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Catastrophic Transitions of Construction Contracting Behavior

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Abstract

The ways to manage a construction project very much depend on the attitude of the people involved. Collectively this is identified as construction contracting behavior (CCB). The CCB of the construction industry is adversarial as pinpointed in many industry-wide reviews. A more co-operative project delivery approach has therefore been advocated. In fact, drive for efficiency provides the incentive for co-operation. Nevertheless, members of a project team, in representing their respective organizations, are often in conflict. The dichotomous pair of co-operation and aggression forces therefore co-exist. It is not uncommon to note CCB turns aggressive as the construction activities of a project intensify. This change is often sudden thus matches well with the phenomenon of hystersis described by the Catastrophe Theory (CT). It is hypothesised that the dynamics of CCB can be modelled by CT. The 3-variables CT models include CCB (as dependent variable), co-operation forces (as normal factor) and aggression forces (as splitting factor). With data collected from a survey fitted by the Cuspfit programme, it was found that trust intensity is an effective normal factor. Contract incompleteness and competitive inertia are splitting factors that trigger aggression.

Keywords: Construction contracting behavior, Catastrophe Theory, Co-operation, Aggression

Introduction

The construction industry is infamous for its adversarial culture. The proliferation of disputes within the industry has caused acute concern over the adverse effect of protracted disputes. Furthermore, the antagonistic contracting attitude per se needs to be overhauled (Cheung and Suen 2002; Cheung et al. 2003; Bayliss et al. 2004). This view is expressed in a number of industry-wide reviews (Latham 1994; Egan 1998; CIRC 2001). Fostering co-operation in construction contracting has been suggested to alleviate this situation. However, this is considered to be a revolutionary attitude change that can only be made possible with a culture transformation. The reported co-operation fostering efforts can be broadly classified into three categories: case studies, identification of critical success factors and legal analyses. Case studies are instrumental in sharing innovations and achievements (Black et al. 1999; Bayliss et al. 2004; Bayliss 2002; Cheung et al. 2002), These are excellent learning models for the practice of co-operative contracting. Nonetheless, sceptics often comment that each construction project is unique; hence it is risky to generalize the success attained in a particular venture. Identification of success factors often goes hand in hand with case studies (Liu and Fellows 2001). The identified success factors are mostly behavioral or attitudinal, thus augmenting the common belief that contracting behavior is in fact manifestation of the attitude of those involved. Liu and Fellows (2001) suggest that the Chinese culture appears to be more receptive to the concept of co-operative contracting. This notion is echoed by the study of Cheung (2001) which points out that the contract law regime of the People's Republic of China features many characteristics of relational contracting forwarded by Macneil (1980, 1981), the American legal scholar who introduced economic considerations to contract law. Flexibility in contractual relations was succinctly advocated. His suggestion was later supported by the empirical work of Macaulay (1985) who observed that re-negotiation of contract terms is commonly practised and that adjustments should occur without resorting to court. To this end, the legal footing for co-operative contracting needs to be identified. In sum, examining the compatibility of the legal system in supporting the practice of co-operation in construction contracting form the backbone of legal analyses in this area. Yet not surprisingly, the legal profession under the common law system has been swift to point out the lack of a legal basis for any contractual duty to cooperate (Newman 2000) and that such a duty is difficult to enforce due to the absence of a recognized legal concept (Colledge 2000). Furthermore, the sole reliance on contractual force in executing construction contracts already marks a clear departure from the spirit of co-operation. More importantly, commanding co-operative contracting behavior is a management issue, and improving the performance of construction projects is one of the driving forces to promote co-operation between contracting parties. Its failure would germinate seeds for disputes, and eventually lead to programme disruption, relation deterioration, time and financial loss (Cheung 2001).

Notwithstanding the call for reforms as aforementioned, contracting behavior remains largely adversarial in the construction industry (Latham 1994; Egan 1998; CIRC 2001). The conventional design-bid-build approach is not conducive in enhancing co-operation (Cheung et al. 2003). In the absence of a co-operative environment, contractual terms, however comprehensive, would not be able to cover all eventualities. Unanticipated happenings are testing and a co-operative contracting behavior could curb disputes nourishing (Luo 2002; Cheung 2002). Co-operative contracting behavior operates as a self-enforcing safeguard that enables a more effective and less costly alternative to exhaustive contractual remedies (Luo 2002). That means with a co-operative contracting attitude, a flexible approach to deal with unanticipated eventualities can be adopted (Luo 2002). In terms of implementing co-operation, Bayliss et al. (2004) suggested that "*co-operative attitude can be instilled, fostered and maintained through cogent project management, thus, commanding a co-operative contracting behavior is a management issue, acquiring skill of managing it basically depends on the understanding of the fundamentals involved*". Notwithstanding, the fact remains that parties to a construction contract represent the interests of their respective organizations that may not always be compatible. Cheung (2007) further demonstrated that trust is the prerequisite for co-operation in a partnering project in Hong Kong.

This paper reports a study which examines the dynamics of construction contracting behavior (CCB) with regard to the competing driving forces of co-operation and aggression in project management. To achieve this, the dynamics of CCB is modelled by Catastrophe Theory (CT) developed by Thom (1975). Its mathematical treatment allows an analytical examination of the dynamics among the interacting variables. Because the CT model is characterized by a bifurcation zone within which the behavior becomes bimodal. If a co-operating party feels aggrieved, she remains co-operative up to a point beyond which she will suddenly attack. This jump is described as catastrophe attack. Once this happens, considerable effort is needed to bring back the party to a co-operative mode due to the existence of the folded behavioral surface of the CT model. Thus, under a CT framework, a small change in the aggression drive can produce a significant sudden change in contracting behavior; this phenomenon is called divergence. With this generic framework, the CCB framework can be developed by the identification and establishment of indicators for the three variables; contracting behavior, co-operation and aggression drivers. Further details on Catastrophe Theory are provided in another section of this paper.

