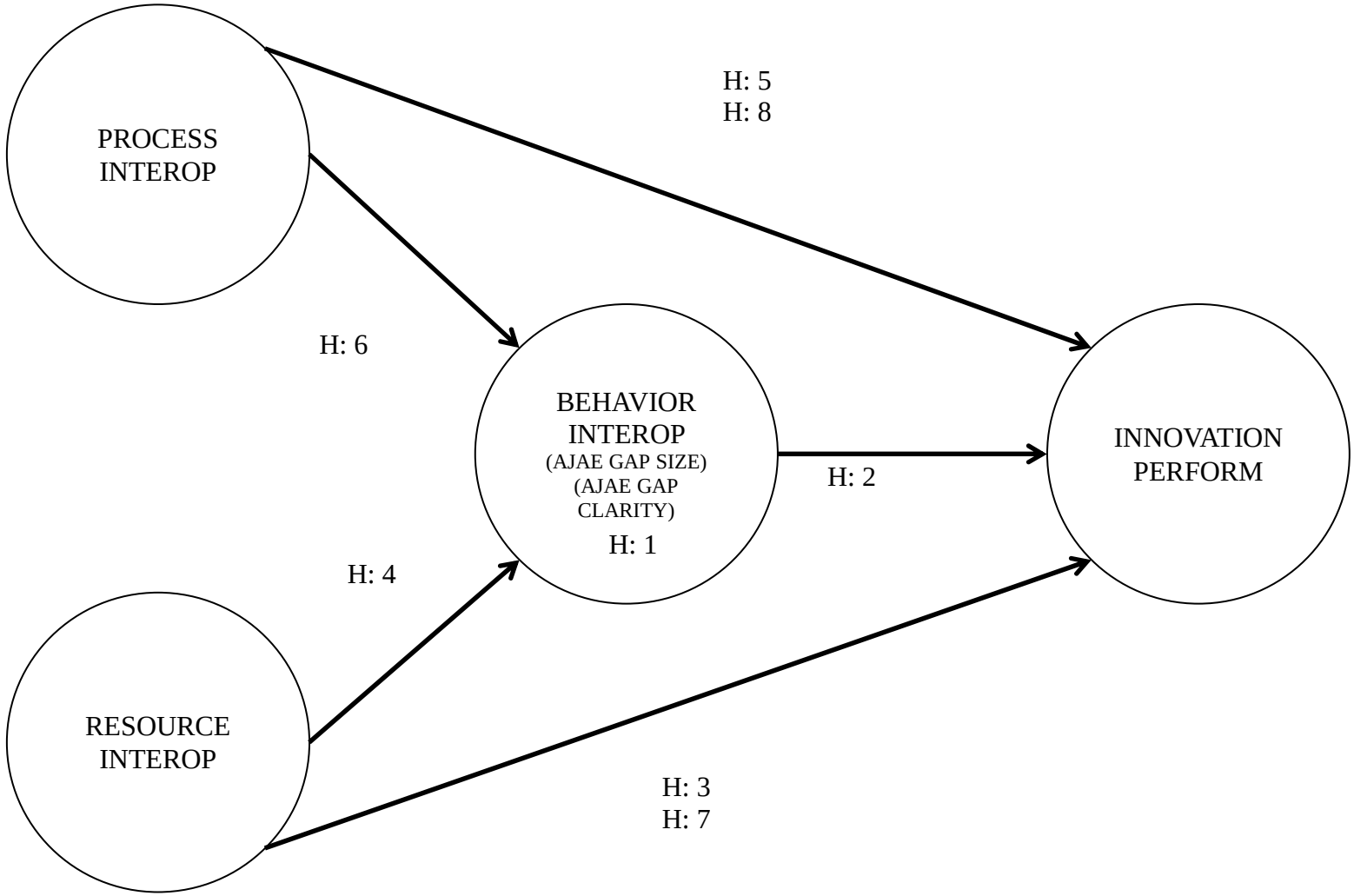
HYPOTHESIS 6: Interfirm process interoperability is significantly and directly associated with behavioral interoperability (higher levels of process interoperability are directly associated with higher levels of behavioral interoperability)

Given the role that human interaction has in successful problem solving initiatives, we anticipate that behavioral interoperability holds the key to achieving interfirm innovation performance. In consequence, we anticipate that the positive relationship that both process and resource interoperability have with improved innovation performance will be mediated by behavioral interoperability.

HYPOTHESIS 7: Interfirm behavioral interoperability significantly mediates the relationship between resource interoperability and innovation performance.

HYPOTHESIS 8: Interfirm behavioral interoperability significantly mediates the relationship between process interoperability and innovation performance

Figure 3.1: Hypothesized Model



The option to co-develop with a supply chain partner (ally) introduces numerous complicating factors at the boundaries of the firm that would not be encountered in either the make or buy governance structures (Coase, 1937; Geyskens, Steenkamp, & Kumar, 2006; Williamson, 1979). The hypothesized model categorizes these relational complexities into the groupings of resources, processes and behavior. The model presented herein offers a possible explanation for how such interfirm relationships can maximize the potential of working together, thus enabling the ally option as a feasible and valuable strategic tool for supply chain managers.

3.4 Research methodology and data analysis

The US automotive industry is undergoing significant transformations in powertrain technology due to the simultaneous pressures of increasing global competition, improving alternative fuels technology, and increasing governmental efficiency standards (Berggren, Magnusson, & Sushandoyo, 2009). These converging pressures result in a unique business environment where automotive companies must constantly engage in innovation initiatives. Given limited resources, OEM's increasingly rely on tier one suppliers for innovation. Evidence of this exists in the shifting locus of innovation (as measured by R&D intensity) from OEMs to tier one suppliers in the automotive industry (Rothenberg & Ettlie, 2011).

These factors make innovation in powertrain technologies a salient context to test the theoretical model presented in this essay. Dr. John Ettlie, co-chair of this dissertation, is also a member of a separate research team that conducted a survey of R&D powertrain projects. Dr. Ettlie provided access to a non-published portion of this data set for the purpose of this present study. This access was provided given the relevance of the non-published portion to the theoretical interoperability constructs presented in the prior section of this essay.

3.4.1 CB-SEM (with bootstrapping)

Interoperability cannot be directly measured. We therefore must rely on reflective measures that can indicate the presence of interoperability. Testing the research hypotheses therefore requires a methodology that enables the simultaneous analyses of multiple constructs as measured using reflective indicators. Covariance-based structural equation modeling (CB-SEM) is a methodology that enables this type of analysis and is therefore used for this study. This methodology is appropriate for two reasons. First, our model comprises numerous latent constructs that are neither directly observable nor measurable. Instead, we use observable and measureable reflective indicators that allow us to test the relationship between the latent constructs in our model. CB-SEM allows for such a situation. Second, CB-SEM allows for testing competing models where the fit indices of each model can be compared. This feature is necessary for testing the hypothesized mediating relationships according to the Baron and Kenny (1986) mediation test guidelines. The bootstrap analysis allows testing the statistical power of the data set.

Partial least squares structural equation modeling (PLS-SEM) is another competing methodology that was also considered for this study. While PLS-SEM is often used when sample sizes are small, as is the case in this study, the methodology does not provide the needed fit indices required to adequately test our hypotheses, in particular the mediation tests. Rather, PLS-SEM requires a high degree of theoretical confidence in the structure of the hypothesized model and therefore focuses its explanatory power in the strength and statistical significance of the paths in the model. Given the nascent nature of the theories presented in this dissertation and the necessary importance of the fit indices needed to assess our model, CB-SEM becomes the preferred approach for this study.

3.4.2 Secondary data set

The secondary data set used in this analysis comes from a survey conducted by a separate research team on powertrain-related development projects in the US automotive industry. The data was collected in late 2010 and 2011 and was part of a larger study comparing the U.S. and China across numerous industries.

The powertrain portion of the study was chosen since it focused on the interfirm innovation initiatives that are of interest to our research question. Further, only the U.S. portion of the data was analyzed since, according to the original research team, the China portion of the data suffered from a lack of validity given the unwillingness of the informants to elaborate on open-ended questions. Additionally, the uniformity of answers across items and informants added to further validity concerns regarding the China data. The U.S. portion of the study, however, did not suffer from these issues[2].

The survey items included in the powertrain study combine both five-point Likert scale items and open-ended questions to gather data at both the company level and at the project level. Since our research focuses on the interfirm relationship and its impact on innovation performance at the project level, we narrow our focus of the data to just those survey items where the specific interfirm relationship and project are the units of analysis. In all, the data set described 76 unique powertrain-related projects in the automobile industry.

Informants of the study included engineering and R&D managers, directors and a few vice presidents. While the original data set included measures for 50 items, 11 of these items were identified as relevant to our hypothesized model and as potential reflective indicators for the

[2] The University of Michigan Transportation Research Institute – Automotive Analysis Division, led collection of the powertrain data set and the survey was partially funded by NSF grant number 0725056.

constructs of innovation performance, resource interoperability, process interoperability and behavioral interoperability.

The sample size in this study of n=76 is not ideal for testing our model. An oft-cited guideline for conducting CB-SEM is a minimum of n=10 for every measured variable in the model (Nunnally, Bernstein, & Berge, 1967). Anderson and Gerbing (1988) reported unbiased estimates at sample sizes as low as n=50, however, recommended a sample size of n=150 or more in order to avoid large error estimates. Bentler and Chou (1987) reported that the ratio of sample size to free parameters could be as low as 5:1, but that higher sample sizes are recommended to achieve trustworthy significance testing of the estimated parameters. The sample size of this study is above the minimum guidelines reported by both (Bentler & Chou, 1987) and Anderson and Gerbing (1988) yet is low enough to cause concern regarding the statistical power of any results. Bootstrapping can be used to help assess statistical power and is therefore applied to this study as a post-test to the CB-SEM analysis (Mooney & Duval, 1993).

3.4.3 Operationalizing the constructs

Given the nature of this secondary data analysis, the original survey was not specifically designed with the purpose of testing interoperability constructs, yet sufficient scale items were identified that were relevant to the constructs of our hypothesized model. This enables us to test our hypothesis using this existing data set in an industry (automotive) where innovation in powertrain technologies has become a de facto differentiator in competitive advantage. Effective buyer-supplier relationship management in this setting is key in determining success, especially since the locus of innovation, as measured by R&D intensity, has systemically been shifting from OEMs to tier-one suppliers (Rothenberg & Ettlie, 2011). As a result, we expect this data set to be highly relevant in the context of our research question.

We operationalize the constructs of our model using these data and conduct a confirmatory factor analysis before proceeding to test the hypothesized path model. While parts of the original data set have been used in other research currently under review for publication, the items used to operationalize the three dimensions of interoperability in this study are not part of any other study and are newly considered in this research. The only items used in this study that have also been used in other research are the innovation performance items, which are the dependent variables in our study.

Behavioral interoperability is operationalized using coded qualitative responses from the survey. Findings from the case study portion of this dissertation (Essay Two) were initially shared with members of the powertrain study research team and also presented at the 2013 Decision Sciences Institute conference. In particular, the relevance of both AJAE gap size and AJAE gap clarity as measures of behavioral interoperability were highlighted as key emerging topics. The powertrain study research team subsequently coded all open-ended responses from the interviews for these two concepts and made their coded results available to our current study for this dissertation. Inter rater reliability correlation scores for the coding of AJAE gap size and AJAE gap clarity were reported as .932 and .827, respectively. We expect that these two measures be negatively correlated to each other and that both are appropriate indicators of behavioral interoperability. Smaller gap size reflects increased behavior interoperability while higher levels of clarity reflect increased behavior interoperability. This will be assessed in the construct reliability scores obtained in analysis of the measurement model.

Process interoperability is operationalized with three items from the survey: 1) difficulty of coordinating the development of the project with customers, 2) difficulty of coordinating the development of the project with suppliers and 3) sophistication of project management tools and

methods used to manage the project. We expect relationships that are identified as more difficult to coordinate to be indicative of higher levels of process interoperability. Difficulty to coordinate is a sign that much effort (investment) is being placed into managing the project. As a result of the high level of effort, we expect there to be an increased level of process interoperability. Similarly, we expect those projects using more complex management tools and methods to be indicative of higher levels of process interoperability. If a project has a higher level of process interoperability, then it can be argued that more complex management tools are needed to ensure an effective and consistent procedural interface between the two firms.

Resource interoperability is operationalized with three items from the survey: 1) the level of company resources mobilized for the project, 2) how often alliances and partnerships are used for external technology networking and 3) how often joint ventures are used for external technology networking. Resource interoperability is more likely to exist in the presence of resource munificence as opposed to an environment of resource scarcity. Similarly, a company's propensity for using alliances, partnerships and joint ventures could indicate a corresponding level of maturity in establishing interfirm linkages to share rent-generating resources across firm boundaries (Dyer & Singh, 1998).

Our unit of analysis is the interfirm new product development R&D project. The survey includes three items relevant to innovation performance at the project level: 1) prospect of overall success (technical and commercial) for the project, 2) relative importance of the project to the company and 3) belief that the technological solution at the core of the project will remain as the dominant approach in the next five years. Successful innovation performance not only meets the financial and technical objectives of the new product development project, but it does so in a manner that is both impactful at the company level and has the prospects of generating

rents for a prolonged period of time. These three measures therefore capture the essence of innovation performance at the project level.

As mentioned previously, all measures used for this study have not been used in any other study with the exception of 'prospects for project success', one of three measures used as reflective indicators of our dependent variable, innovation performance. The research team that originally collected the data validated this measure using a three-step approach. I quote with permission a direct communication received by Dr. John Ettlie regarding this validation:

> First we predicted that the stage of the project and the odds of success being known would be correlated, so we correlated project phase (early=1, middle =2, or late phase=3) with prospects of success. For the U.S. data, we can report significant results in the predicted direction, r=.334, p=.008, n=63.
>
> Second, we correlated the prospects for success with longitudinal data on revenues of these firms given the assumption that these power train R&D projects were central to their overall technology strategy and that they were central to new vehicle compliance with increasing environmental standards in both countries. Most of these firms launch global cars and trucks, so the impact of environmental regulation is trans-border for the typical case we studied, whether originating in the U.S., China, or Europe (Teece, 2009, p.127). The results for the longitudinal, criterion validation of the dependent variable were very encouraging.
>
> For the U.S. cases, we also can report very significant correlations between what managers estimate for R&D project success and percentage increases in sales resulting after these data were collected. We collected archival revenue data for all of the firms conducting R&D in the U.S., and after eliminating outliers we found the following: the correlations (all using two-tailed tests) between self-reported project success and annual revenue changes are, for revenue changes between 2007 and 2008, r= .334 (p=.095, n=29); for revenue changes between 2007 and 2009, r=.564 (p=.003, n=29); for revenue changes between 2007 and 2010, r=.255 (p=.208, n=26); and for revenue changes between 2008 and 2009, r=.544 (p=.004, n=26). We concluded that the self-reported success levels for these R&D projects were a valid indicator of the true underlying performance of these R&D organizations.
>
> Another normed measure that validates the data is the R&D ratio (R&D investment as a percentage of sales) in the US sample. The average R&D ratio of the firms that participated in the survey is 3.98%, while archival NSF data for this industry has a mean 4% ratio.

