Chapter 4
Catastrophic Transitions of Construction Contracting Behaviour

Sai On Cheung and Tak Wing Yiu

Abstract This chapter reports a study on the examination of construction contracting behaviour (CCB) under the influence of the competing forces of co-operation and aggression. The CCB dynamics under these forces are modeled on the Catastrophe Theory (CT) developed by Thom (1975). Mathematical treatment allows analytical examination of the dynamics among the interacting variables. A bifurcation zone within which the behaviour becomes bimodal characterises CT model. Under a CT framework, a small change in the aggression drive can produce a significant sudden change in contracting behaviour; this phenomenon is called divergence. The CCB framework is developed by the identification and establishment of indicators for the three variables; contracting behaviour, co-operation and aggression drivers. These variables are used to test the catastrophic phase transitions of CCB. It is found that 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, problems can be easily be escalated to become disputes.

4.1 Characteristics of Construction Contracting

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 needs to be

---

S. O. Cheung (✉)
Construction Dispute Resolution Research Unit, Department of Civil and Architectural Engineering, City University of Hong Kong, Hong Kong, People's Republic of China
e-mail: saion.cheung@cityu.edu.hk

T. W. Yiu
Department of Civil and Environmental Engineering, Faculty of Engineering,
The University of Auckland, Auckland, New Zealand
e-mail: k.yiu@auckland.ac.nz

S. O. Cheung (ed.), *Construction Dispute Research*,
DOI: 10.1007/978-3-319-04429-3_4,

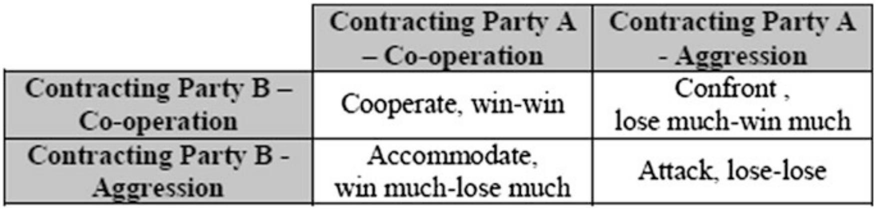
overhauled (Bayliss et al. 2004; Cheung et al. (2003a, b); Cheung and Suen 2002). This view is expressed in a number of industry-wide reviews (Construction Industry Review Committee (CIRC) 2001; Egan 1998; Latham 1994). Fostering co-operation in construction contracting has been suggested to alleviate this situation. However, this is considered to be a revolutionary attitude change that can only be made possible with a transformation in culture. 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 (Bayliss 2002; Bayliss et al. 2004; Black et al. 2000; Cheung et al. 2002) and are valuable learning models for the practice of co-operative contracting. Nonetheless, skeptics often comment that every construction project is unique; hence it is risky to generalise 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 behavioural or attitudinal, thus augmenting the common belief that contracting behaviour 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). 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 of co-operative contracting has 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 recognised 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 behaviour 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 behaviour remains largely adversarial in the construction industry (Construction Industry Review Committee (CIRC) 2001; Egan 1998; Latham 1994). The conventional design-bid-build approach is not conducive in enhancing co-operation (Cheung et al. (2003a, b). Contractual terms, however comprehensive, would not be able to cover all eventualities. Unanticipated happenings are testing and a co-operative contracting behaviour could curb disputes nourishing (Cheung 2002; Luo 2002). Co-operative contracting behaviour 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 can be adopted to deal with unanticipated eventualities (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 behaviour 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 organisations 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.

4.2 Construction Contracting Behaviour: Co-operation Versus Aggression Forces

According to Hill (2001), contracting behaviour 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 behaviour 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 behaviour 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 (Fenn et al. 1997; Yiu and Cheung 2006). Opportunism is therefore common. Contracting parties would exercise opportunistic and aggressive behaviour 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 Fig. 4.1, 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 behaviour of



	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

Fig. 4.1 Payoff matrix of construction contracting behaviour (CCB)

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 Fig. 4.1.

The payoff matrix in Fig. 4.1 suggests that co-operative behaviour is not innate. Instead, practice of co-operative behaviour is characterised 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. 2003a, b; Wong et al. 2005). This implies that the contracting behaviour of one party is dynamically associated with the others. It is therefore hypothesised that a threshold exists for the transition from co-operative to aggressive contracting behaviour. When this threshold is reached, a sudden change in behaviour will occur. The theoretical explanation of such a behavioural transition can be found in Catastrophe Theory (Thom 1975).