Construction Contracting Behavior (CCB): Co-operation vs Aggression Forces

According to Hill (2001), contracting behavior is regarded as “a means for parties to reconcile their expectations, future actions and consequent valuations to increase the size of aggregate pie”. The view is also shared by Buckley and Casson (1988) who suggest that co-operative behavior is a mutual forbearance in the allocation of resources such that one party is made better off and no one is worse off than it would otherwise be. In the course of an ongoing contractual relationship, disputing parties may adopt co-operative behavior in order to retain a harmonious relationship with the other. This co-operative working environment would have allowed effective enforcement of their rights and obligations (Harmon 2003; Yiu and Cheung 2006). However, in construction, acting co-operatively is easier to be said than done, especially when conflicts are inherent in all construction projects (Yiu and Cheung 2006; Fenn et al. 1997). Opportunism is therefore common. Contracting parties would exercise opportunistic and aggressive behavior by only taking care of one's self-interest, regardless of the detrimental consequences of their collaborators. For example, they may seek to enforce their contractual rights as much as possible on one hand, while look for means to evade their obligations on the other; they may even estimate the other party’s likelihood to default. It is therefore evident that there are two co-existing conflicting forces that affect CCB: *co-operation* force and *aggression* force.

Aggression force refers to the strengths and stimuli that motivate one to make aggressive moves, whereas co-operation force is the strengths and stimuli that motivate one to make co-operative moves. These two dichotomous forces co-exist in all construction projects. As illustrated in Figure 1, these forces can be framed into the classic framework of Prisoner’s Dilemma (PD) (Axelrod 1984). PD refers to a two-party non-constant-sum game in which some outcomes are preferred by both parties, and the occurrence of certain outcomes depends on the behavior of the other party. In this game, it is assumed that each individual player ("prisoner") is trying to maximise his own interest, without any concern for the well-being of the other player. The PD framework suggests that a similar payoff matrix can be applied in the area of human interaction and it has become fundamental to certain theories of human co-operation (Axelrod 1984). Hence, a similar approach as the PD framework can be applied to model CCB. A payoff matrix of CCB is constructed and displayed in Figure 1.

< Figure 1 here >

The payoff matrix in Figure 1 suggests that co-operative behavior is not innate. Instead, practice of co-operative behavior is characterized by reciprocal moves, i.e. if one side behaves co-operatively, he would expect a reciprocating co-operative response from the other (Cheung et al. 2003; Wong et al. 2005). This implies that the contracting behavior of one party is dynamically associated with the other's. It is therefore hypothesised that a threshold exists for the transition from co-operative to aggressive contracting behavior. When this threshold is reached, a sudden change in behavior will occur. The theoretical explanation of such a behavioural transition can be found in Catastrophe Theory (1975).

Catastrophe Theory (CT)

Catastrophe Theory was developed by Thom (1975) and subsequently popularized by Zeeman (1976, 1977). It is a mathematical model of nonlinear systems in which discontinuous behavior is determined by smooth changes in a small number of parameters (Wagenmakers et al. 2004). Hence, one of the possible applications of CT is attitude-based analysis. It has been applied to a wide range of areas such as physics (Tamaki et al. 2003), geology and rock mechanics (Qin et al. 2001), psychology (Ploeger et al. 2002; van der Maas et al. 2003) as well as social sciences (Holyst et al. 2000). In management, it has also been applied to study technology management (Herbig 1991; Bacck and Cullen 1992), organizational change (Gresov 1993), competitive strategies (Oliva et al. 1988), customer behavior (Oliva et al. 1992), motivation in organizations (Guastello 1987), forecasting and decision making (Wright 1983) and conflict resolution (Yiu and Cheung 2006).

Catastrophe Model of Construction Contracting Behavior

Catastrophe Theory describes how small and continuous changes of independent variables can have sudden, discontinuous effect on a dependent variable. Its basic form is called ‘cusp catastrophe’ (Thom 1975). The cusp model involves one dependent variable and two independent variables. The independent variables take two extreme forms with different qualitative meanings: one is called the *normal* factor and the other is called the *splitting* factor (Bacck and Cullen 1992). The normal factor changes directly with the dependent variable (Gresov et al. 1993), while the splitting factor is ‘*a moderator variable which specifies conditions under which the normal factor will affect the dependent variable in a continuous fashion, and other circumstances under which the normal factor will produce discontinuous changes in the dependent variable…it is the splitting factor that determines the “breaking point” or threshold of change in the dependent variable…’*(Bacck and Cullen 1992). According to CT, when the intensities of the normal factor and the splitting factor reach a threshold level, the dependent variable will undergo a sudden and radical change. This unique nature is represented by the split of the contracting behavior surface (B) of the CT model (Figure 2 refers).

In this study, it is hypothesized that a party’s contracting behavior is influenced by two stimulators: co-operation force and aggression force. The CT model describes the changes in CCB, as a result of the interaction between the two forces, depicted as the contracting behavior surface (B) (Figure 2 refers). For any combination of the co-operation and aggression forces, that means for any point on the control space (C), there is at least one likely form of corresponding behavior indicated as a point above the corresponding point in the control space and at an appropriate height on the behavior axis (vertical axis). The full set of such points together forms the contracting behavior surface (B). In general, there is only one probable mode of behavior. However, where co-operation and aggression forces are roughly equal, as shown the middle of the graph there are two sheets representing two possible forces of behavior. They are connected by a third sheet to form a continuous pleated surface. This sheet represents the least likely behavior, in this case, neutrality (Zeeman 1977). Towards the origin, the pleat on the contracting behavior surface becomes increasingly narrow and eventually vanishes. The line defining the edges of the pleat is called the fold curve and its projection onto the control surface is a cusp-shaped curve.

< Figure 2 here >

Construction Contracting Behavior as Dependent Variable

As discussed, improved performance of construction projects provides a driving force to adopt a co-operative approach, and it is necessary to better understand such construction contracting behavior. As shown in Figure 2, construction contracting behavior is manifested by a combination of co-operation and aggression forces. Based on literature review, its influential variables are identified and summarised in Table 1.