3.5 Results

The data analysis looks at both the measurement model and path model separately and in succession (Anderson & Gerbing, 1988). Following this two-step approach, a bootstrapping analysis is conducted to assess the statistical power of the results (Mooney & Duval, 1993). Given the importance of the data normality assumption, we first begin with a data properties analysis and then proceed to the SEM analysis.

3.5.1 Data properties

The data was first analyzed for normality. Skewness, kurtosis and distributional pareto charts are reported in the appendix. A ladders-of-power analysis using chi square-probabilities to maximize the likelihood that a given sample is representative of a normal distribution resulted in five transformation recommendations. The first three were square transformations for the three innovation performance variables. The fourth was a log transformation of the clarity measure, while the fifth was a square root transformation of the management tools sophistication measure. All five transformations were accordingly implemented. The ladders-of-power analyses, including all transformation recommendations and related chi-square values, are also reported in the appendix.

Analysis of the data resulted in the deletion of nine cases where missing data was systematic across multiple measures relevant to this study. This brought our overall sample size to n=67. Analysis of non-related measures of the nine deleted cases revealed no systematic bias in the deleted group. The gap size and gap clarity measures had a higher incidence of missing data as compared to other measures since not all informants provided the in-depth qualitative responses needed to score these measures. As a result, the sample size for gap size was n=35 while for gap clarity was n=39. Again, there was no statistical indication that the informants that did not

provide qualitative responses were different than those that did, thus leading us to assume no bias in non-respondents.

The pairwise covariance matrix is therefore used in the SEM analysis along with maximum likelihood estimators in order to make more full use of all the data set. No imputation of missing data is recommended when using SEM/ML since doing so can bias the results; rather, the use of SEM/ML with a pairwise covariance matrix makes the best use of the available data and is the recommended approach least likely to generate biased results (Peugh & Enders, 2004). The resulting pairwise covariance is reported below:

Table 3.3: Variance/Covariance Matrix

	QQ16	QQ18	QQ19	QQQ9C	QQQ9D	GAP	QQ5SQ	CLARITYL	QQ20SQRT	QQ8SQ
QQ16	0.853									
QQ18	-0.212	0.845								
QQ19	-0.190	0.309	0.747							
QQQ9C	-0.294	0.223	0.198	0.849						
QQQ9D	-0.373	0.127	0.203	0.593	1.382					
GAP	-0.082	0.000	0.074	-0.243	-0.216	1.659				
QQ5SQ	1.300	-1.511	-0.895	-1.614	-1.884	-1.106	29.964			
CLARITYL	0.058	-0.026	-0.061	0.046	0.077	-0.491	-0.076	0.248		
QQ20SQRT	0.001	0.044	0.123	0.075	0.108	-0.020	-0.066	0.010	0.120	
QQ8SQ	0.862	-0.867	-0.792	-2.256	-1.172	-0.414	18.189	0.262	0.076	48.430

3.5.2 Measurement model

Using EQS 6.2 for Windows (Bentler, 2002), a confirmatory factor analysis was conducted to assess the appropriateness of the chosen measures as reflective indicators of the latent constructs in our model. Not only can we test the fit of the measurement model, but results also provide indicators of both reliability and validity. Our initial measurement model included the project's relative importance to the firm (QQ6) as a reflective measure of innovation performance, however this measure did not load well (.355) on the innovation performance construct and was subsequently dropped.

Appropriate fit can be assessed using the comparative fit index (CFI) with desired scores of 0.9 or higher and root mean-square of approximation (RMSEA) with desired scores of .08 or less (Fawcett et al., 2014). The results from the confirmatory factor analysis yielded a CFI of .965 and an RMSEA of .052, both acceptable values. Key model statistics are reported in tables 3 and 4.

Table 3.4: Key Model Statistics

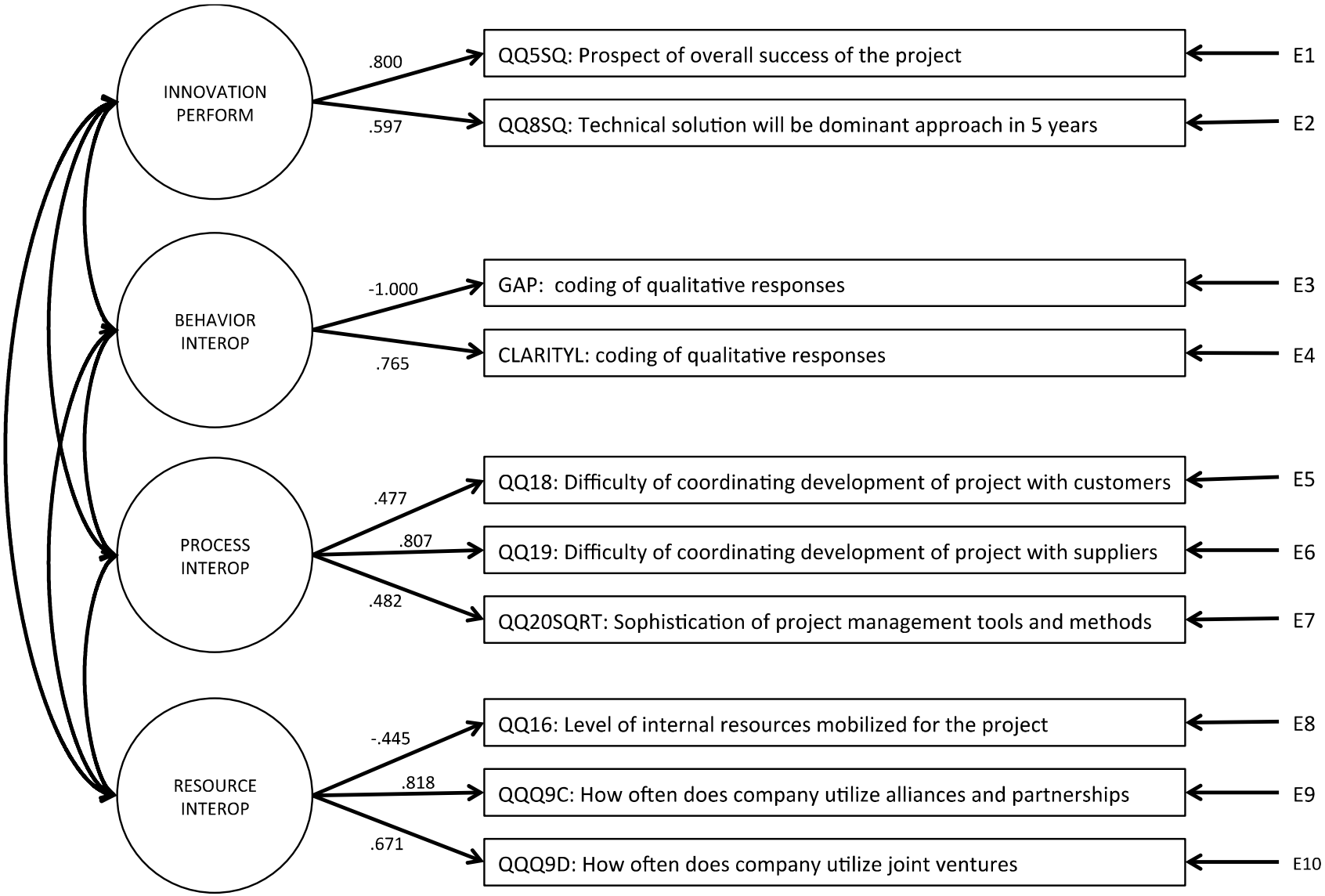
Construct/Item	Mean (SD)	Standardized loadings	Average variance extracted	Composite reliability	Mean shared variance
Innovation Performance			0.465	0.634	0.1395
QQ5SQ: Prospect of overall success of the project	15.5079 (5.4739)	0.800			
QQ8SQ: Technology will be dominant approach in 5 years	16.5909 (6.9592)	0.597			
Behavioral Interoperability			0.946	0.889	0.0247
GAP: Size of gap in JAE	1.4000 (1.2880)	0.765			
CLARITYL: Clarity in JAE	0.9632 (0.4984)	-1.000			
Process Interoperability			0.413	0.628	0.1011
QQ18: Difficulty coordinating project with customers	3.3514 (0.9194)	0.477			
QQ19: Difficulty coordinating project with suppliers	3.1417 (0.8640)	0.807			
QQ20SQRT: Sophisitication of project mgmt tools/methods	1.6074 (0.3458)	0.482			
Resource Interoperability			0.441	0.426	0.1811
QQ16: Level of resources mobilized for the project	2.8333 (0.9236)	-0.445			
QQQ9C: How often company utilize alliances/partnerships	3.1311 (0.9215)	0.818			
QQQ9D: How often does company utilize joint ventures	2.4264 (1.1756)	0.671			

Notes: χ^2(d.f.) = 33.055 (28); CFI = .965; IFI = .969; RSMEA (90% CI) = .052 (.000-.112). All loadings significant at $p < .01$.

Table 3.5: Squared Correlation Matrix - AVE on Diagonal

	PERF	BI	PI	RI
PERF	**0.465**			
BI	0.028	**0.946**		
PI	0.095	0.003	**0.413**	
RI	0.295	0.043	0.205	**0.441**

Figure 3.2: Measurement Model



3.5.2.1 Reliability

Composite reliability scores have a lower cutoff level of .50 (Hair, Hult, Ringle, & Sarstedt, 2014). A higher score of .70 or greater (.60 for exploratory constructs) is generally recommended for establishing internal consistency (Fawcett et al., 2014; Nunnally, 1978). Our study was both exploratory and used secondary data that was not initially designed to measure the constructs of interest in this study. While three of the four constructs exhibited satisfactory composite reliability scores, the fourth (resource interoperability), fell just below the recommended threshold of .50 with a composite reliability of .426. As such, we recommend that a future construct development study be conducted where measures for these constructs can be further developed and refined.

3.5.2.2 Convergent validity

We can assert convergent validity when standardized loadings on the intended construct are greater than .50 and the average variance extracted (AVE) exceeds .50 (Fornell & Larcker, 1981a). In our analysis, the AVE for behavioral interoperability is .946 while the other three AVE values ranged from .413 to .465. Standardized loadings were also near or above .50 (table 3). The lowest standardized loading was -.445. While there is a strong level of convergent validity for behavioral interoperability, the other three constructs have marginal levels of convergent validity that are near the threshold guidelines.

3.5.2.3 Discriminant validity

In order to assert discriminant validity, the mean shared variance should be below .50 (Fornell & Larcker, 1981a, b). Alternatively, the AVE for each construct should be greater than any covariance value with another construct (Fornell & Larcker, 1981a, b). In our analysis, all mean variance values are less than .50. Additionally, AVE values for all constructs are greater

than any single squared correlation value for that construct with the other constructs (table 4). We therefore have support for discriminant validity.

3.5.2.4 Statistical power analysis – bootstrapping

Given the lower sample size of this data set, a bootstrap analysis is conducted to assess the statistical power of our measurement model and underlying data set. Using EQS 6.1 for Windows (Bentler, 2002), bootstrapping conducts an iterative and random sampling of the data set used in this analysis, conducts the SEM analysis for our posited model, and then calculates key fit statistics for each iteration. The key statistics are then averaged across all iterations and reported accordingly. A data set has a high level of statistical power if the bootstrap results are consistent with the SEM results. Our bootstrap analysis randomly takes 67 samples (with replacement) from our dataset of 67 cases and does so for 1000 iterations. Of those 1000 iterations only 815 instances actually converged; the remaining 185 instances did not. The ultimate sample size for the bootstrapping analysis was 815 times 67, or 54,605. While our initial SEM analysis generated a CFI of .965, the bootstrap average over the 815 iterations that converged reported an average CFI of .692. While the initial SEM analysis reported an RMSEA of .052 (.000-.112), the bootstrap analysis reported an average RMSEA of .202 with an average upper bound of .159 and an average lower bound of .243). In both cases the bootstrap result is significantly weaker than the original SEM result. Since the original SEM results report acceptable statistics, we can conclude that our model is a legitimate explanatory model for the data set at hand. Alternatively stated, with high statistical certainty we cannot reject the null hypothesis that the data does fit the model. The weak bootstrap results, however, suggest that the data, not the model, may be a weak link in our analysis. Further replication with a larger sample size is therefore recommended before we can assert statistical power in the results of this study.

3.5.3 Path model

With a measurement model that has acceptable fit, reliability and validity statistics, the analysis next proceeds to testing the hypothesized relationships with a path model analysis. In order to test the posited mediating relationship that behavioral interoperability has on both process and resource interoperability, we take a two-step approach where the first step tests the relationship between both process and resource interoperability and innovation performance with no mediator in the model (figure 3). The second step then introduces behavioral interoperability as the mediating construct while still maintaining direct paths between both process and resource interoperability and innovation performance (figure 4). Evidence of mediation exists if 1) step one reveals a statistically significant relationship between the independent variables (process and resource interoperability) and innovation performance, and 2) the strength of the direct relationship attenuates in the presence of a mediation variable. Full mediation occurs if the direct relationship attenuates to zero while partial mediation occurs when the direct relationship attenuates, yet to a value greater than zero (Baron & Kenny, 1986).

As discussed in Essay One, a mediating rather than a moderating relationship is hypothesized given the critical role that human interaction plays in the actual innovation process. Ultimately, it is humans, not resources or processes that generate the solutions and insights needed to achieve innovation performance. As such the positive influence of both resource and process interoperability are anticipated to flow through behavioral interoperability in assessing the relationship between resource/process interoperability and innovation performance. For this reason, a moderating model is not theoretically justified. Further, any moderation analysis would require a two-sample invariance test (James & Brett, 1984), which would require splitting the

current sample size of n=67 into two groups of n=33 and n=34, a prohibitively small sample size for CB-SEM. This analysis therefore only tests the mediation model.