4.3 Catastrophe Theory

Catastrophe Theory was developed by Thom (1975) and subsequently popularised by Zeeman (1976, 1977). It is a mathematical model of nonlinear systems in which discontinuous behaviour is determined by smooth changes in a small number of parameters (Wagenmakers et al. 2004). 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). One of the popular applications of CT is attitude-based analysis. In management, it has also been applied to study technology management (Bacck and Cullen 1992; Herbig 1991), organisational change (Gresov et al. 1993), competitive strategies (Oliva et al. 1988), customer behaviour (Oliva et al. 1992), motivation in organisations (Guastello 1987), forecasting and decision making (Wright 1983) and conflict resolution (Yiu and Cheung 2006).

4.3.1 Catastrophe Model of Construction Contracting Behaviour

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 moderating 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 behaviour surface (B) of the CT model (Fig. 4.2 refers).

In this study, it is hypothesised that a party’s contracting behaviour 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 these two forces, depicted as the contracting behaviour surface (B) in Fig. 4.2. 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 behaviour indicated as a point above the corresponding point in the control space and at an appropriate height on the behaviour axis (vertical axis). The full set of such points together forms the contracting behaviour surface (B). In general, there is only one probable mode of behaviour. 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 behaviour. They are connected by a third sheet to form a continuous pleated surface. This sheet represents the least likely behaviour, in this case, neutrality (Zeeman 1977). Towards the origin, the pleat on the contracting behaviour 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.

4.3.2 Construction Contracting Behaviour 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

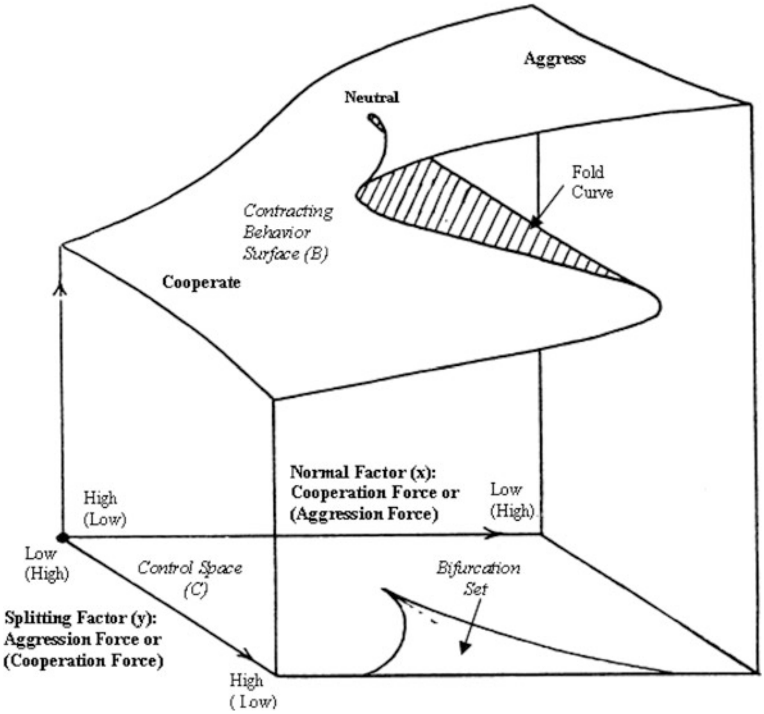


Fig. 4.2 A hypothetical catastrophe model of construction contracting behaviour

such construction contracting behaviour. As shown in Fig. 4.2, construction contracting behaviour is manifested by a combination of co-operation and aggression forces. Based on literature review, its influential variables are identified and summarised in Table 4.1.