< Table 1 here >

Co-operation Force and Aggression Force as Independent Variables

As per the model presented in Figure 2, co-operation and aggression forces are two co-existing conflicting forces that affect construction contracting behavior. Co-operation force prompts contracting parties to focus on mutual interests and concerns. This force would generally invoke co-operative and accommodating response, which would restrain the inherent human instinct of concerning only self-interests. Aggression force, in contrast, prompts contracting parties to focus only on self-interests. This behavior is often adversarial against others, invoking aggression, retaliation and defensive response. The dichotomous nature of these two forces can be demonstrated by the framework of Prisoner's Dilemma (PD) as afore-described. It is therefore imperative that contracting parties shall prevent such moves so as to maintain good relationships. In summary, in modelling CCB, both co-operation and aggression forces should be considered. Their influential variables are identified and presented in Table 2 and 3 respectively.

The fitness of the model presented in Figure 2 and the appropriateness of the independent variables are to be tested empirically. The steps in conducting the fit measurements are discussed in the following section.

< Table 2 here >

< Table 3 here >

Model Fitting

Early CT model fitting employed regression and stochastic differential equations to estimate model parameters (Yiu and Cheung 2006; van der Maas et al. 2003; Gresov et al. 1993). Cobb (1980) proved that there is a family of probability density functions, of which a stable equilibrium corresponds to a node and an unstable equilibrium corresponds to an anti-node. A stable equilibrium state is a point of high probability. The cusp surface (i.e. the contracting behavior surface) is then viewed as a maximum probability response surface (Cobb 1981; Cobb et al. 1983). With these probability density functions, parameters can be estimated using the method of maximum likelihood estimation (Yiu and Cheung 2006; van der Maas et al. 2003; Cobb 1981; Cobb et al. 1983). In other words, the control variables can be estimated from the data with stochastic differential equations (Gresov et al. 1993; Cobb 1978, 1980; Cobb et al. 1983, 1985). Mathematically, the contracting behavior surface can be expressed by equation (1) (Cobb et al. 1980, 1983):

$$f\left(z \mid \alpha, \beta\right) \exp\left(\alpha y + \frac{1}{2}\beta y^2 - \frac{1}{4}y^4\right) \text{……………………………………………………..…. (1)}$$

where $y = \dfrac{(z-\lambda)}{\sigma}$, λ and σ scale the observed behavioral variable *z* to *y*;

α and β are linear functions of the independent variables x_1 to x_n, with $\alpha = a_0 + a_1x_1 + a_2x_2 + ... + a_nx_n$ and; …………………………………………..…… (2)

$\beta = b_0 + b_1x_1 + b_2x_2 + ... + b_nx_n$ …………………………...…………...………. (3)

Cobb (1980) also developed a computer program based on this model fitting technique. Although this maximum likelihood method is considered as a satisfactory method for fitting cusp catastrophe model, it is not often used (Wagenmakers et al. 2004) and unfortunately, this program often breaks down for non-apparent reasons (Ploeger et al. 2002). Hartelman (1997) later solved this problem by introducing an improved program called Cuspfit (Hartelman 1997; Ploeger et al. 2002). Hartelman (1997) and Wagenmakers et al. (2004) suggested that this program is a more robust and flexible version than Cobb's original program. It employs a more reliable optimization routine which allows users to constrain parameter values and to employ different sets of starting values. Cobb's algorithm calculates whether the cusp model or the linear model gives the best description of the relationship between the independent and the dependent variables (Wagenmakers et al. 2004; Ploeger et al. 2002; Cobb 1980). Cuspfit, however, is equipped with additional functions and is thus capable of fitting similar models such as logistic and linear models and detect rapid changes in the dependent variable (Wagenmakers et al. 2004). It can also be used to test the three models; linear, logistic and cusp. Such comparison is useful in distinguishing an arbitrarily fast acceleration from a catastrophic change. Furthermore, Cuspfit could be used to test the presence of bifurcations by comparing the fit of the cusp model to the fit of both logistic and linear models (Hill 2001; Ploeger et al. 2002; Hartelman 1997).

In addition to the maximum likelihood method, Hartelman (1997) introduced two fit measures in Cuspfit – Akaike Information Criterion (AIC) and Bayes Information Criterion (BIC). AIC is the goodness-of-fit index that takes account of the number of parameters. Mathematically, it is defined as minus twice the log-likelihood plus twice the number of parameters, i.e. "AIC = -2 log L +2 k"; the model with the smallest AIC will be the best fit (Hill 2001; Ploeger et al. 2002; Hartelman 1997). As for BIC, it is a goodness-of-fit indicator which takes into account the number of data points and implements Occam's razor (Thorburn 1915) by quantifying the trade-off and parsimony (Hill 2001; Ploeger et al. 2002; Schwarz 1978; Raftery 1995). Mathematically, BIC is calculated by the equation "$BIC = -2 \log L + k \log n$", where L is the maximum likelihood, k is the number of free parameters and n is the number of observations (Raftery 1995). Models with lower BIC values are preferred for model fitness purpose. If the AIC and BIC values of the cusp model are lower than those of the logistic and the linear models, then the cusp model shall be the best fit among the three (Hill 2001; Ploeger et al. 2002; Hartelman 1997).

Another notable feature of Cuspfit is the possibility of introducing restrictions on parameters to test specific hypotheses (Hartelman 1997). In catastrophe analysis, if one expects that one or more of the independent variables do not contribute to the normal or the splitting variable, it is possible to fix parameters at zero, so that only the non-fixed parameters are estimated. Since there are two independent variables in the cusp catastrophe model, with reference to equations (2) and (3), it is possible to construct a total of 16 different cusp models by substituting the four parameters a_1, a_2, b_1 and b_2 to zero. Then, comparing the AIC and BIC values with the unrestricted catastrophe model, the appropriate independent variables--- the normal and the splitting variables of the proposed model can be identified (Ploeger et al. 2002; van der Maas 2003; Hartelman 1997). The fit measures indicate which of the 16 cusp models is the most appropriate. As such the set of independent variables; i.e. the normal and the splitting variables is also identified (Schwarz 1978). A number of successful applications with this approach have been reported (Hill 2001; Ploeger et al. 2002; van der Maas 2003; Hartelman 1997; Stewart and Peregoy 1983).