Results of the mediation analysis reveal that process interoperability has no statistical influence on either behavioral interoperability or innovation performance. Resource interoperability, as predicted, is positively related to behavioral interoperability but is *inversely* related to innovation performance, which is opposite from what was initially hypothesized. Behavioral interoperability, as predicted, is positively related to innovation performance. There is no attenuation of the relationship between resource interoperability and innovation performance when behavioral interoperability is introduced as a mediator, therefore the data does not support a mediating relationship. Both step 1 and step 2 models exhibited acceptable fit statistics with CFI scores of .904 and .913, and RMSEA scores of .084 and .084, respectively.

Figure 3.3: Path Model Step 1 – Mediation Test

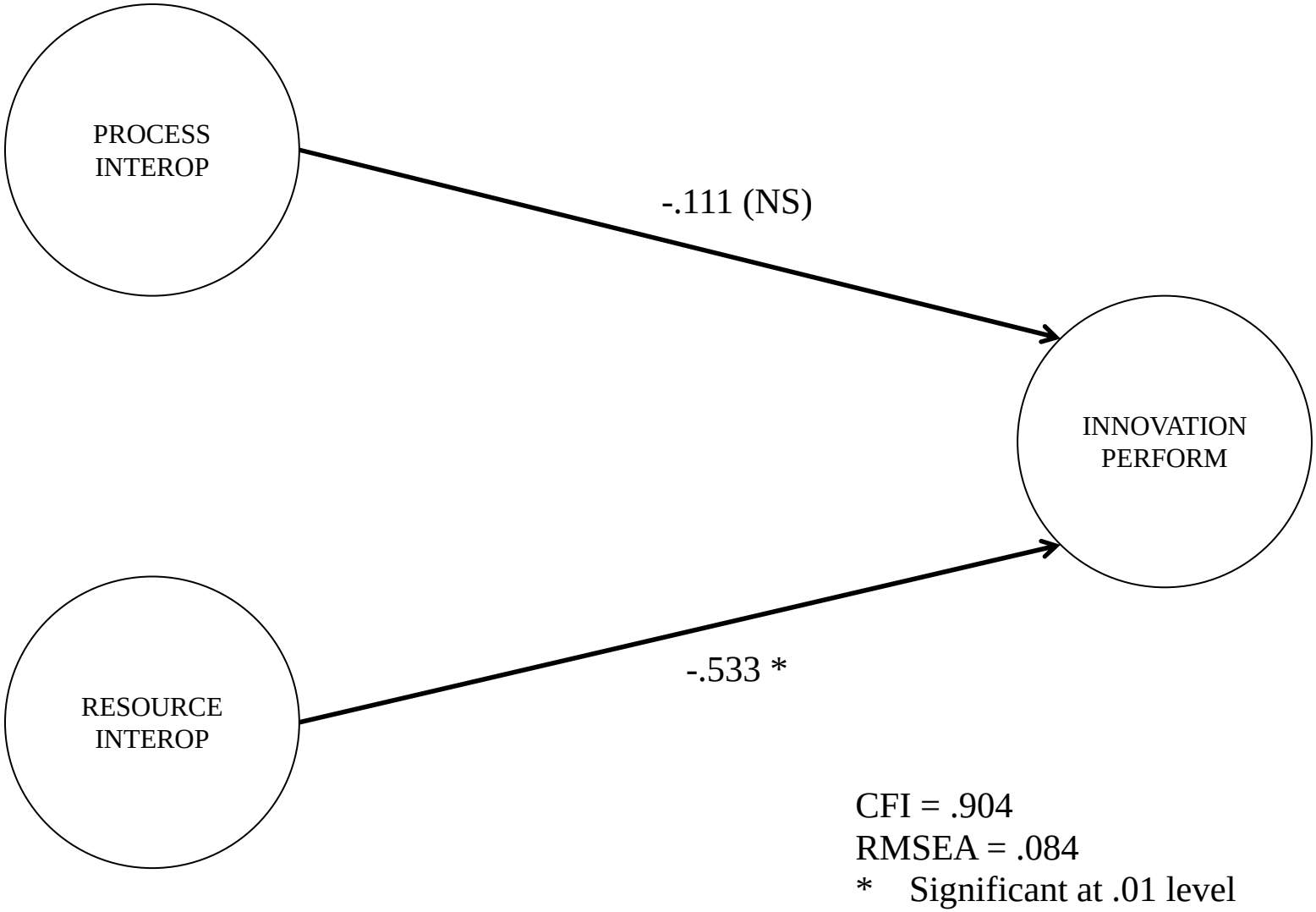
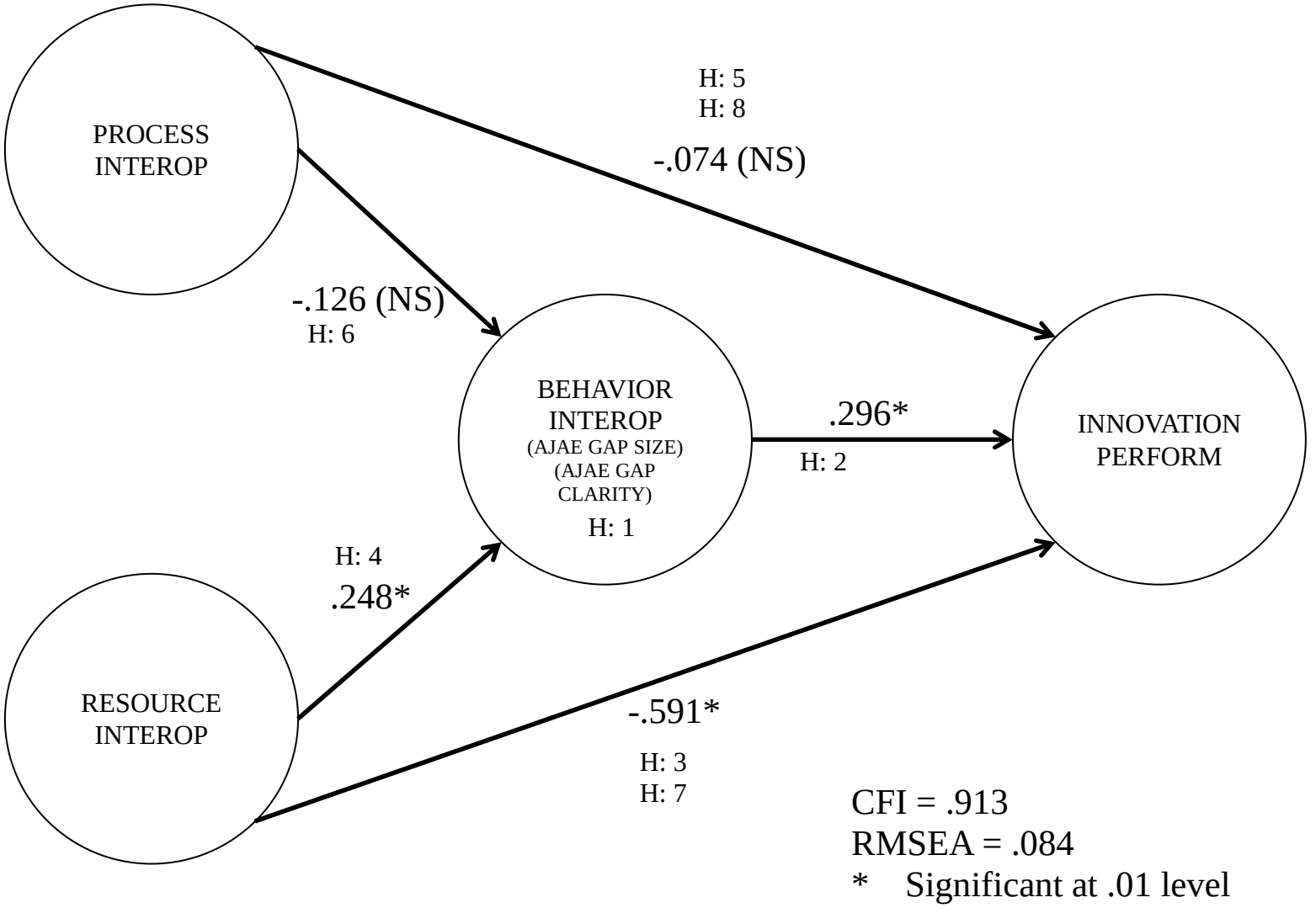


Figure 3.4: Path Model Step 2 –Mediation Test



3.6 Discussion

3.6.1 Results

In summary, three of the eight hypotheses are supported (Table 5). These results suggest that while the overall model may not accurately capture the relationship between the constructs of interoperability, the impact that these constructs have on innovation performance is statistically significant. The following section discusses the results of each hypothesis.

Table 3.6: Hypotheses Overview

H1	Both AJAE gap size and AJAE gap clarity are reflective indicators of the interfirm behavioral interoperability construct	SUPPORTED
H2	Interfirm behavioral interoperability is significantly and directly associated with innovation performance.	SUPPORTED
H3	Interfirm resource interoperability is significantly and directly associated with innovation performance	NOT SUPPORTED
H4	Interfirm resource interoperability is significantly and directly associated with behavioral interoperability	SUPPORTED
H5	Interfirm process interoperability is significantly and directly associated with innovation performance	NOT SUPPORTED
H6	Interfirm process interoperability is significantly and directly associated with behavioral interoperability	NOT SUPPORTED
H7	Interfirm behavioral interoperability significantly mediates the relationship between resource interoperability and innovation performance.	NOT SUPPORTED
H8	Interfirm behavioral interoperability significantly mediates the relationship between process interoperability and innovation performance	NOT SUPPORTED

Analysis of the data set supports our first hypothesis (H:1) that AJAE gap size and AJAE gap clarity are both relevant dimensions of behavioral interoperability. It also supports the second hypothesis (H:2) that behavioral interoperability is positively related to innovation performance. These two findings alone provide new insight into how differing expectations of joint action can influence innovation performance in the context of interfirm new product development projects. Further, they highlight that managing both AJAE gap size and clarity within supply chain partnerships merits inclusion in the innovation discussion.

A counterintuitive and interesting finding of the analysis is that resource interoperability and innovation performance are negatively related (H:3) while resource interoperability and behavioral interoperability are positively related (H:4). Inspection of the factor loadings for the resource interoperability construct in the measurement model reveals that resource munificence is negatively correlated to resource interoperability while utilization of partnerships, alliances

and joint ventures are positively related to resource interoperability. It appears that a scarcity of resources (as opposed to resource munificence) is correlated with a higher incidence of formal external collaboration initiatives. This has a logical basis in that firms that find themselves with limited resources seek external collaboration opportunities where they can leverage the resources of other firms to achieve that which they could not achieve on their own (Dyer & Singh, 1998). A higher level of resource interoperability appears to be evident in these situations. The same scarcity of resources that leads firms to collaborate with external parties appears to also have an adverse impact on innovation performance. If we consider the resource-based view of the firm theory (Barney, 1991; Harmancioglu, Droge, & Calantone, 2009; Wernerfelt, 1984), that a firm can establish a competitive advantage in the marketplace leveraging its resources, then these opposing results are understandable.

Another potential explanation of this counterintuitive finding is that the sample used in this dataset surveyed companies that typically have a long-term relationship with their supply chain partners such that resource interoperability is already established at a high level. Further increases in investment in resources may experience diminishing returns as evidenced by the data. The results of the negative relationship in the analysis may be indicating such a situation.

A third potential explanation is that innovation performance is more likely to be achieved when firms combine a diversity of resources, rather than redundant resources. Sampson (2007), for example, argues that technological diversity can have a positive (yet curvilinear) relationship with innovation performance. The data observed in this dataset may in fact be reflecting this very phenomenon where lower levels of resource interoperability may actually be contributing to higher levels of innovation performance.

Diversity of resources can be considered as both the form of the resource and the criticality of the resources committed to the relationship. If one partner commits their prime resources to the relationship while the other partner does not (and reserves their prime resources for another supply chain partner), then issues in resource interoperability can emerge. This is an area with potential for future study.

Another unexpected finding is that process interoperability has no statistical relationship with either innovation performance (H:5) or behavioral interoperability (H:6). Process interoperability was operationalized with three measures: two of them captured the difficulty of coordinating with customers and supplier, while the third measure captured the sophistication of project management tools and techniques used to manage the project. Give the extant supply chain literature on the benefits of process integration across supply chain partners (Frohlich & Westbrook, 2001; Schoenherr & Swink, 2012) we recommend further construct development research be done to strengthen the measurement of the process interoperability construct.

Finally, our mediation analysis did not yield any results that suggest that behavioral interoperability acts as a mediator. Since process interoperability did not exhibit a direct relationship with innovation performance, the mediation analysis related to this dimension was a moot point (H:8). The resource interoperability dimension, however, was a different case. Step one of the mediation analysis showed that resource interoperability is negatively related to innovation performance with a path loading of -.533 (figure 3). When we introduce behavioral interoperability in step two, the path loading remains relatively unchanged at -.591 (figure 4). No attenuation of the relationship occurs in the presence of behavioral interoperability, therefore a mediation model is not supported (H:7).

3.6.2 Managerial implications

The lack of a mediating relationship, while not aligned with the initial hypothesis, is interesting in and of itself and has important managerial implications. Namely, this suggests that resource interoperability does not influence the ability for behavioral interoperability to positively impact innovation performance. Managers need not wait to establish high levels of resource interoperability before they can reap the benefits of establishing behavioral interoperability. Similarly, managers need not be dissuaded to pursue behavioral interoperability if the relationship currently lacks desired levels of resource interoperability. The benefits achieved by having lower sized gaps in AJAE and higher levels of clarity of those expectations can generate a positive impact on innovation performance independent of the state of other interoperability dimensions. This finding is significant.

The original research question of 'what role does AJAE play in achieving innovation performance within supply chain partnerships (ally)'? is answered with this analysis. Both smaller AJAE gap size and increased levels of AJAE gap clarity are reflective of higher levels of behavioral interoperability. Additionally, higher levels of behavioral interoperability are statistically and directly related with improved innovation performance. In short, understanding and managing AJAE is relevant to achieving improved innovation performance. Therefore firms that can understand and manager AJAE with supply chain partners will have the 'ally' option available as a strategic alternative to the 'make' or 'buy' options.