4.3.3 Co-operation Force and Aggression Force as Independent Variables

As per the model presented in Fig. 4.2, co-operation and aggression forces are two co-existing conflicting forces that affect construction contracting behaviour. 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. These behaviours are often adversarial and invoke aggression, retaliation and defensive responses. The dichotomous nature of these two forces can be demonstrated by the framework of Prisoner's Dilemma (PD) as

Table 4.1 Influential variables of construction contracting behaviour

Variables	Definitions	References
Communication channel	The extent of effective communication affects contracting behaviour. Having a smooth and efficient communication channel among contracting parties enables them to work efficiently and effectively	Cheung et al. (2003b, 2004), Crane et al. (1999), Harmon (2003)
Possibility of goal achievement	Contracting behaviour 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. (2003b), Harmon (2003), Luo (2002)
Relationship among contracting parties	The dynamic of contracting behaviour depends on the goodness of relationships among project participants	Chua et al. (1999)
Profitability	Profit-maximising is significantly affect parties' contracting behaviour. If they satisfy with their profit expectations, they would behave in a co-operative way	Swedberg (1987)
Effectiveness of problem solving	Contracting behaviour 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	Crane et al. (1999), Luo (2002)
Experience of handling similar projects	Contracting parties would unlikely behave aggressively if they have good experience on projects with similar complexity	Chua et al. (1999), Gresov et al. (1993)
Achievement of cost target	Project's financial situation affects parties' contracting behaviour. This is especially when the planned budget are probably achieved	Bacck and Cullen (1992), Cheung et al. (2004), Crane et al. (1999), Luo (2002)
Alignment of time frame	Time element of construction project affects parties' contracting behaviour. 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	Cheung (1993), Crane et al. (1999), Luo (2002)
Contract sum	The greater the contract sum of a project, the greater the defensiveness of contracting parties	Hartman (1993)

afore-described. It is therefore imperative that contracting parties shall prevent such moves so as to maintain good relationships. In summary, in modeling CCB, both co-operation and aggression forces should be considered. Their variables are presented in Tables 4.2 and 4.3 respectively.

The fitness of the model presented in Fig. 4.2 and the appropriateness of the independent variables are to be tested empirically. The steps in conducting the fit measurements are discussed here-follow.

4.4 Model Fitting

Early CT model fitting employed regression and stochastic differential equations to estimate model parameters (Gresov et al. 1993; van der Maas et al. 2003; Yiu and Cheung 2006). 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 behaviour 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 (Cobb 1978, 1980; Cobb et al. 1983; Gresov et al. 1993). Mathematically, the contracting behaviour surface can be expressed by Eq. 4.1 (Cobb 1980, 1983):

$$f(z|\alpha,\ \beta)\ \exp\left(\alpha y + \frac{1}{2}\beta y^2 - \frac{1}{4}y^4\right) \tag{4.1}$$

where $y = \frac{(z-\lambda)}{\sigma}$, λ and σ scale the observed behavioural variable z to y; α and β are linear functions of the independent variables x_1 to x_n, with

$$\alpha = a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n \tag{4.2}$$

and;

$$\beta = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n \tag{4.3}$$

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 optimisation routine which allows users to constrain parameter

Table 4.2 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	Doz (1996), Tallman and Shenkar (1994)
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	Chua et al. (1999), Luo (2002)
Openness level	Willingness of sharing thoughts and feelings. The extent of carrying out open communication among contracting parties	Doz (1996), Piper (2001)
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. (2000), 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	Cheung et al. (2004), Doz (1996), Luo (2002)
Effectiveness in solving/ sharing of problem(s)	Appropriateness of incorporating contract provisions for mutual consultations among contracting parties	Cheung et al. (2003b), Doz (1996), Luo (2002), 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. (2000), Cheung et al. (2003b), Luo (2002)

Table 4.3 Variables of aggression force

Variables	Definitions	References
Quality of the past/previous dealings	Satisfaction of previous dealings among contracting parties	Luo (2002), Tallman and Shenkar (1994)
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	Doz (1996), Luo (2002)
Contract incompleteness	Aggression forces are likely to invoked if many ambiguous terms exist in contract conditions	Goldberg (1992), Luo (2002)

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 (Cobb 1980; Ploeger et al. 2002; Wagenmakers et al. 2004). 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 (Hartelman 1997; Hill 2001; Ploeger et al. 2002).

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. "$\mathrm{AIC} = -2 \log L + 2k$"; the model with the smallest AIC will be the best fit (Hartelman 1997; Hill 2001; Ploeger et al. 2002). 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; Raftery 1995; Schwarz 1978). Mathematically, BIC is calculated by the equation "$\mathrm{BIC} = -2 \log L + k \log n$", 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 (Hartelman 1997; Hill 2001; Ploeger et al. 2002).

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 Eqs. 4.2 and 4.3, it is possible to construct a total of 16 different cusp models by substituting the four parameters a1, a2, b1 and b2 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 (Hartelman 1997; Ploeger et al. 2002; Van der Maas et al. 2003). 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 (Hartelman 1997; Hill 2001; Ploeger et al. 2002; Stewart and Peregoy 1983; Van der Maas et al. 2003).