Data Collection

To facilitate data collection, a questionnaire was designed to measure the perceptions of construction participants on the dependent and independent variables. The items of this questionnaire are listed in Tables 1, 2 and 3. The targeted respondents were construction professionals including as project managers, architects, engineers, surveyors and mediators who had at least 5 years project management experience. With reference to their recent projects, they were asked to indicate the relative significance of the variables representing CCB, co-operation force and aggression force on a seven-point Likert scale. A total of 250 questionnaires were sent out and 91 sets were completed and returned. The overall return rate is therefore 36.40%. The returned questionnaires were completed by construction professionals including project managers (15%), architects (15%), engineers (25%), quantity surveyors (42%), mediators (1%) and others (2%). Most of the respondents were holding senior positions in the industry, with 57% having more than 10 years of experience. The profiles of the respondents assure the authenticity of this study in reflecting the industry’s opinion. The profiles of the respondents according to their work experience and professional background are summarised in Figure 3.

< Figure 3 here >

Results and Discussions

The collected data were analyzed by the Cuspfit program (Cobb 1980; Hartelman 1997). The following three steps were involved:

Step 1: Modelling and testing of the appropriateness of the control variables.

Step 2: Investigating statistical fit of the models, and

Step 3: Identifying the bimodal nature of CCB.

The above procedure has been successfully adopted in other studies employing the Cuspfit program (Hill 2001; Ploeger et al. 2002; van der Maas 2003; Stewart and Peregoy 1983).

Step 1: Modelling and Testing of the Appropriateness of the Control Variables

Tables 2 and 3 list the influential variables of co-operation and aggression forces identified in the literature review. To examine which pair(s) of variables from these two forces is(are) appropriate to serve as the normal and the splitting factors, a total of 70 trials (devised from the combination of CCB variables, fourteen variables of co-operation force and five variables of aggression force) were analyzed by the Cuspfit programme. The Cuspfit programme fits the catastrophe model with the control variables α, β, and the behavior variable z to cross-sectional data by using the maximum likelihood method. With reference to equations (2) and (3), the linear function, α (the normal factor), and β (the splitting factor), for the two control variables, (x_1: co-operation force) and (x_2: aggression force) can be written as:

$\alpha = a_0 + a_1x_1 + a_2x_2$ …………………………..…(4)
$\beta = b_0 + b_1x_1 + b_2x_2$. ……………………….. (5)

According to algorithm by Cobb (1980), the setting of the control variables a_1 and b_2 of equation (4) and a_2 and b_1 of equation (5) can be fixed as zero. Hence, the linear function of α (the normal factor), and β (the splitting factor) can be devised under two conditions:

Condition 1: when $a_1 = 0$, and $b_2 = 0$, then
$\alpha = a_0 + a_2x_2$ ……………………………………………………………………...…(6)
$\beta = b_0 + b_1x_1$…………………………………………………………..………….... (7)
i.e. x_1 = splitting factor and x_2 = normal factor

or

Condition 2: when $a_2 = 0$, and $b_1 = 0$, then

$\alpha = a_0 + a_1x_1$ ……………………………………………………………………………..(8)

$\beta = b_0 + b_2x_2$……………………………………………………………………………... (9)

i.e. x_1 = normal factor and x_2 = splitting factor

To test the appropriateness of the control variables, each trial included 16 catastrophe models which were constructed by substituting the four parameters a_1, a_2, b_1 and b_2 randomly with zero. The AIC and BIC of these models were compared with those of the unrestricted model (Ploeger et al. 2002; van der Maas 2003). Significant trial(s) was (were) selected when *the lowest AIC and BIC can also fulfil either Condition 1 or Condition 2.* Accordingly, two significant catastrophe models (i.e. Model 10) were identified from two trials (Trials A and B) (Table 4 refers). Their statistical results are presented in Tables 5 and 6. These two models generally show that the degree of trust intensity (as the normal factor), contract incompleteness and competitive inertia (as the splitting factors) critically affect the sudden change of CCB.

< Table 4 here >

< Table 5 here >

< Table 6 here >

Step Two: Investigating Statistical Fit of the Models

Having confirmed the appropriateness of the normal and the splitting factors in the two identified models, the output of the Cuspfit programme also provide information on the statistical fit of the two significant models. This programme is able to test three types of models: linear, logistic and catastrophe model. The algorithm of Cobb (1980) is able to calculate whether the catastrophe, or the linear model gives a better description of the relationship between the independent and dependent variables. While the work of Hartelman (1997) enables a comparison of the catastrophe model with the logistic model. The comparison is to distinguish an arbitrarily fast acceleration from a catastrophic change (Ploeger et al. 2002). When the AIC and the BIC of the catastrophe model are lower than those of the logistic and linear models, the catastrophe model then gives a better fit (van der Maas 2003).. With reference to Tables 5 and 6, model 10 of both Trials A and B gave the lowest AIC and BIC values when compared with the linear and logistic models, hence, both models were statistically fit.

Step 3: Identifying the Bimodal Nature of Construction Contracting Behavior

The third step of analysis is to identify the bimodal nature of CCB. The Cuspfit programme gives a bifurcation diagram which shows how the data fit into the bifurcated region. If reasonable portion of the data points are located within the bifurcation set, the area between the bifurcation lines, the CCB is bimodal (Ploeger et al. 2002; van der Maas 2003). Figures 4 and 5 show the plotting results and the visual displays of the bifurcation curves respectively.