3.6.3 Limitations

Interoperability needs further construct development given its nascent nature in supply chain literature. The nature of the secondary data set used in this study limits the ability of this research to explore a more full treatment of the construct, yet provides a starting point from

which future research can build upon. Future studies that expand upon relevant indicators and establish more robust levels of reliability of the three dimensions of interoperability will strengthen the foundation for this research stream going forward.

Additionally, studies with larger samples sizes will likewise enhance the statistical power of the hypothesized model and potentially uncover alternative theories that refine that which has been presented in this essay. One inherent limitation in this research stream regarding increased sample size is the guarded nature of firms with respect to sharing both dyadic relationship data and information regarding innovation initiatives. Sharing dyadic relationship data with a third party carries risks for the sharing firm, especially if the data suggests strained relations and the other parties finds out that their partner has shared such data with a third party. Knowledge of this could further strain the relationship.

Innovation initiatives represent a source of competitive advantage and any risk of related information leaking to competitors through third parties renders this a difficult topic to fully explore with firms. There are remedies to these issues, but such remedies often require legal agreements (non-disclosure agreements) and other processes that limit the ability of a researcher to gather large numbers of data points for analyses and often constrain the ability to publish results.

3.6.4 Extensions

Findings in this study provide numerous seeds from which unique yet relevant lines of inquiry can emerge and develop. One potential competing theory could be that behavioral interoperability is endogenous to resource and process interoperability rather than the other way around as is presented in this study. There is much that can be explored with respect to the nature of the relationship between the three dimensions of interoperability. Another alternative

theory is that interoperability is a second-order formative construct with the three dimensions of behavioral, resource and process interoperability acting as the underlying constructs. These alternative models merit discussion, debate and further research.

This study has focused on the role that AJAE have on behavioral interoperability. Earlier in this essay, we listed numerous other potential factors that may also impact behavioral interoperability. These included firms' respective views on distributive/procedural justice, appropriate levels of financial transparency, risk profiles and corporate culture. One aspect of interfirm supply chain partnerships that can profoundly impact these factors is the respective business model (desired outcome) that each firm pursues. Focus on a given business model may require a certain set of priorities and views that are not shared when pursuing other business models. These differences may become apparent when both firms attempt to solve a common problem differently and in ways that suboptimize the desired outcome for the other firm. When two firms engage in a relationship, the match or mismatch of their business models may largely impact the interoperability of those two firms.

This research used the interfirm project as the unit of analysis. Extensions could include expanding the unit of analysis to the business unit level, plant level or company level. The research could also expand the unit of analysis to include a triad supply chain relationship. While the dyad is the basic unit of the supply chain, emerging research suggest that triads may also be a relevant unit of analysis in supply chain research (Choi & Wu, 2009). In addition to considering alternate units of analyses, extensions could also include studying longitudinal or panel data so that the impact of time could be included in the model.

Another area of research that may benefit from the lens of interoperability and AJAE is virtual engineering (Montoya, Massey, Hung, & Crisp, 2009), where firms collaborate

engineering design activities over virtual communication networks and tools. Ettlie and Pavlou (2006) used virtual engineering cases of NPD to test the relationship between dynamic capabilities and NPD performance. Interoperability may be an additional construct to their model that can more fully describe the relationship between dynamic capabilities and performance. On the one hand, interoperability may be a moderating construct while on the other hand interoperability may be endogenous such that dynamic capabilities mediates the relationship between interoperability and performance. In short, there are multiple research extension opportunities for the constructs presented in this essay.

3.7 Conclusion

While the importance of good supplier relations is not new to supply chain literature, exploring the nuanced behavioral elements of good relations remains a fertile area with much research opportunity. In this essay, we have provided empirical support for the theory that AJAE in interfirm relations has a statistically significant relationship with innovation performance. These results argue that managers desiring improved innovation performance in the context of interfirm NPD initiatives should focus on two dimensions related to joint action expectations: 1) the size of the gap in AJAE and 2) clarity of those expectations. Clarity arises when firms take time to understand the costs and benefits associated with various levels of joint action from both their own perspective and that of the partner firm. Further, these two dimensions related to AJAE are related to a firm's ability to establish interoperability with its supply chain partners.

Interoperability is a construct that captures the ability of two entities to provide services to and receive services from each other. Whereas integration and collaboration are measures of actual exchange between two entities, interoperability measures the readiness or capability for those entities to so engage in successful exchanges. Firms that have established certain levels of

interoperability will be able to engage in collaborative and integrative initiatives (ally) both more efficiently and more effectively than those that do not. Those firms that continue to struggle with executing an ally strategy will waste both scarce time and resources and will find themselves at a disadvantage to those firms that are able to successfully pursue an ally strategy.

Our research highlighted three dimensions of interoperability: resource, process and behavioral. Of these three dimensions, only behavioral interoperability was found to have a positive impact on innovation performance in the context of a joint interfirm NPD project. In today's environment of ever-increasing clockspeeds of business, establishing behavioral interoperability thus becomes an important concept that managers should consider when managing supply chain relationships, especially for those seeking to maximize the innovation potential that resides within.

4 Conclusion

Supply chain relationships are becoming increasingly important, especially for those supply chains where deliberate innovation is a critical outcome and a determinant of success. Innovation today increasingly takes place across firm boundaries where improved telecommunication and computing tools have facilitated the shift from a centralized innovation model to one that is more dispersed across the supply chain. The shift in the locus of innovation from automotive OEMs towards their tier one suppliers is an example of this trend (Rothenberg & Ettlie, 2011). Increasingly, the interfirm relationship has become an important unit of analysis with respect to understanding innovation and successful new product development initiatives.

Interoperability is a construct traditionally used both in military and information technology fields of research to describe the ability for different groups to successfully interact (LaVean, 1980). This dissertation extended the construct of interoperability to the field of supply chain management and in particular to the study of interfirm relationships. Three distinct levels of interoperability were proposed: resource interoperability, process interoperability and behavioral interoperability. While much supply chain research traditionally focuses on the factors that support resource and process interoperability, research on the behavioral aspects related to effective supply chain interoperability is still nascent and was the domain for the present research.

This dissertation argued that economic models alone are insufficient to explain differential success in interfirm innovation performance given the complex human interactions involved. Rather, behavioral interoperability need also be considered in tandem with economic models. Asymmetrical joint action expectations (AJAE) is posited as relevant to and indicative of behavioral interoperability. Essay one in this dissertation built upon a traditional economic

analysis, where firms engage in activities as a function of balancing the marginal costs and marginal benefits of those activities. Joint action between interfirm supply chain partners is applied to this analysis where both firms engage in a shared level of joint action, however, bring with them differing marginal cost and benefit curves. As a result, both firms likely experience differing optimal levels of joint action, which therefore can lead to differing expectations regarding the desired level of joint action for the interfirm relationship. Essay one proposed that larger gaps in AJAE represent lower levels of behavioral interoperability while smaller gaps in AJAE represent higher levels. Further, essay one proposed that higher levels of behavioral interoperability, along with higher levels of resource and process interoperability, are all directly related to higher levels of interfirm innovation performance.

Given the nascent nature of research in AJAE, a multi-case field study was conducted to confirm the existence of AJAE and understand its impact on innovation performance. Essay two reported the results of the case study and confirmed both the existence and the relevance of AJAE to innovation performance. Further, essay two revealed that not only is the size of the gap of AJAE important, but so also is the clarity of the expectations related to AJAE. In other words, an important factor related to behavioral interoperability and innovation performance is the understanding that one firm has of not only their own marginal costs and benefits associated with joint action, but also that of the partner firm. As a result, the proposed model was refined to include both AJAE gap size and AJAE clarity as reflective indicators of behavioral interoperability.

Essay three applied structural equation modeling to test the hypothesized model using a secondary dataset of survey responses regarding automotive powertrain R&D projects. Results confirmed the relevance of behavioral interoperability to innovation performance and also

confirmed both AJAE gap size and AJAE clarity as reflective indicators of behavioral interoperability.

This dissertation provides an analytical framework by which other behavioral-related research can be enriched and furthered. Trust-related research, for example, can be applied to the analytical model presented in essay one to understand how increased levels of trust with one or both parties can impact AJAE. Other behavioral-related topics such as risk profiles can also be explored in this context. Interesting questions include what factors can shift the marginal cost and benefit curves associated with joint action and what factors can change the slope of these curves? How do these changes therefore impact the size of the gap in AJAE? When an interfirm relationship is characterized by a large gap in AJAE, how do the firms deal with such gaps? Assuming AJAE clarity is present, do relationships persist despite the gap, do they attempt to close the gap, or do they dissolve the relationship? How do firms close gaps in AJAE and who is able to capture the benefits from so doing? Additionally, are economic rents the only benefits to be negotiated or are there other beneficial rents to be earned, such as learning. It is anticipated that topics such as relational power, citizenship behavior and trust, to name a few, may provide insights into these questions.

Another topic of interest that can extend from this research is a better understanding of the creation, persistence and dissolution of supply chain relationships. Traditional purchasing literature advocates for deep and long-term relationships with one's suppliers. Anecdotal evidence (Babcock, 2011) including Case F in essay two, however, suggest that effective supply chain relationships may not in fact require long-term commitments in order to achieve high levels of relationship quality and performance. Some firms engage in a series of short-term relationships that generate success for both participating firms without the need for the

relationship to be long-term in nature. Applying the theoretical lens of managing AJAE presented in this dissertation may help explain and predict why such relationships can still be successful.

SEM analysis assumes linear relationships between the constructs. An interesting question to investigate in future research would be whether or not the relationship between smaller gaps/greater clarity in AJAE is in fact linear with innovation performance. Alternatively, the relationship could be curvilinear where diminishing returns occur with higher levels of behavioral interoperability.

Another line of inquiry could apply this research to a broader unit of analysis. This dissertation focused on the supply chain dyad. However, in complex projects, innovation could come from multiple tiers of the supply chain. Studying the innovation of entire supply chains as opposed to dyads may provide interesting insights as to how firms can participate in and help create an innovation ecosystem that leads to differential performance.

Another dimension that can be explored is the intent of the relationship entered into. An observation in the case studies that was not elaborated on in Essay Two was the concept of how some firms' primary focus was on the outcome of the project at hand while others firms focused more on the long-term benefit potentially derived from the relationship. In Case D, CTC tolerated a significant gap in AJAE with GBC due to the longevity of the established relationship and the future potential rents to be gained in both the product category being studied and in adjacent product categories provided by GCM to other business units. In short, CTC tolerated the gap due to their focus on the relationship as opposed to the outcome of the project at hand. In Case F, however, the relationship was created for a single project where both parties understood that the relationship would dissolve upon project completion. In that setting, gaps in

AJAE were not tolerated and investments in communication of expectations were made up front. This was done because the relationship had only 'one shot' at achieving the performance needed and extracting the benefits needed to justify investment in creating the relationship to begin with.

Culture (Hofstede, 1984) is another construct that can be introduced in future research of behavioral interoperability and AJAE. Differences in national culture may have an impact on respective marginal cost and benefit curves of partner firms. How dyads close the AJAE gap may also be impacted by culture.

This dissertation has approached optimality as if it were a single point. What if we take a more broad approach and consider a range of AJAE gap size that is acceptable? If so, then where is the tipping point where the size of the asymmetry does in fact matter?

Essay three argued that in the context of transaction cost economics (Williamson, 1979), the ability for a firm to establish behavioral interoperability with a supply chain partner is critical to that firm's ability to consider and implement 'ally' as a feasible governance structure as opposed to the 'make' or 'buy' structures of governance (Geyskens et al., 2006; Williamson, 2008). Absent this ability, the firm will be left with a more limited strategic toolbox. The high incidence rate of alliance failures, reported as high as 50% (Kale & Singh, 2009; Nidumolu et al., 2014; Park & Ungson, 2001), again suggests that economic models alone may not be sufficient to explain differential interfirm innovation performance. The ability of firms to manage AJAE with their supply chain partners was shown in this dissertation to be relevant to both behavioral interoperability and innovation performance. As such, this dissertation presents an important step forward in better understanding how firms can create a supply chain ecosystem where innovation can flourish.

APPENDICES

APPENDIX A: CASE STUDY INTERVIEW PROTOCOL

Figure A.1: Interview protocol

INTERVIEW GUIDE: Interviewing the Buying Firm

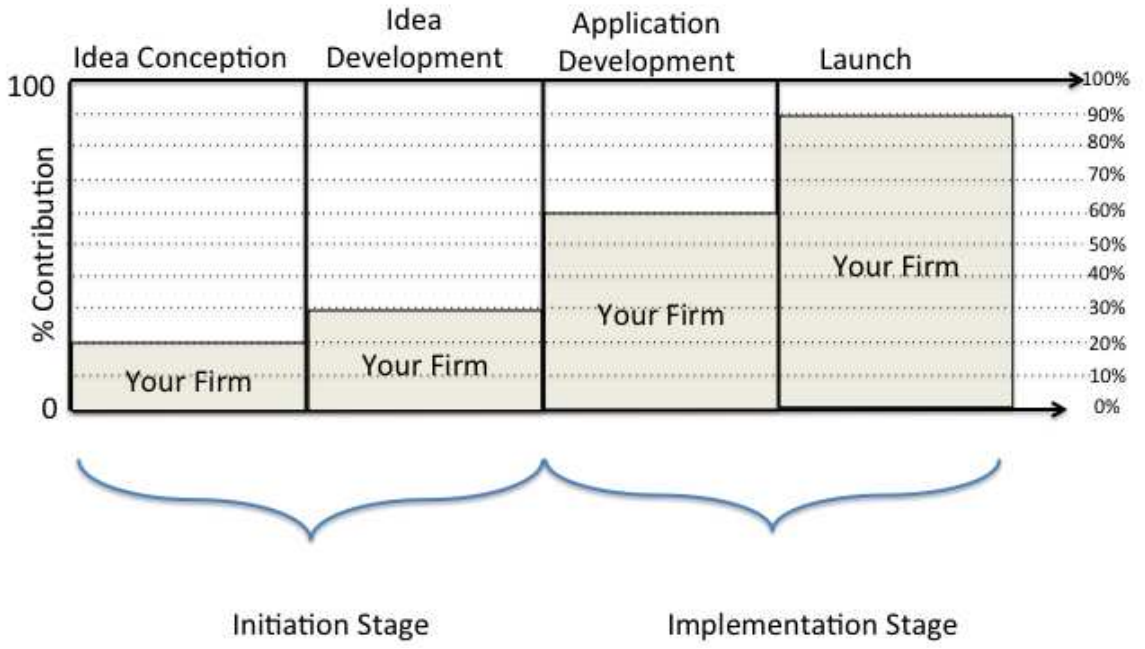
1. For this particular project <RESTATE NAME OF PROJECT> that we are focusing on, who has the ownership of the value-adding intellectual property?