4.5 Data Collection

To facilitate data collection, a questionnaire was designed to measure the perceptions of construction professionals on the dependent and independent variables. The items of this questionnaire are listed in Tables 4.1, 4.2 and 4.3. 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 Fig. 4.3.

4.6 Results and Discussions

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

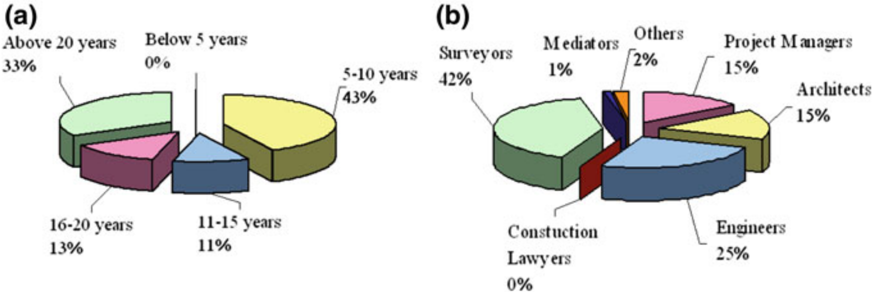


Fig. 4.3 Profiles of respondents by **a** working experience and **b** professions

(I). Step 1: Modeling and testing of the appropriateness of the control variables.
(II). Step 2: Investigating statistical fit of the models, and
(III). 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; Stewart and Peregoy 1983; Van der Maas et al. 2003).

(i) Step 1: Modelling and Testing of the Appropriateness of the Control Variables

Tables 4.2 and 4.3 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 analysed by the Cuspfit programme. The Cuspfit programme fits the catastrophe model with the control variables α, β, and the behaviour variable z to cross-sectional data by using the maximum likelihood method. With reference to Eqs. 4.2 and 4.3, 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:

$$\alpha = a_0 + a_1x_1 + a_2x_2 \tag{4.4}$$

$$\beta = b_0 + b_1x_1 + b_2x_2 \tag{4.5}$$

According to algorithm by Cobb (1980), the setting of the control variables a1 and b2 of Eq. 4.4 and a2 and b1 of Eq. 4.5 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

$$\alpha = a_0 + a_2x_2 \tag{4.6}$$

$$\beta = b_0 + b_1x_1 \tag{4.7}$$

where x_1 = splitting factor and x_2 = normal factor

or

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

$$\alpha = a_0 + a_1x_1 \tag{4.8}$$

$$\beta = b_0 + b_2x_2 \tag{4.9}$$

where 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 a1, a2, b1 and b2 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 et al. 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 4.4 refers). Their statistical results are presented in Tables 4.5 and 4.6. 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.

ii) 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 et al. 2003). With reference to Tables 4.5 and 4.6, 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.

iii) Step 3: Identifying the Bimodal Nature of Construction Contracting Behaviour

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 et al. 2003). Figs. 4.4 and 4.5 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

Table 4.4 Findings of Catastrophe Analyses

	Model 10 from Trial A	Model 10 from Trial B
Dependent Variables	Construction Contracting Behaviour	Construction Contracting Behaviour
Normal Factor (α)	Trust Intensity[a]	Trust Intensity[a]
Splitting Factor (β)	Contract Incompleteness[b]	Competitive Inertia[c]

Surveyed variables (rated on a Likert scale from (1) strongly disagree to (7) strongly agree):-

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 led to your party more likely taking advantage over the others.

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

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

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

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 Fig. 4.5, in a case where the point originated from the co-operative state (point C), a change from co-operative behaviour to aggressive behaviour 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 behavioural change

Table 4.5 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[a]									−0.1431E + 03	4	0.2942E + 03	0.3042E + 03
Logistic[a]									−0.1135E + 03	5	0.2370E + 03	0.2496E + 03

Note [a] 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 4.6 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[a]									−0.1402E + 03	4	0.2884E + 03	0.2985E + 03
Logistic[a]									−0.1163E + 03	5	0.2426E + 03	0.2552E + 03