Within the bimodal zone, i.e. within the area of the bifurcation line, there exists a choice of 2 points, one in the aggressive state and the other in the co-operative state. As a point in the bimodal zone can be in either state (co-operative or aggressive), without additional information one cannot predict the outcome of further movement from such a point. However, if prior movements (i.e. past histories) are known, one could then predict the eventual state for the next movement from that point (Herbig 1991). With reference to Figure 5, in a case where the point originated from the co-operative state (point C), a change from co-operative behavior to aggressive behavior is looming (path CAB) if the trust intensity continues to decrease (i.e. CCB becomes aggressive, the path goes further from point A up to B because of their bimodal nature within the bimodal zone). Within a CT framework, CCB will not revert to co-operation even when trust intensity increase again. Likewise, if the CCB is in the aggressive state (point D), a significant increase in trust intensity will be required to effect a behavioral change (called hysteresis effect) to co-operative behavior (DEF). Hence, when the behavioral state falls within the bimodal region, it is difficult to predict the action of the contracting party. To predict which state of behavior will occur, information of the present behavioral state on the curves and recent histories of both the control variables are needed (Hill 2001; Zeeman1977; Herbig 1991). This highlights the importance of avoiding the building up of aggression forces. In parallel trust building is an effective way to release the tensions between the contracting parties.

< Figure 4 here >

< Figure 5 here >

Concluding Remarks

Most of the industry-wide reviews recommend that construction professionals should foster a new culture through more extensive use of co-operative contracting. This is considered to be one of the effective ways to reduce dispute and conflict. However, due to the fact that conflicts are inevitable in all construction projects, acting co-operatively is easier to be said then done. Contracting parties often behave aggressively in order to protect and enforce their contractual rights on one hand while look for means to shun their obligations on the other. In this connection, the dichotomous pair of co-operation and aggression forces co-exists in all construction contracting environment. This paper reports a study that examined the dynamics of CCB in the light of these two co-existing forces. Modelled under a catastrophe theory (CT) based framework, three-variable Cat models were developed. In these models, CCB is the behavioural variable and co-operation and aggression forces were arranged as normal and splitting factors. A total of 70 models was analyzed by the Cuspfit programme. Two catastrophe models were found significant. With CCB being the behavioural variable, the normal and splitting factors are trust and contract incompleteness respectively. This model affirms the positive roles that trust can play in balancing aggression. In addition, the empirical evidence fits well with the risk-based view of trust by Das and Teng (2004) who advocate that the presence of risk and uncertainty are conducive to trust development. This model suggests that if the contract is incomplete, thus unable to deal with all eventualities, the uncertainties and risks involved will be high. This type of situations has been identified by Bhattacharye et al. (1998) as ideal for co-operative effort. It is a pragmatic approach to deal with crisis resulted from the manifestation of uncertainties and risks. In those circumstances, relying on contractual provisions or legal remedies gets the contracting parties nowhere. Instead, a flexible and co-operative problem-solving attitude is needed in order to navigate through the crisis. In this respect, trust and co-operation are indeed tightly knitted. The second significant CT CCB model is similar to the one obtained from Trial A except the splitting factor is competitive inertia (CI). CI refers to the reluctance to cooperate. This may due to the hand-line and opportunistic attitude of a self-interest contracting party (Lyons and Mehta 1997). This situation is common in subcontractors who have little to lose in a ruptured contractual relationship. They are not burdened by the priori capital investment nor relationship building.

In sum, within the CT framework (Figure 5 refers), if a contracting party is in the aggressive state, a significant increase in trust intensity is needed to install a co-operative behaviour change due to the bimodal nature of CCB. In this connection, trust-building would be an important ingredient to balance aggression which dovetails the conventional wisdom of ‘prevention is better than cure’.

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Figures and Tables

	Contracting Party A – Co-operation	**Contracting Party A - Aggression**
Contracting Party B – Co-operation	Cooperate, win-win	Confront , lose much-win much
Contracting Party B - Aggression	Accommodate, win much-lose much	Attack, lose-lose

Figure 1 A payoff matrix of Construction Contracting Behavior (CCB)