Mostly the Buying Firm		Shared Equally Across Both		Mostly the Supplier Firm
O	O	O	O	O

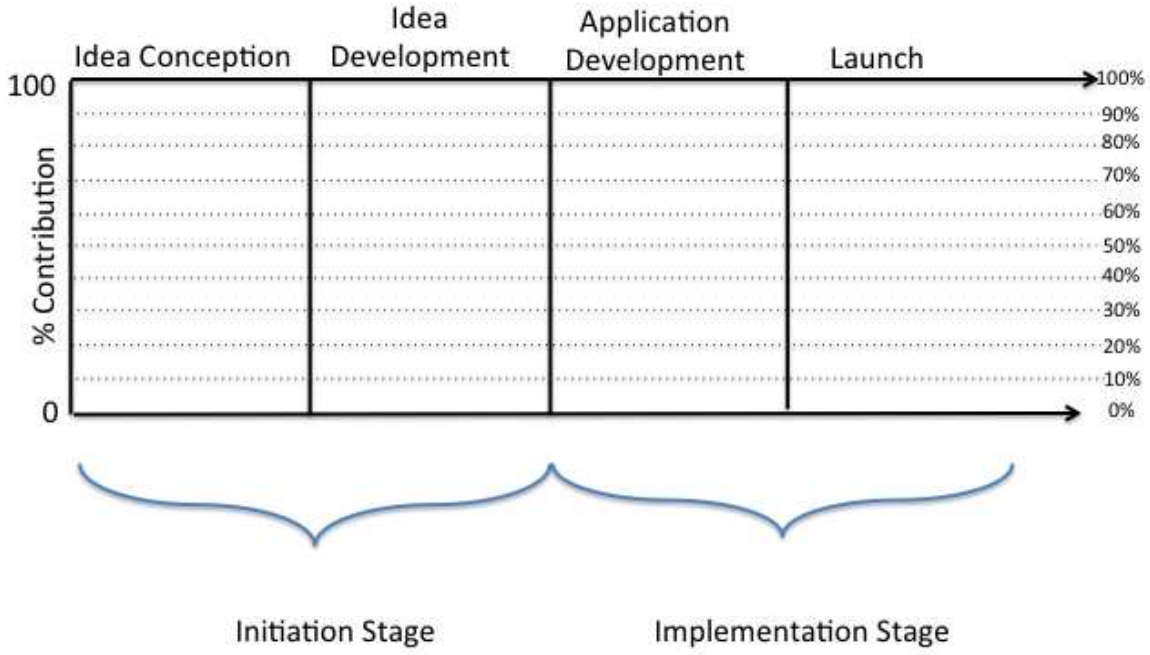
2. Do you have a technology agreement with the partner firm? If yes, please briefly describe.

Figure A.1 (cont'd)

SAMPLE: Innovation/Contribution Timeline



YOUR COMPANY – PLEASE FILL IN: Innovation/Contribution Timeline



Initiation Stage

3. Please fill in the timeline above showing your company's % contribution to the innovation project for each of the periods of the timeline. Please describe each phase

Figure A.1 (cont'd)

4. When exactly did the relationship with <INSERT SUPPLIER NAME> form for this particular project?
5. Who initiated the relationship?

Implementation Stage

6. Do you believe that your supplier has an "A" team and a "B" team regarding product development? If so, then how would you classify the resources that <INSERT SUPPLIER NAME> has made available to your firm for this particular project? Why do you think this was so?
7. Were there any factors that positively or negatively impacted the ability to bring the innovation to market? Please explain..
8. What, if anything, do you wish <INSERT SUPPLIER NAME> would have done differently?

Joint Action Expectations

The level of joint action between two firms can be described as how intensely two firms interact for a common purpose. We are interested in both the *actual* level of joint action that existed and the *desired* level of joint action that existed. Below is a sample figure that depicts three different scenarios:

A) The actual level of joint action for the project is the same as the desired level
B) The actual level of joint action for the project is lower than the desired level
C) The actual level of joint action for the project is higher than the desired level

SAMPLE: Innovation/Joint Action Timeline

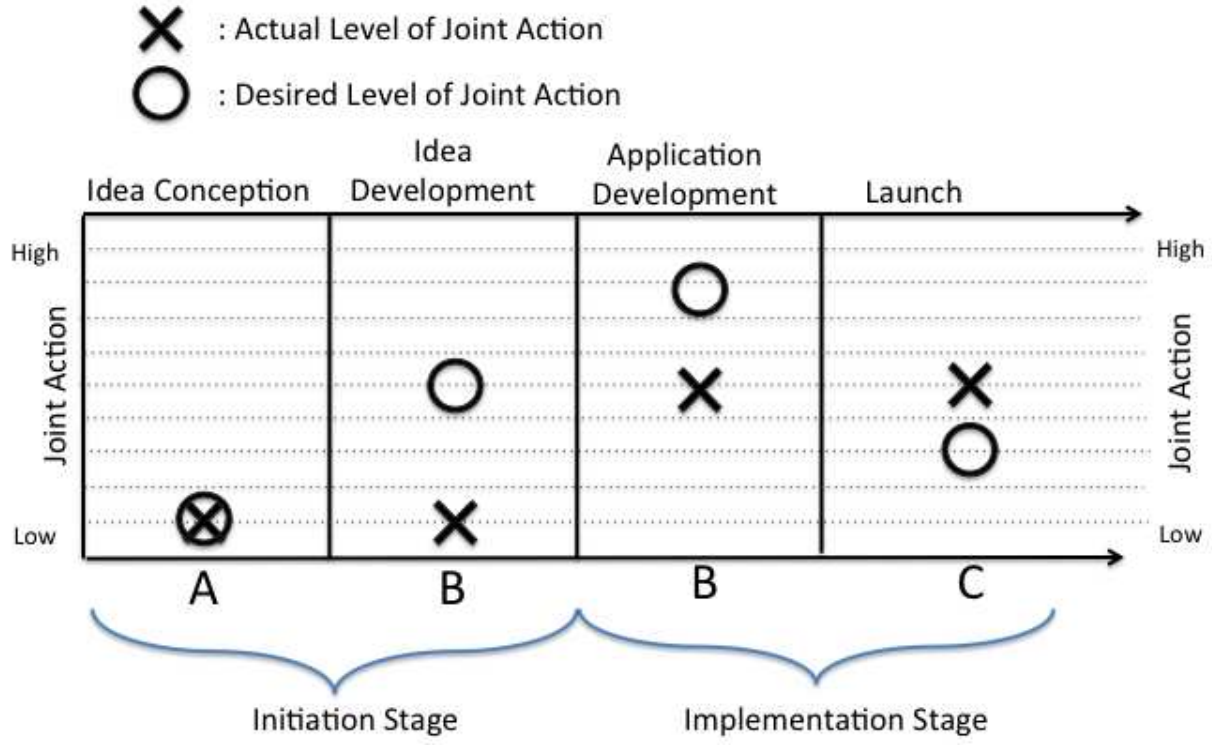
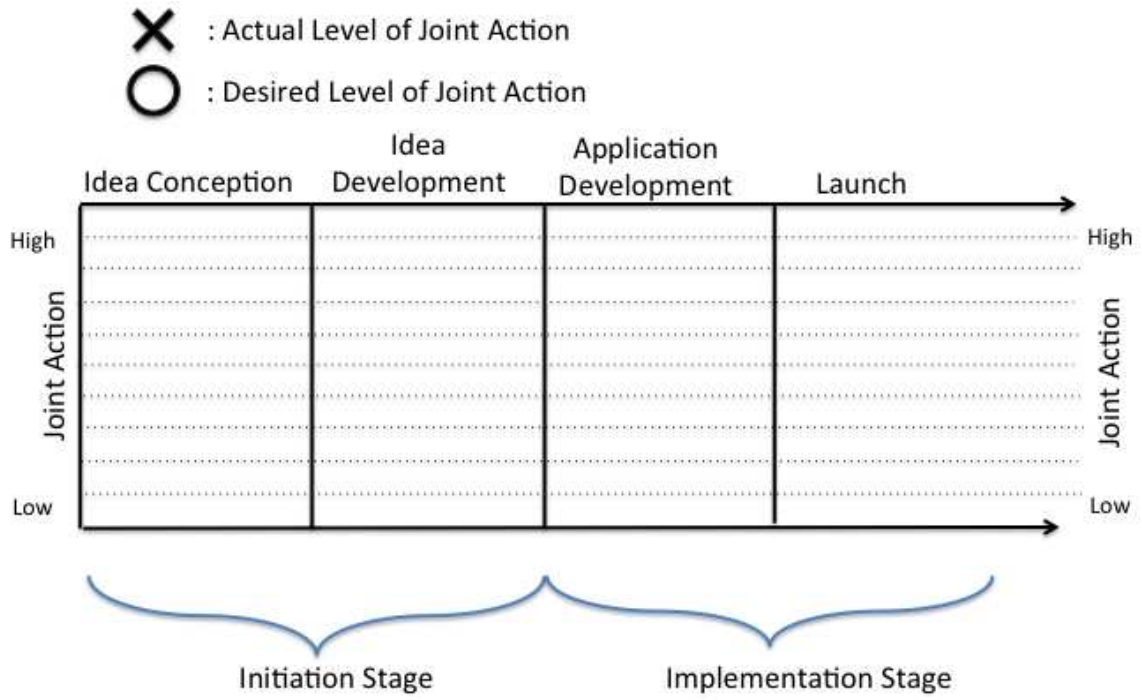


Figure A.1 (cont'd)

YOUR COMPANY – PLEASE FILL IN: Innovation/Joint Action Timeline



9. Please fill in the figure above with the actual and desired levels of joint action for each stage of the project development cycle and discuss the following for each stage:
    a. Describe the nature of the joint action
    b. Are you satisfied with <INSERT SUPPLIER NAME> level of joint action in the project? Too much, too little?
        i. If too much, why? How has your partner gone "too far"
        ii. If too little, why? What opportunities exist?
    c. Are you satisfied with ***your company's*** level of joint action in the project? Too much, too little?
        iii. If too much, why? How has your company gone "too far"
        iv. If too little, why? What opportunities exist?
    d. If a gap exists between actual and desired levels of joint action, did this gap impact the outcome of the project? If yes, in what ways?

Figure A.1 (cont'd)

Performance of the Innovation Project

10. How did this project perform along the following dimensions?

Did not challenge existing ideas	1	2	3	4	5	6	7 Challenged existing ideas
Did not offer new ideas	1	2	3	4	5	6	7 Offered new ideas
Not Creative	1	2	3	4	5	6	7 Creative
Did not offer superior value to the customer	1	2	3	4	5	6	7 Offered superior value to the customer
Late	1	2	3	4	5	6	7 Ahead of Schedule
Over Budget	1	2	3	4	5	6	7 Under Budget
Market Acceptance Worse than Expected	1	2	3	4	5	6	7 MarketAcceptance Stronger than Expected

APPENDIX B: SURVEY MEASURES FROM US POWERTRAIN R&D STUDY

Figure B.1: R&D study survey protocol

Innovation performance

QQ5) How do feel about the ***prospects of the overall success*** (technical & commercial) for the project?
1=not likely to succeed but we will learn a lot; 2=less than 50/50 chance of success; 3=50/50 chance of success; 4=good chance of success; 5=a sure thing, very good odds of success.

QQ6) How does this project compare to others you are familiar with in terms of its ***relative importance*** to the company?
1=Not Important, 2=Marginally Important, 3=Somewhat Important, 4=Important, 5=Very Important

QQ8) How much do you believe that the technological solution that is the core of the project will remain as the ***dominant approach in the next 5 years*** where you are:
1=Very unsure; 2=Somewhat unsure; 3=Neither certain nor unsure; 4=Somewhat certain; 5= Very certain

Process interoperability

QQ18) (For b-to-b suppliers) How would you rate the ***difficulty of coordinating*** the development of this project with your <u>customers</u> where….
1=Very Easy, 2=Easy, 3=Neither Easy Nor Difficult, 4=Difficult, 5=Very Difficult
(if difficult, please explain_____)

QQ19) (For manufacturers and suppliers) How would you rate the ***difficulty of coordinating*** the development of this project with your <u>suppliers</u> where….
1=Very Easy, 2=Easy, 3=Neither Easy Nor Difficult, 4=Difficult, 5=Very Difficult
(if difficult, please explain_____)

QQ20) What project management tools or ***methods*** (if any) were used for this project (e.g.,Gantt charts)?_____

Figure B.1 (cont'd)

Resource interoperability

QQ16) How would you describe your company's ***level of resources mobilized*** for this project?
1=Extremely Scarce Resources 2= Somewhat Scarce Resources, 3=Neither Scarce nor Ample Resources, 4=Ample Resources, 5=More than Ample Resources

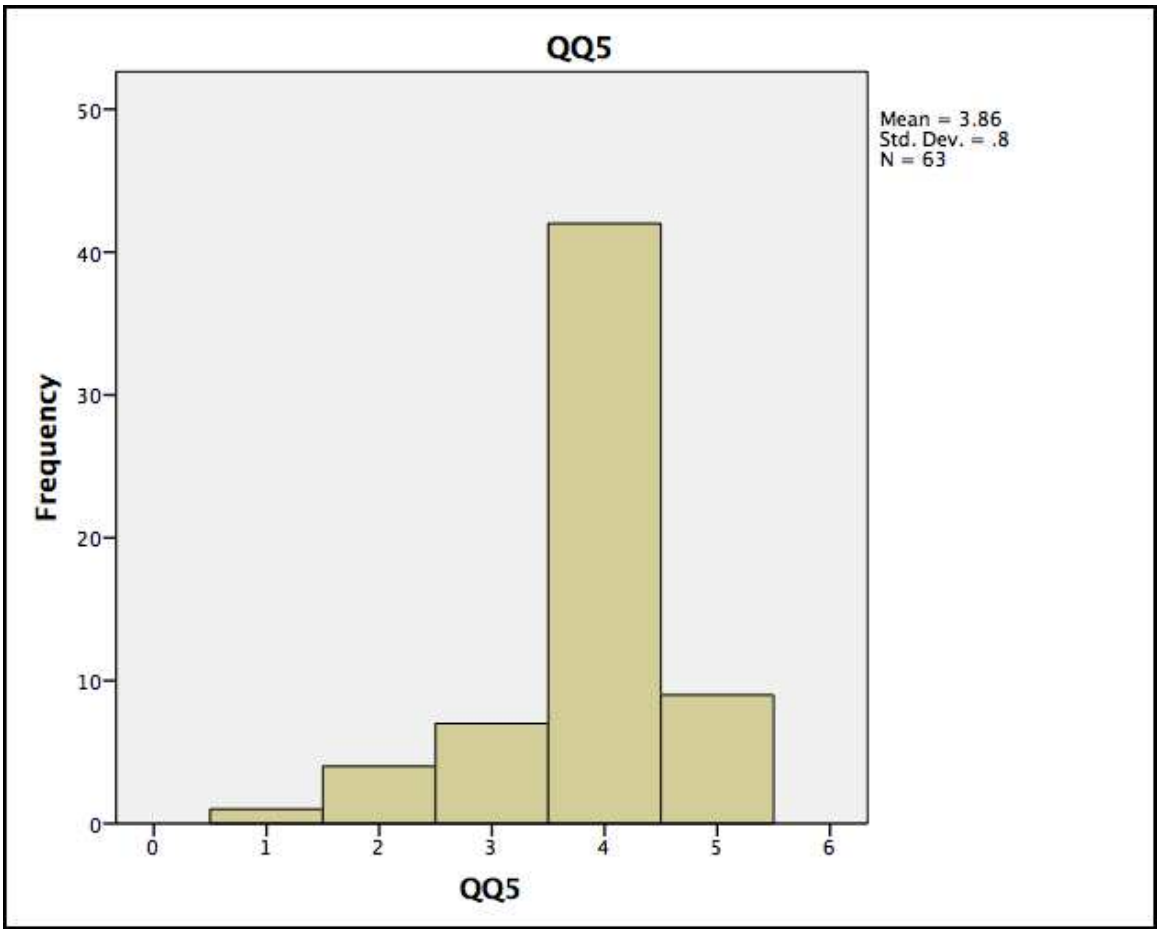
QQQ9) How often do you utilize the following mechanisms for ***external technology networking***?