Note [a] 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

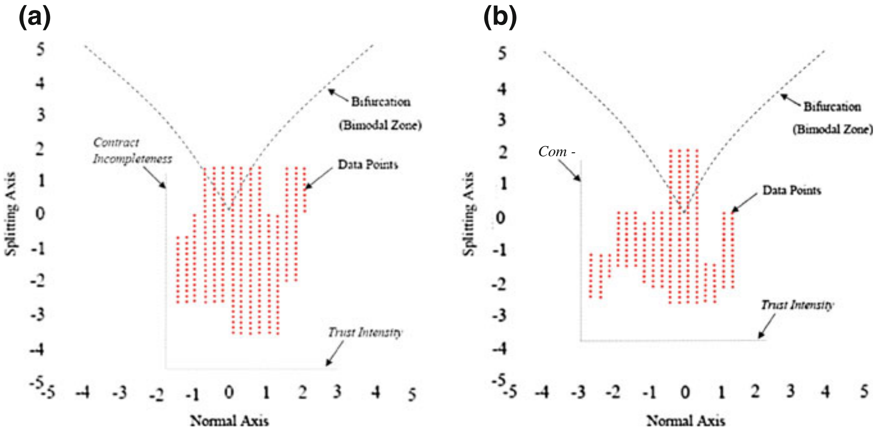


Fig. 4.4 Bifurcation diagram in the control space of the catastrophe models with **a** trust intensity as normal factor and contract incompleteness as splitting factor; **b** trust intensity as normal factor and competitive inertia as splitting factor

(called hysteresis effect) to co-operative behaviour (DEF). Hence, when the behavioural state falls within the bimodal region, it is difficult to predict the action of the contracting party. To predict which state of behaviour will occur, information of the present behavioural state on the curves and recent histories of both the control variables are needed (Herbig 1991; Hill 2001; Zeeman 1977). 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.

4.7 Chapter Summary

Most of the industry-wide reviews recommend that construction contracting should embrace a culture of co-operation. 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 construction projects, acting co-operatively is easier to be said than 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 chapter examines the dynamics of CCB in the light of these two co-existing forces. Modeled 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 analysed by the Cuspfit programme. Two catastrophe

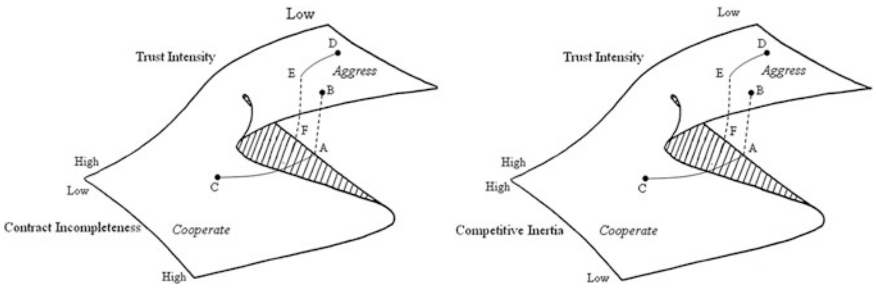


Fig. 4.5 Contracting behavioural surface of the two significant catastrophe models of construction contracting behaviour (from Trials A and B)

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 situation is ideal platform to demonstrate the functionalities of co-operative efforts (Bhattacharya et al. 1998). 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 hard-line and opportunistic attitude of a self-interest seeking contracting party (Lyons and Mehta 1997). This situation is common with desperate subcontractors who have little to lose in a ruptured contractual relationship. They are not burdened by the priori capital investment or relationship building. Problems can easily be escalated to become disputes when parties are in aggressive mode.

In sum, within the CT framework (Fig. 4.5), if a contracting party is in the aggressive state, a significant increase in trust intensity is needed to install a co-operative behaviour change as suggested by 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’.

Acknowledgments Special thanks to Professor Van der Maas for his advice on the use of the Cuspfit programme and Miss On Kiu Chiu for collecting data for the study. The content of this chapter has been published in Volume 134(12) of the Journal of Construction Engineering and Management and is used with the permission from ASCE.

References

Axelrod, R. (1984). *The evolution of cooperation*. New York: Basic Books.

Bacck, D., & Cullen, J. B. (1992). A catastrophe theory model of technological and structural change. *The Journal of High Technology Management Research, 3*(1), 125–145.

Bayliss, R. (2002). Project partnering—A case study on MTRC's Tseung Kwan O Extension. *HKIE Transactions, 9*(1), 1–6.