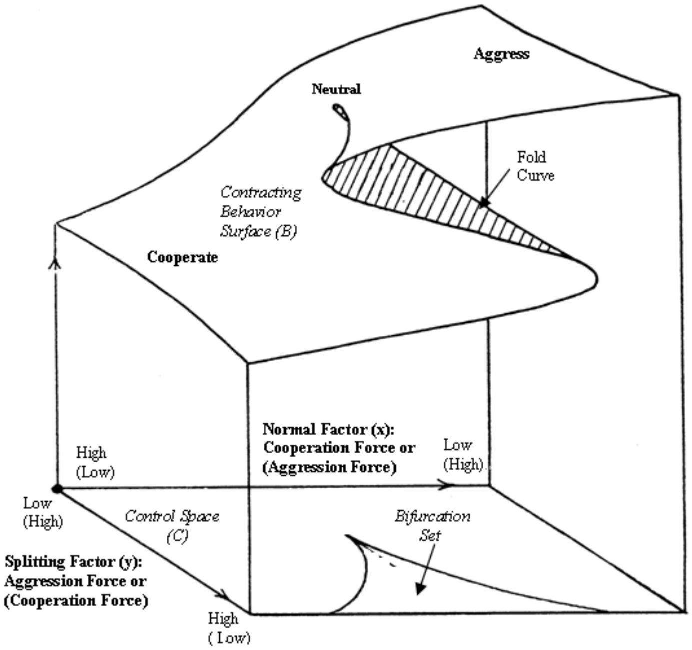


Figure 2 A Hypothetical Catastrophe Model of Construction Contracting Behavior

Table 1 Influential variables of Construction Contracting Behavior

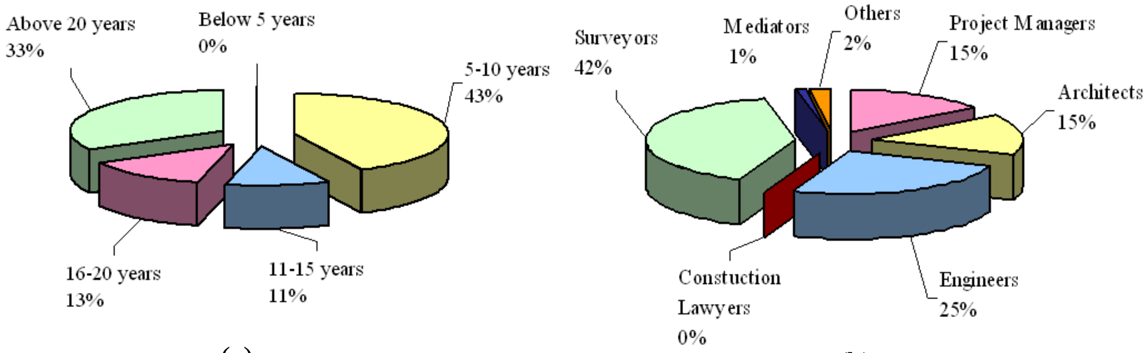
Variables	**Definitions**	**References**
Communication Channel	The extent of effective communication affects contracting behavior. Having a smooth and efficient communication channel among contracting parties enables them to work efficiently and effectively.	Cheung et al. (2003, 2004); Harmon (2003); Crane et al. (1999)
Possibility of Goal Achievement	Contracting behavior can be influenced by the goal setting of a project team. For example, if mutual goals are likely achieved, the contracting parties would behave co-operatively.	Cheung et al. (2003); Luo (2002); Harmon (2003)
Relationship among Contracting Parties	The dynamic of contracting behavior depends on the goodness of relationships among project participants	Chua et al. (1999)
Profitability	Profit-maximizing is significantly affect parties' contracting behavior. If they satisfy with their profit expectations, they would behave in a co-operative way.	Swedberg (1987)
Effectiveness of Problem Solving	Contracting behavior is influenced by effectiveness of problem solving. Previous studies suggested that it can be measured by the degree of mutual consultation and concerns of contracting party.	Luo (2002); Crane et al. (1999)
Experience of Handling Similar Projects	Contracting parties would unlikely behave aggressively if they have good experience on projects with similar complexity.	Gresov et al. (1993); Chua et al. (1999)
Achievement of Cost Target	Project's financial situation affects parties' contracting behavior. This is especially when the planned budget are probably achieved.	Luo (2002); Bacck and Cullen (1992); Cheung et al. (2004); Crane et al. (1999)
Alignment of Time Frame	Time element of construction project affects parties' contracting behavior. Contracting parties would behave aggressively when a project is not likely to be completed on time.	
Amount of Disputes	When disputes arise, no matter how specific are contractual terms, contracts alone are unable to effectively govern project operations and maintain continuity of relationship between contracting parties.	Luo (2002); Crane et al. (1999); Cheung (1993)
Degree of Contract Sum	The greater the contract sum of a project, the greater the defensiveness of contracting parties.	Hartman 1993

Table 2: Influential Variables of Co-operation Force

Variables	**Definitions**	**References**
Teamwork Intensity	Effectiveness of disputes resolution by teamwork approach of a project team.	Cheung et al. (2004); Crane et al. 1999; Hartman (1993)
Trust Intensity	Degree of confidence and trust building in contracting parties	Luo (2002); Tallman and Shenkar (1994)
Effectiveness of Communication	Satisfied previous dealings among contracting parties could facilitate effectiveness of communication	Tallman and Shenkar (1994); Doz 1996)
Goodness in Relationships between Project Participants	A good personal and working relationship among contracting parties would intensify their co-operation forces and facilitate project progress	Luo (2002); Chua et al. (1999)
Openness Level	Willingness of sharing thoughts and feelings. The extent of carrying out open communication among contracting parties.	Doz (1996); Piper (1980)
Commitment Maintenance	Commitments of contracting parties are enduring when they are highly involved in project issues.	Luo (2002)
Goal Mutuality	Establishment of common goal between contracting parties	Black et al. (1999); Luo (2002)
Availability of Information	Efficiency of information exchange among contracting parties and their experience in handling similar project(s)	Luo (2002); Zeeman (1977)
Involvement Intensity	Degree of voluntariness in project participation.	Zeeman (1977)
Incentive Intensity to Risks and Savings Sharing	Degree of contractual risk allocations among contracting parties, the provision of tangible reward (s), and the degree of risk averseness of contracting parties	McKim (1992)
Effectiveness in Dispute Resolution	Appropriateness of incorporating contract provisions to resolve disputes, unforeseeable events and contingencies.	Luo (2002); Cheung et al.(2004); Doz (1996)
Effectiveness in Solving / Sharing of Problem(s)	Appropriateness of incorporating contract provisions for mutual consultations among contracting parties	Cheung et al. (2003); Luo (2002); Doz (1996); Piper (2001)
Contract Completeness	Explicitness, term specificity and contingency adaptability of contract conditions	Luo (2002)
Inter-party Reciprocity	Desire to maintain future business relationships among contracting parties	Black et al. (1999); Cheung et al. (2003); Luo (2002)

Table 3: Influential Variables of Aggression Force

Variables	**Definitions**	**References**
Quality of the Past / Previous Dealings	Satisfaction of previous dealings among contracting parties	Tallman and Shenkar (1994); Luo (2002)
Level of Competitive Pressure	Amount of pressure perceived by contracting parties would directly affect their aggressiveness	Gresov et al. (1993)
Intensity of Competitive Force/Competitive Inertia	Competitive force or competitive inertia is determined by the aggressiveness of contracting parties on comparison to the actions being taken by their competitors.	Gresov et al. (1993); McKim (1992)
Likelihood of Disputes	The higher the likelihood of disputes, the higher the aggression forces of contracting parties are induced.	Luo (2002); Doz (1996)
Contract Incompleteness	Aggression forces are likely to invoked if many ambiguous terms exist in contract conditions	Luo (2002); Goldberg (1992)



(a) (b)

Figure 3 Profiles of respondents by (a) working experience and (b) professions

Table 4 Findings of Catastrophe Analyses

	Model 10 from Trial A	**Model 10 from Trial B**
Dependent Variables	Construction Contracting Behavior	Construction Contracting Behavior
Normal Factor (α)	Trust Intensity*	Trust Intensity*
Splitting Factor (β)	Contract Incompleteness**	Competitive Inertia***

* Trust Intensity is defined as the degree of confidence and trust building in the contracting parties.

** Contract Incompleteness is defined as the degree of term specificity and contingency adaptability in a contract.

***Competitive Inertia is the degree of aggressiveness of a contracting party on comparison to the actions being taken by counterpart.