C. Alliances and Partnerships
1=not at all 2=not very often 3=somewhat often 4=often 5=very often

D. Joint-ventures
1=not at all 2=not very often 3=somewhat often 4=often 5=very often

APPENDIX C: DATA NORMALITY AND TRANSFORMATION ANALYSIS

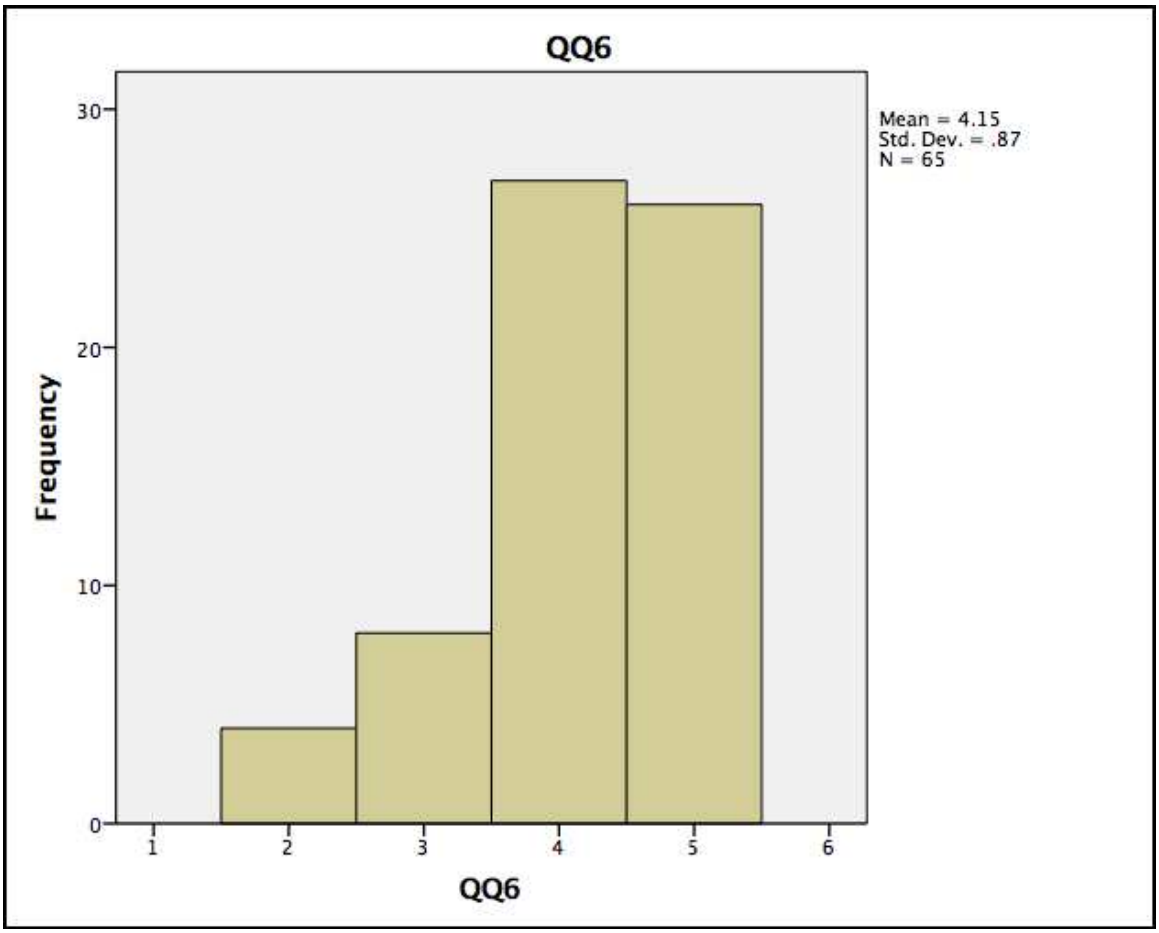
Figure C.1: Normality analysis and data transformation analysis



.	ladder	QQ5	
Transformation	formula	chi2(2)	P(chi2)
cubic	QQ5^3	3.1	0.212
square	QQ5^2	3.3	0.192
identity	QQ5	16.41	0
square root	sqrt(QQ5)	26.46	0
log	log(QQ5)	38.23	0
1/(square root)	1/sqrt(QQ5)	50.81	0
inverse	1/QQ5	62.84	0
1/square	1/(QQ5^2)	.	0
1/cubic	1/(QQ5^3)	.	0

Recommendation: Use 'square' transformation.

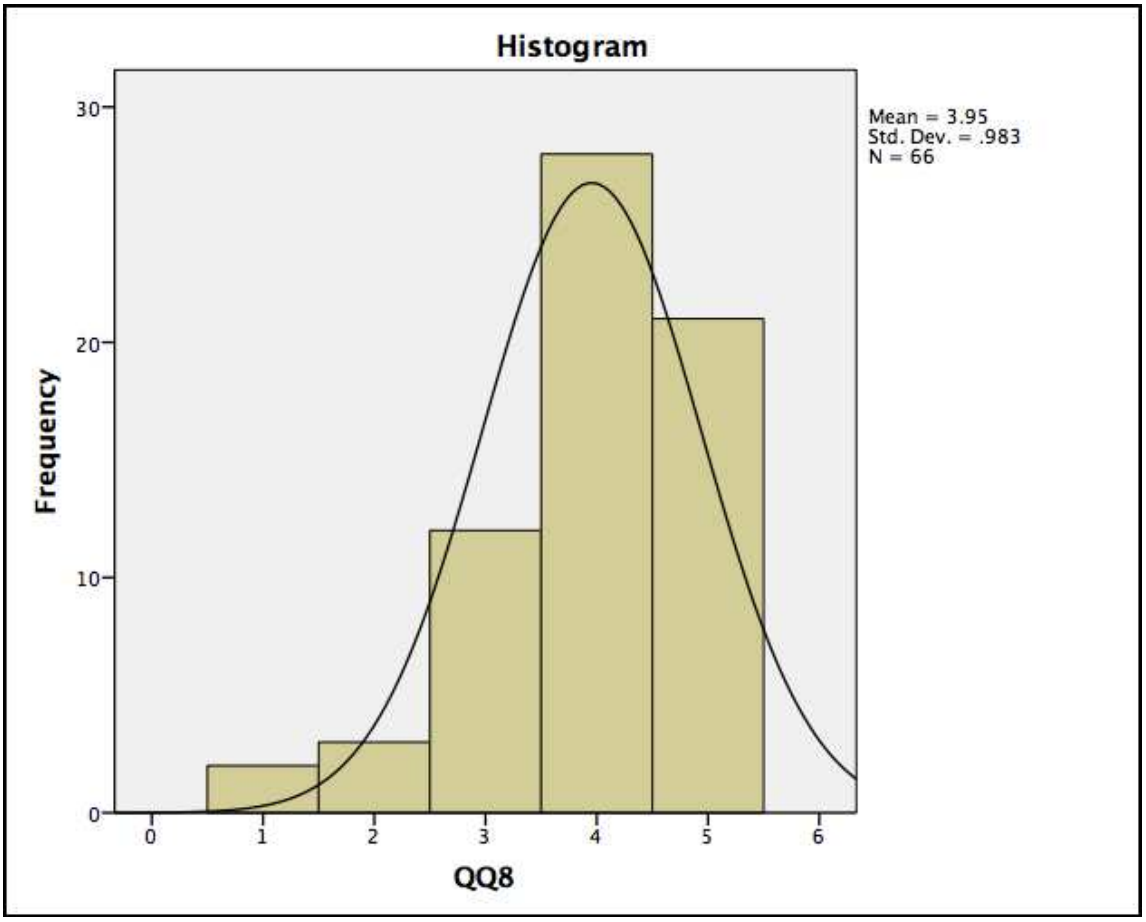
Figure C.1 (cont'd)



. ladder QQ6			
Transformation	formula	chi2(2)	P(chi2)
----------	----------	----------	-------
cubic	QQ6^3	18.82	0
square	QQ6^2	5.29	0.071
identity	QQ6	7.46	0.024
square root	sqrt(QQ6)	11.98	0.003
log	log(QQ6)	17.51	0
1/(square root)	1/sqrt(QQ6)	23.35	0
inverse	1/QQ6	28.99	0
1/square	1/(QQ6^2)	38.38	0
1/cubic	1/(QQ6^3)	44.64	0

Recommendation: Use 'square' transformation.

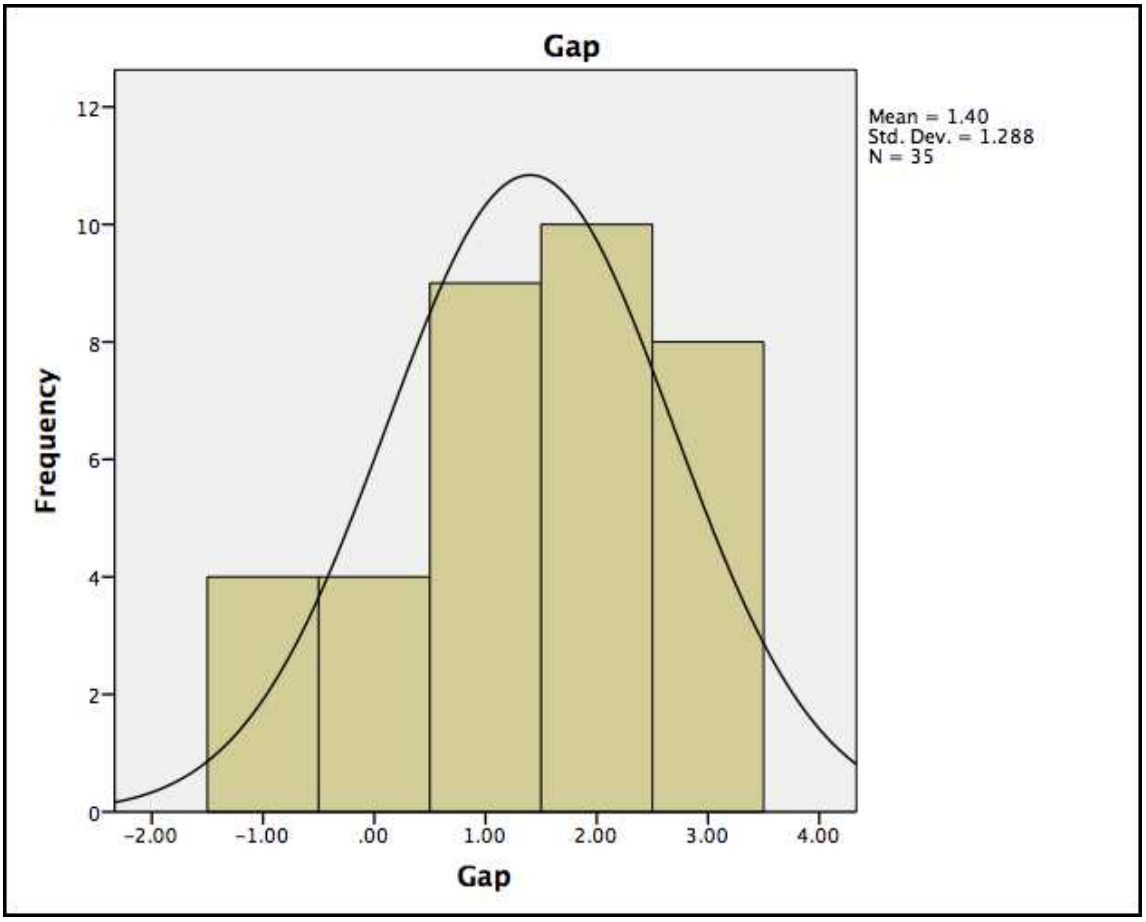
Figure C.1 (cont'd)



. ladder QQ8			
Transformation	formula	chi2(2)	P(chi2)
----------	----------	----------	-------
cubic	QQ8^3	14.1	0.001
square	QQ8^2	3.81	0.148
identity	QQ8	10.29	0.006
square root	sqrt(QQ8)	20.85	0
log	log(QQ8)	33.75	0
1/(square root)	1/sqrt(QQ8)	46.47	0
inverse	1/QQ8	56.97	0
1/square	1/(QQ8^2)	69.08	0
1/cubic	1/(QQ8^3)	73.47	0

Recommendation: use the 'square' transformation

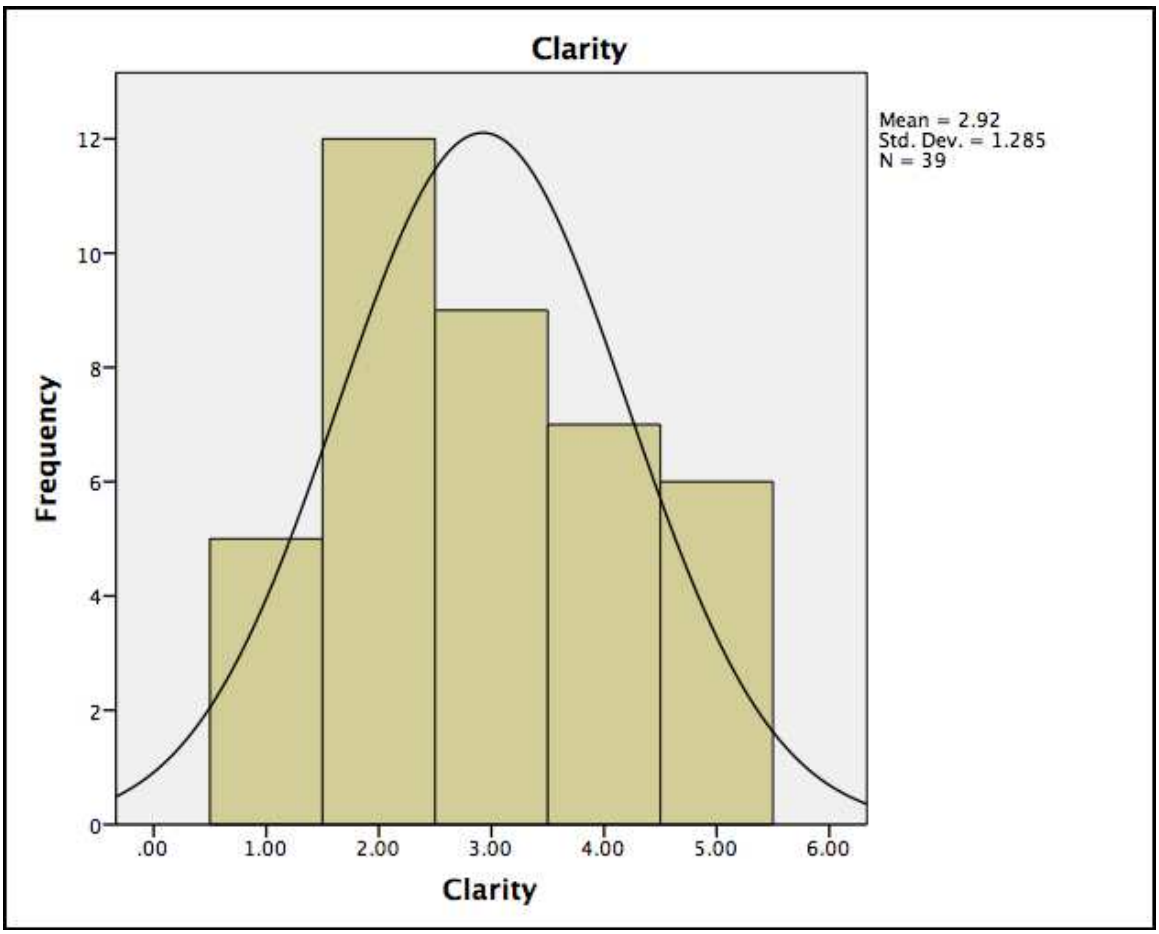
Figure C.1 (cont'd)



. ladder GapSh			
Transformation	formula	chi2(2)	P(chi2)
----------	----------	----------	-------
cubic	GapSh^3	5.69	0.058
square	GapSh^2	5.5	0.064
identity	GapSh	2.78	0.249
square root	sqrt(GapSh)	4.47	0.107
log	log(GapSh)	8.24	0.016
1/(square root)	1/sqrt(GapSh)	12.52	0.002
inverse	1/GapSh	16.12	0
1/square	1/(GapSh^2)	20.25	0
1/cubic	1/(GapSh^3)	21.72	0

Note: Because of the negative values, I first did a shift in the data creating variable GapSh = Gap +2. This enabled me to feasible investigate all transformations without running into the negative number issue.
Recommendation: Do nothing - maintain identify

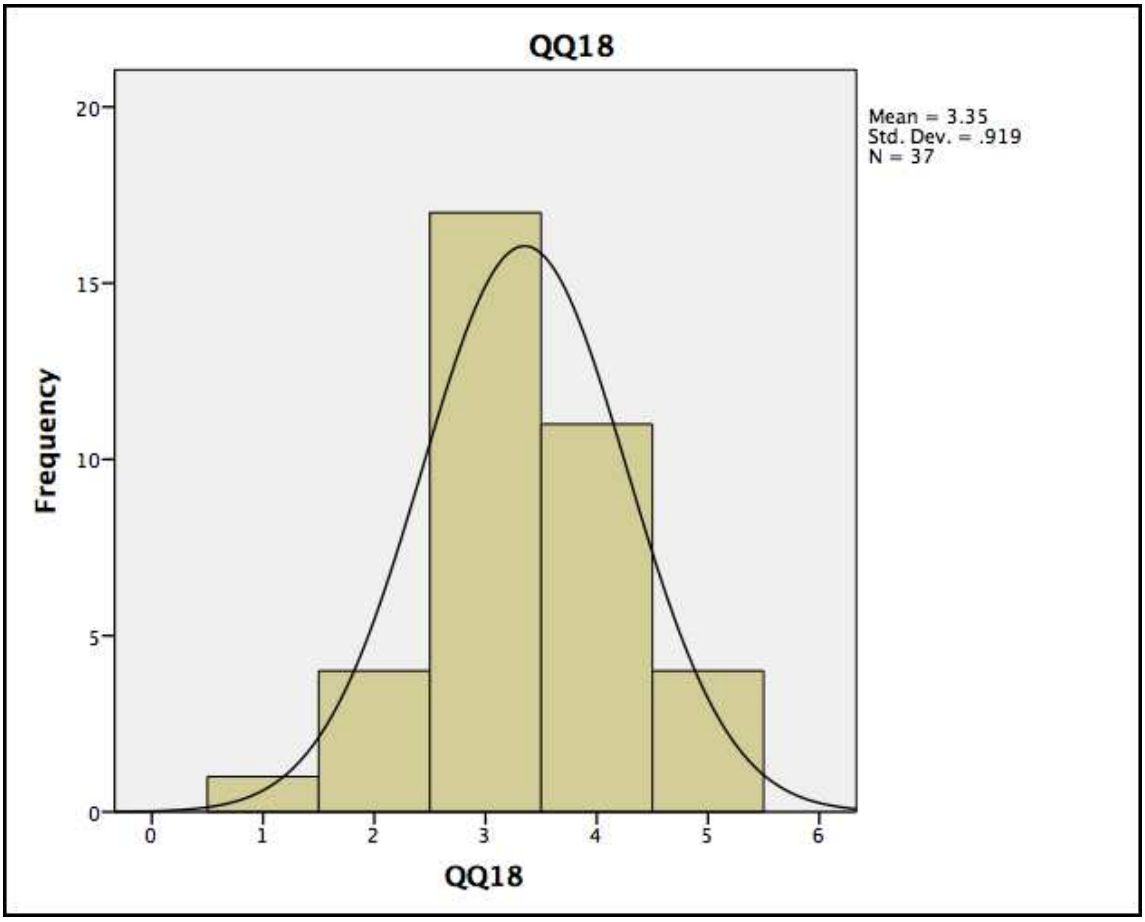
Figure C.1 (cont'd)



. ladder Clarity			
Transformation	formula	chi2(2)	P(chi2)
----------	----------	----------	-------
cubic	Clarity^3	5.54	0.063
square	Clarity^2	5.07	0.079
identity	Clarity	5.91	0.052
square root	sqrt(Clarity)	4.17	0.125
log	log(Clarity)	3.14	0.208
1/(square root)	1/sqrt(Clarity)	5.61	0.061
inverse	1/Clarity	9.11	0.011
1/square	1/(Clarity^2)	14.24	0.001
1/cubic	1/(Clarity^3)	16.29	0

Recommendation: transform data using the 'log' function

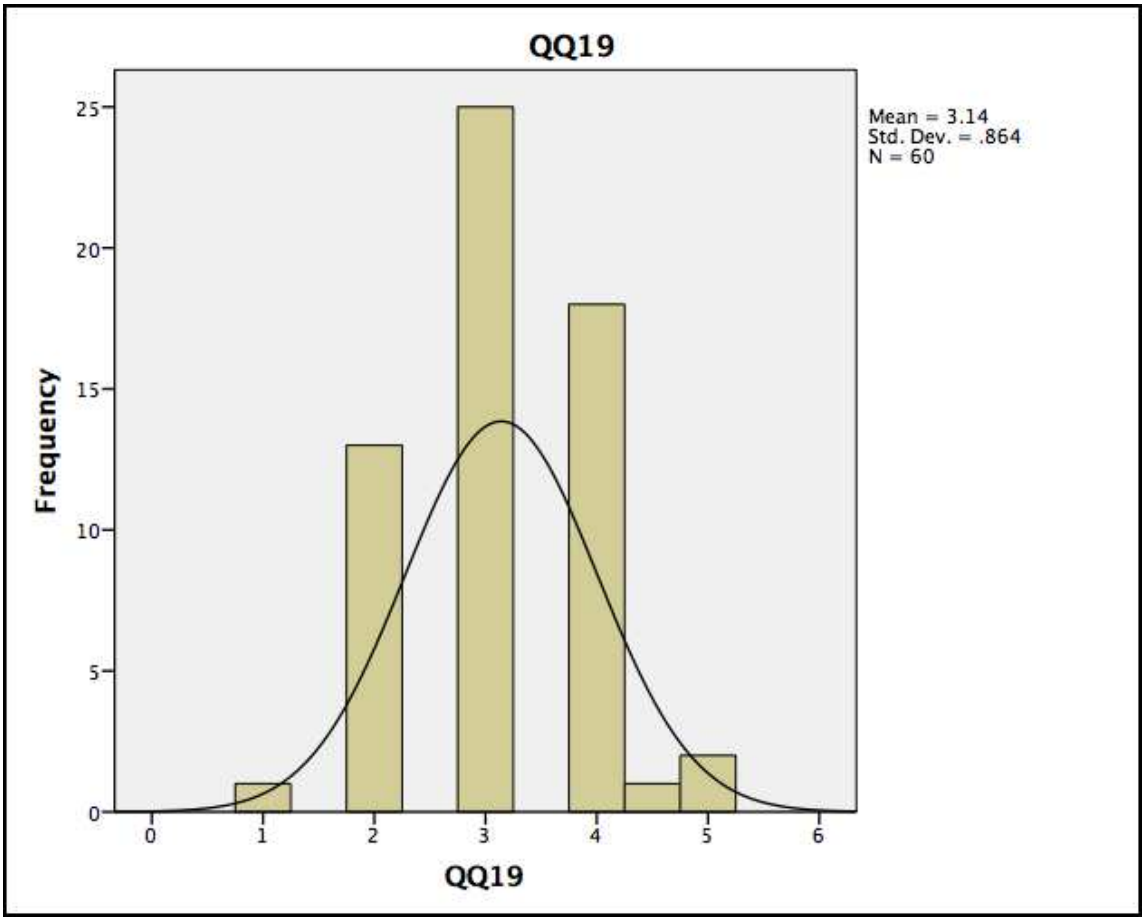
Figure C.1 (cont'd)



Transformation	formula	chi2(2)	P(chi2)
cubic	QQ18^3	7.96	0.019
square	QQ18^2	3.32	0.19
identity	QQ18	0.33	0.847
square root	sqrt(QQ18)	5.28	0.071
log	log(QQ18)	14.17	0.001
1/(square root)	1/sqrt(QQ18)	25.14	0
inverse	1/QQ18	35.39	0
1/square	1/(QQ18^2)	48.84	0
1/cubic	1/(QQ18^3)	54.24	0

Recommendation: Maintain identity - no transformation

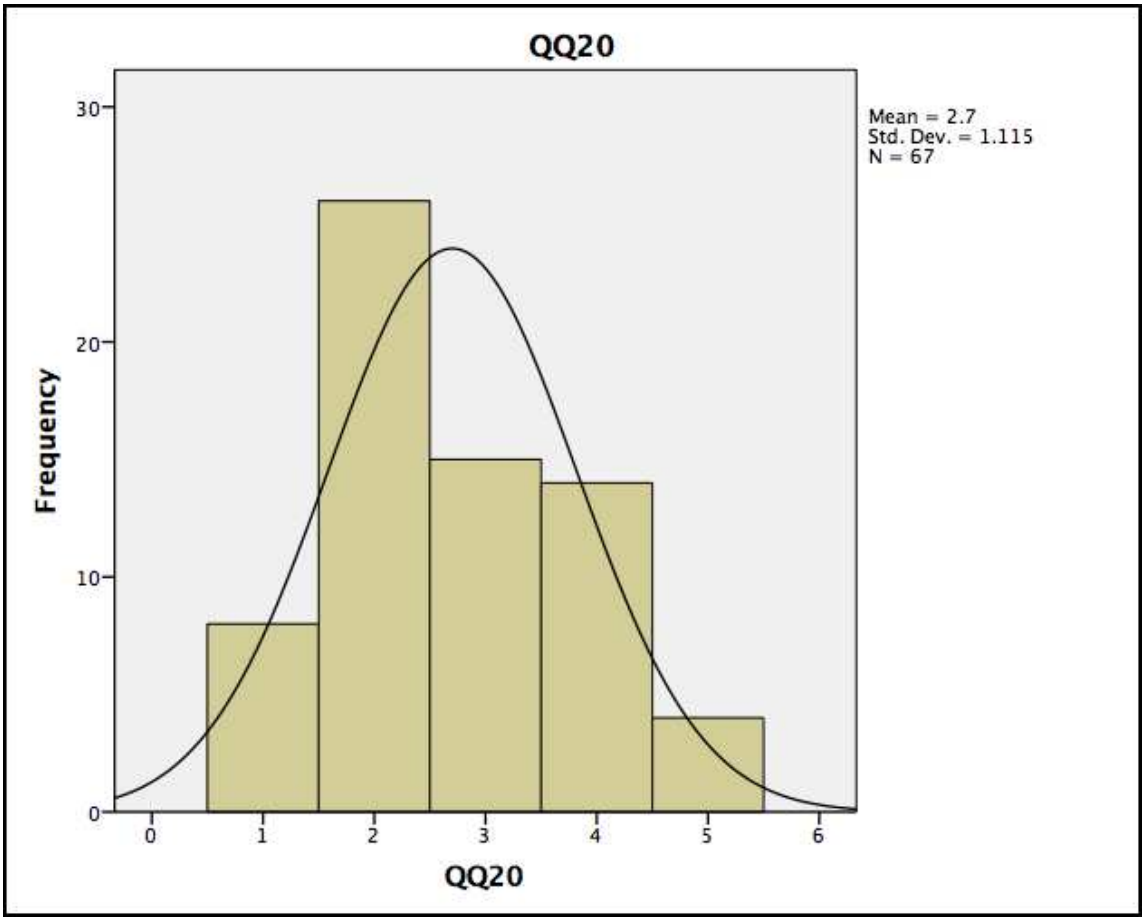
Figure C.1 (cont'd)