Note: The surveyed variables of Trust Intensity, Contract Incompleteness and Competitive Inertia are given in Appendix A.

Table 5 Catastrophe Analysis of Significant Trial A (adopted from Ploeger et al.(2002))

Model	a_0	a_1	a_2	b_0	b_1	b_2	λ	σ	Log likelihood	Parameters	AIC	BIC
1	-0.30	0	0	-1.31	0	0	0.20	1.54	-0.1282E+03	4	0.2645E+03	0.2745E+03
2	0.88	0	0	-2.01	0	-1.65	-0.56	1.59	-0.1199E+03	5	0.2498E+03	0.2623E+03
3	-5.00	0	0	-2.89	-1.30	0	2.61	2.33	-0.1174E+03	5	0.2448E+03	0.2574E+03
4	5.00	0	0	-4.54	1.27	-0.83	-2.10	2.32	-0.1149E+03	6	0.2417E+03	0.2568E+03
5	-0.33	0	-0.51	-1.55	0	0	0.20	1.55	-0.1239E+03	5	0.2579E+03	0.2704E+03
6	0.09	0	-0.35	-1.04	0	-1.17	-0.15	1.35	-0.1192E+03	6	0.2504E+03	0.2654E+03
7	-5.00	0	-0.60	-3.60	-1.33	0	2.32	2.28	-0.1153E+03	6	0.2425E+03	0.2576E+03
8	-4.82	0	-2.00	-5.00	-1.70	-1.96	1.75	2.21	-0.1125E+03	7	0.2390E+03	0.2565E+03
9	-0.36	0.97	0	-2.08	0	0	0.18	1.55	-0.1163E+03	5	0.2425E+03	0.2551E+03
10	*0.69*	*0.84*	*0*	*-2.04*	*0*	*-1.40*	*-0.40*	*1.47*	*-0.1107E+03*	6	*0.2334E+03*	*0.2485E+03*
11	-0.43	0.96	0	-2.07	-0.08	0	0.22	1.55	-0.1163E+03	6	0.2445E+03	0.2596E+03
12	0.72	0.92	0	-2.26	-0.22	-1.50	-0.38	1.50	-0.1106E+03	7	0.2352E+03	0.2528E+03
13	-0.29	0.91	-0.38	-2.20	0	0	0.14	1.55	-0.1144E+03	6	0.2407E+03	0.2558E+03
14	0.19	0.76	-0.23	-1.51	0	-1.14	-0.17	1.36	-0.1104E+03	7	0.2348E+03	0.2524E+03
15	-0.46	0.89	-0.39	-2.18	-0.19	0	0.25	1.55	-0.1143E+03	7	0.2426E+03	0.2602E+03
16	0.00	0.79	-0.32	-1.59	-0.35	-1.21	-0.04	1.36	-0.1100E+03	8	0.2360E+03	0.2561E+03
Linear*									-0.1431E+03	4	0.2942E+03	0.3042E+03
Logistic*									-0.1135E+03	5	0.2370E+03	0.2496E+03

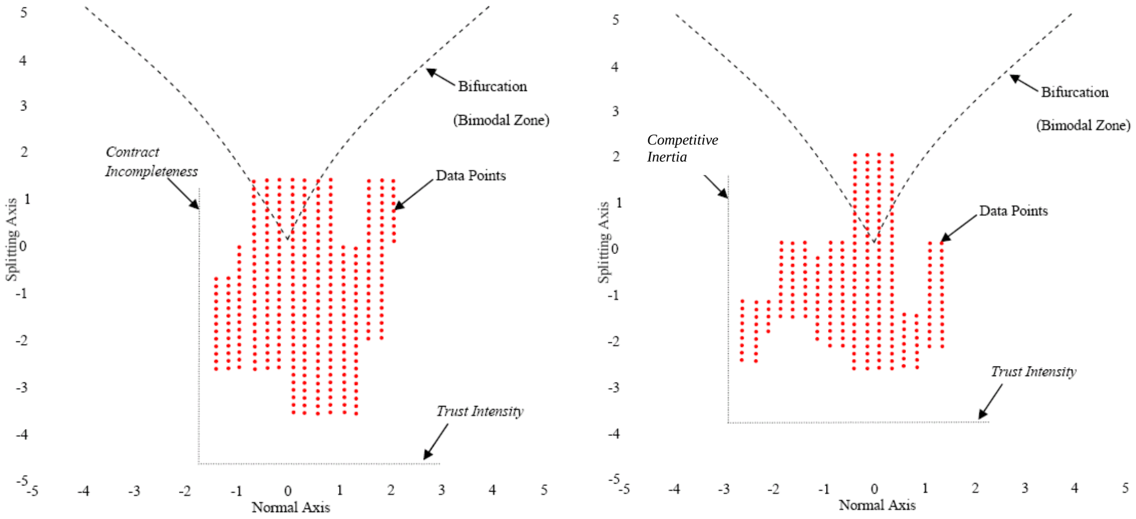
Note: * Unconstrained linear and logistic models; Model 1-16: cusp models

a_0 is the constant of the normal variable; b_0 is the constant of the splitting variable; a_1 and b_2 are parameters of the normal factor; a_2 and b_1 are parameters of the splitting factor; λ is the location, σ is the scale and zeros are fixed parameters.

Table 6 Catastrophe Analysis of Significant Trial B (adopted from Ploeger et al.(2002))

Model	a_0	a_1	a_2	b_0	b_1	b_2	λ	σ	Log likelihood	Parameters	AIC	BIC
1	-0.26	0	0	-2.27	0	0	0.15	1.77	-0.1287E+03	4	0.2655E+03	0.2755E+03
2	0.21	0	0	-1.52	0	-0.88	-0.14	1.53	-0.1254E+03	5	0.2608E+03	0.2733E+03
3	-5.00	0	0	-3.75	-1.37	0	2.37	2.37	-0.1186E+03	5	0.2473E+03	0.2598E+03
4	-5.00	0	0	-3.67	-1.35	0.03	2.39	2.37	-0.1186E+03	6	0.2492E+03	0.2643E+03
5	-0.26	0	-0.18	-2.30	0	0	0.14	1.77	-0.1283E+03	5	0.2666E+03	0.2792E+03
6	-0.01	0	-0.09	-1.37	0	-0.82	-0.02	1.50	-0.1253E+03	6	0.2625E+03	0.2776E+03
7	-5.00	0	-0.26	-3.78	-1.37	0	2.35	2.36	-0.1182E+03	6	0.2483E+03	0.2634E+03
8	-5.00	0	-1.20	-5.00	-1.63	-1.43	1.98	2.35	-0.1161E+03	7	0.2461E+03	0.2637E+03
9	-0.31	1.02	0	-3.17	0	0	0.14	1.78	-0.1182E+03	5	0.2464E+03	0.2589E+03
10	*0.11*	*0.89*	*0*	*-2.07*	*0*	*-0.90*	*-0.07*	*1.51*	*-0.1146E+03*	*6*	*0.2413E+03*	*0.2563E+03*
11	-0.69	0.97	0	-3.05	-0.30	0	0.34	1.77	-0.1181E+03	6	0.2481E+03	0.2632E+03
12	0.05	0.90	0	-2.07	-0.20	-0.93	-0.02	1.51	-0.1145E+03	7	0.2431E+03	0.2607E+03
13	-0.30	1.03	-0.21	-3.21	0	0	0.13	1.78	-0.1177E+03	6	0.2474E+03	0.2624E+03
14	0.07	0.89	-0.02	-2.06	0	-0.89	-0.05	1.51	-0.1146E+03	7	0.2433E+03	0.2608E+03
15	-0.67	0.98	-0.21	-3.09	-0.29	0	0.33	1.77	-0.1176E+03	7	0.2491E+03	0.2667E+03
16	-0.11	0.88	-0.06	-2.03	-0.25	-0.89	0.06	1.50	-0.1145E+03	8	0.2450E+03	0.2651E+03
Linear*									-0.1402E+03	4	0.2884E+03	0.2985E+03
Logistic*									-0.1163E+03	5	0.2426E+03	0.2552E+03

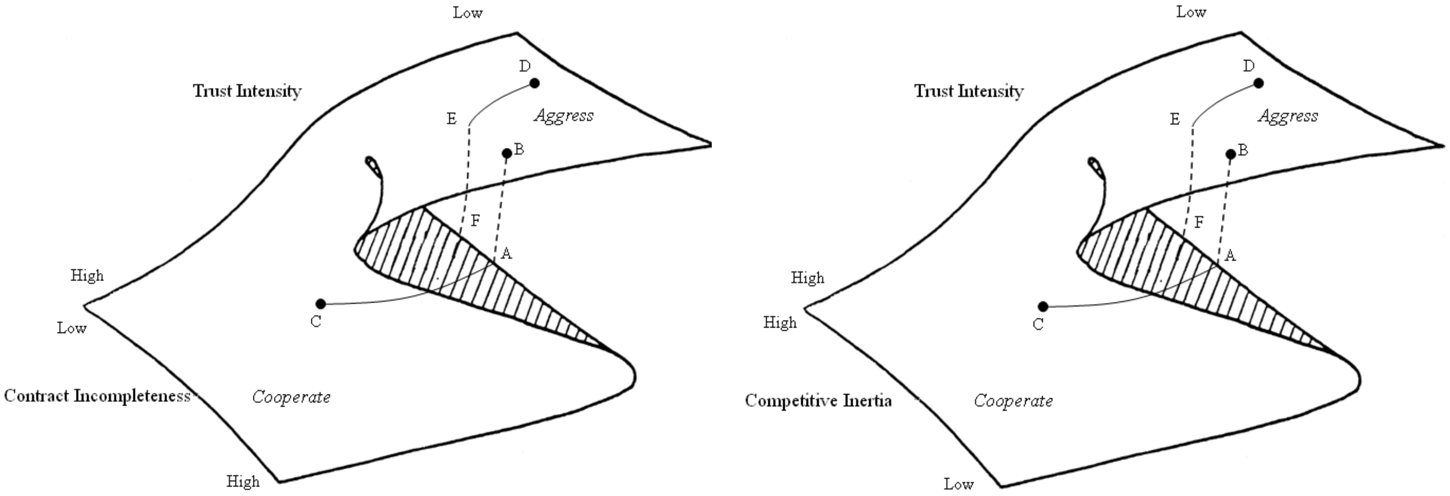
Note: Same as Table 5



(a)

(b)

Figure 4 Bifurcation diagram in the control space of the catastrophe models with (a) trust intensity as normal factor and contract incompleteness as splitting factor; (b) trust intensity as normal factor and competitive inertia as splitting factor



(a) (b)

Figure 5 Contracting Behavioural Surface of the Two Significant Catastrophe Models of Construction Contracting Behavior (From Trials A and B)

Appendix A:

A sample of surveyed variables[#] for Trust Intensity, Contract Incompleteness and Competitive Inertia:

Trust Intensity:-

1. Your project team paid due regard to the respective rights, benefits and responsibilities and the plan, polices and strategies stipulated in the Contract;
2. The previous dealing(s) between the project participants reinforced confidence of your project team in working with each other;
3. Overly detailed contractual procedures to deal with contingencies were unlikely deterred your project team's motivation to maintain commitment.

Contract Incompleteness:-

1. Guidelines and possible solutions for handling various unanticipated contingencies/future problems had been incorporated in the Contract.
2. The substantial amount (monetary) of investment in this project had led to more likely to incorporate more detailed contract conditions and contractual procedures to deal with contingencies.
3. The long project duration had led to the incorporation of more detailed contract conditions and contractual procedures to deal with contingencies.

Competitive Inertia: -

1. The actions being taken by other contracting parties were strongly aggressive.
2. The capital necessary for the project operation had been in general insufficient.
3. Low interdependency between project participants had lead to your party more likely taking advantage over the others.

[#] All of the above variables were rated on a Likert scale from (1) Strongly Disagree to (7) Strongly Agree.