. ladder QQ19			
Transformation	formula	chi2(2)	P(chi2)
----------	----------	----------	-------
cubic	QQ19^3	10.95	0.004
square	QQ19^2	3.16	0.206
identity	QQ19	0.66	0.718
square root	sqrt(QQ19)	2.23	0.327
log	log(QQ19)	9.49	0.009
1/(square root)	1/sqrt(QQ19)	21.86	0
inverse	1/QQ19	37.05	0
1/square	1/(QQ19^2)	64.64	0
1/cubic	1/(QQ19^3)	.	0

Recommendation: maintain identity - no transformation

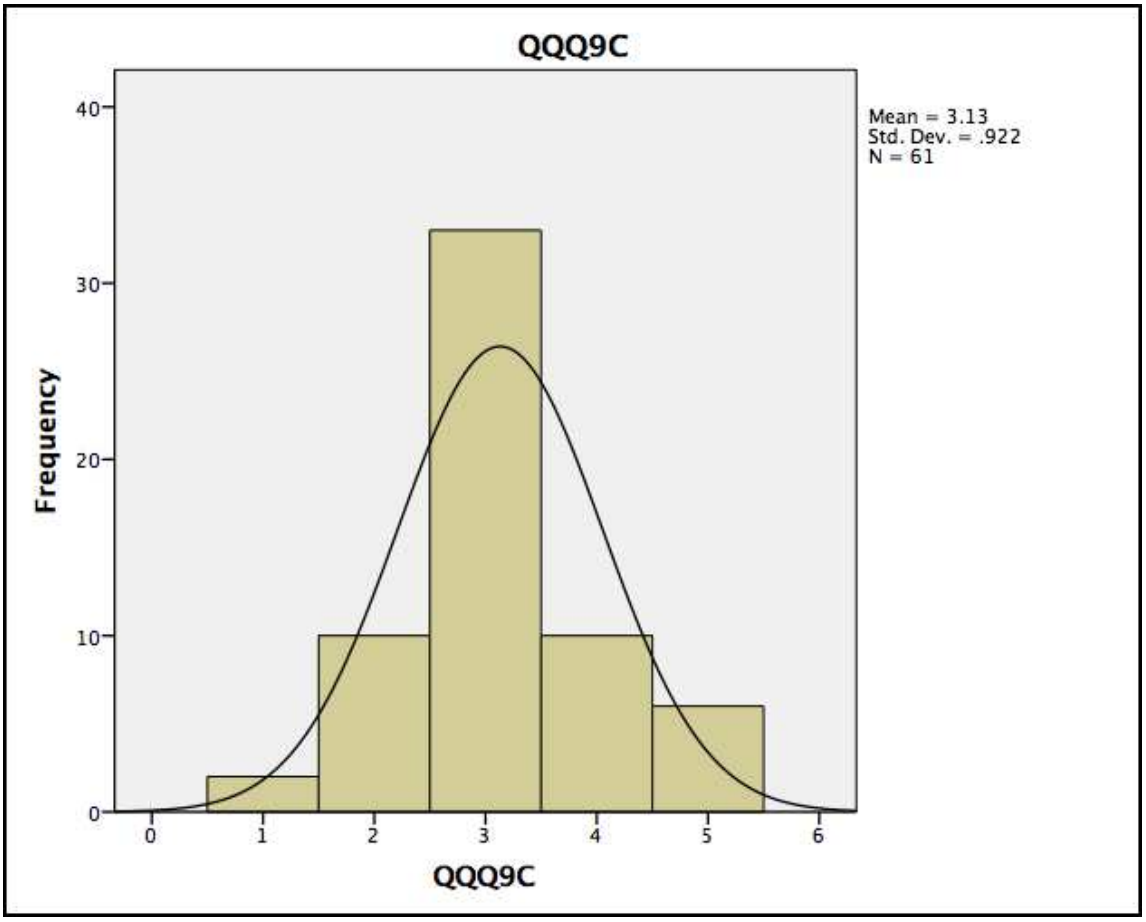
Figure C.1 (cont'd)



. ladder QQ20			
Transformation	formula	chi2(2)	P(chi2)
----------	----------	----------	-------
cubic	QQ20^3	17.96	0
square	QQ20^2	8.51	0.014
identity	QQ20	4.41	0.11
square root	sqrt(QQ20)	2.91	0.234
log	log(QQ20)	3.22	0.2
1/(square root)	1/sqrt(QQ20)	8.82	0.012
inverse	1/QQ20	15.81	0
1/square	1/(QQ20^2)	25.71	0
1/cubic	1/(QQ20^3)	29.65	0

Recommendation: Transform data using 'sqrt' function

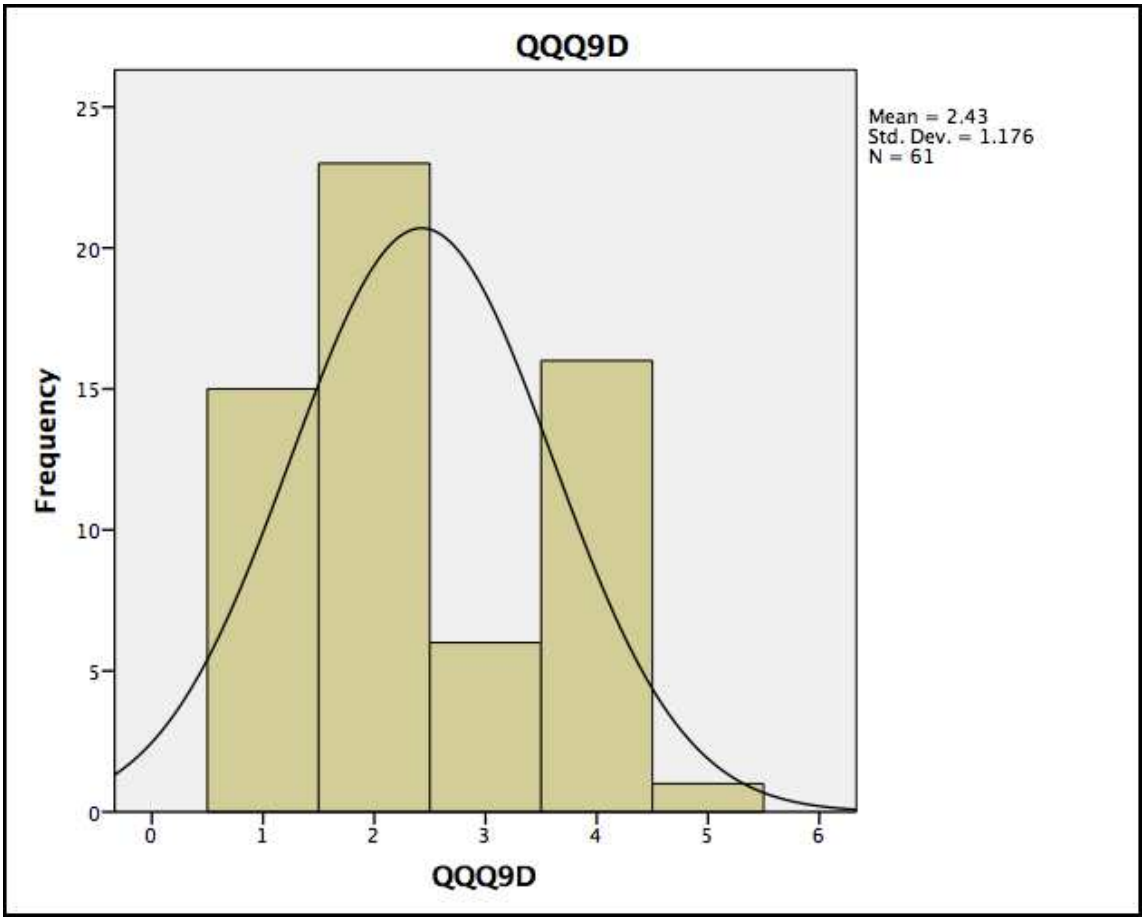
Figure C.1 (cont'd)



. ladder QQQ9C			
Transformation	formula	chi2(2)	P(chi2)
----------	----------	----------	-------
cubic	QQQ9C^3	17.84	0
square	QQQ9C^2	10.15	0.006
identity	QQQ9C	1.36	0.506
square root	sqrt(QQQ9C)	3.41	0.182
log	log(QQQ9C)	13.7	0.001
1/(square root)	1/sqrt(QQQ9C)	27.69	0
inverse	1/QQQ9C	40.91	0
1/square	1/(QQQ9C^2)	58.37	0
1/cubic	1/(QQQ9C^3)	65.57	0

Recommendation: No transformation - maintain identity

Figure C.1 (cont'd)



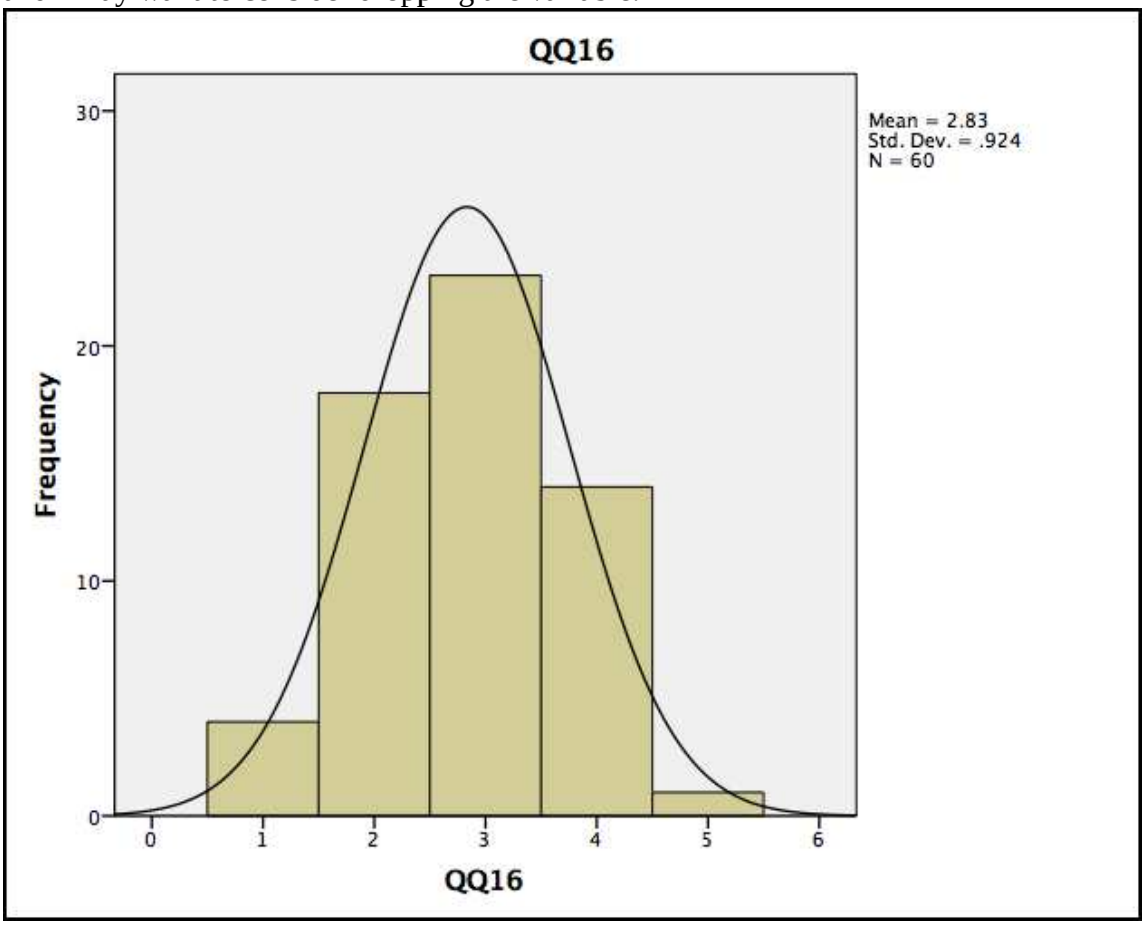
. ladder QQQ9D			
Transformation	formula	chi2(2)	P(chi2)
cubic	QQQ9D^3	11.25	0.004
square	QQQ9D^2	7.15	0.028
identity	QQQ9D	12.9	0.002
square root	sqrt(QQQ9D)	14.53	0.001
log	log(QQQ9D)	12.45	0.002
1/(square root)	1/sqrt(QQQ9D)	10.06	0.007
inverse	1/QQQ9D	9.28	0.01
1/square	1/(QQQ9D^2)	9.98	0.007
1/cubic	1/(QQQ9D^3)	10.61	0.005

Recommendation: No transformation - maintain identity.

Note: Since QQQ9C is similar in measure to QQQ9D, and since QQQ9C is normally distributed, then I recommend maintaining QQQ9D per identity, even though the square function would

Figure C.1 (cont'd)

provide marginal improvement in normality. This variable may be problematic in our analysis and I may want to consider dropping the variable.



. ladder QQ16			
Transformation	formula	chi2(2)	P(chi2)
cubic	QQ16^3	13.81	0.001
square	QQ16^2	4.16	0.125
identity	QQ16	1	0.606
square root	sqrt(QQ16)	2.54	0.281
log	log(QQ16)	9	0.011
1/(square root)	1/sqrt(QQ16)	18.06	0
inverse	1/QQ16	27.05	0
1/square	1/(QQ16^2)	39.39	0
1/cubic	1/(QQ16^3)	44.61	0

Recommendation: no transformation - maintain identity

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