Bayliss, R., Cheung, S. O., Suen, C. H., & Wong, S. P. (2004). Effective partnering tools in construction: A case study on MTRC TKE Contract 604 in Hong Kong. *International Journal of Project Management, 22*, 253–263.

Bhattacharya, R., Devinney, T. M., & Pillutla, M. M. (1998). A formal model of trust based on outcomes. *Academy of Management Review, 23*(3), 459–472.

Black, C., Akintoye, A., & Fitegerald, E. (2000). An analysis of success factors and benefits of partnering in construction. *International Journal of Project Management, 18*, 423–434.

Buckley, P., & Casson, M. (1988). Cooperative strategies in international business. In F. J. Contractor & P. Lorange (Eds.), *Lexington books* (pp. 31–34) Lexington: Mass.

Cheung, S. O. (2007). *Trust in co-operative contracting in construction*. Hong Kong: City University of Hong Kong Press.

Cheung, S. O., Ng, S. T., Wong, S. P., & Suen, C. H. (2003a). Behavioral aspects of construction partnering. *The International Journal of Project Management, 21*(5), 333–343.

Cheung, S. O. (1993). A study of the application of ADR in the construction industry in Hong Kong, Research Report, Department of Building and Construction, City Polytechnic of Hong Kong.

Cheung, S. O. (2001). Relationalism: Construction contracting under the PRC contract law. *Cost Engineering, AACEI, 43*(11), 38–44.

Cheung, S.O. (2002). Mapping dispute resolution mechanism with contract types, Cost Engineering. AACE, *44*(8), 21–29.

Cheung, S. O., & Suen, C. H. (2002). A multi-attribute utility model for dispute resolution strategy selection. *Construction Management and Economics, 20*, 557–568.

Cheung, S. O., Suen, C. H., & Bayliss, R. (2002). The partnering experience of MTRC Tseung Kwan O Contract 604. *The International Construction Law Review, 19*(4), 510–520.

Cheung, S. O., Suen, C. H., & Cheung, K. W. (2003b). An automated partnering monitoring system—Partnering temperature index. *Automation in Construction, 12*, 331–345.

Cheung, S. O., Suen, C. H., & Cheung, K. W. (2004). PPMS: A web-based construction project performance monitoring system. *Automation in Construction, 13*(3), 361–376.

Chua, D. K. H., Kog, Y. C., & Loh, P. K. (1999). Critical success factors for different project objectives. *Journal of Construction Engineering and Management, ASCE, 125*(3), 142–150.

Cobb, L. (1978). Stochastic catastrophe models and multimodal distributions. *Behavioral Science, 23*(2), 360–416.

Cobb, L. (1980). *Estimation theory parameter estimation for the Cusp Catastrophe model: Proceeding of the Section on Survey Research Methods* (pp. 772–776). Washington, DC: American Statistical Association.

Cobb, L. (1981). Parameter estimation for the Cusp Catastrophe model. *Behavioral Science, 26*, 75–78.

Cobb, L., Koppstein, P., & Chen, N. H. (1983). Estimation and moment recursion Relations for multimodal distributions of the exponential family. *Journal of the American Statistical Association, 80*, 793–802.

Colledge, B. (2000). Obligations of good faith in partnering of U.K.: Construction contracts. *The International Construction Law Review, 17*(1), 174–201.

Construction Industry Review Committee (CIRC). (2001). Tang's Report on the Hong Kong Construction Industry Reform, Construction Industry Review Committee, HKSAR.

Crane, T. G., Felder, J. P., Thompson, P. J., Thompson, M. G., & Sanders, S. R. (1999). Partnering parameters. *Journal of Management in Engineering, 15*(2), 37–42.

Das, T. K., & Teng, B. S. (2004). The risk-based view of trust: a conceptual framework. *Journal of Business and Psychology, 19*(1), 85–116.

Doz, Y. L. (1996). The evolution of cooperation in strategic alliances: Initial conditions or learning processes? *Strategic Management Journal, Special Issue Summer, 17*, 55–83.

Egan, J. (1998). *Rethinking construction, department of the environment, transport and the region*. London: HMSO.

Fenn, P., Lowe, D., & Speck, C. (1997). Conflict and dispute in construction. *Construction Management and Economics, 15*(6), 513–518.

Goldberg, V. P. (1992). The past is the past—Or is it? the use of retrospective accounts as indicators of past strategy. *Academy of Management Journal, 35*, 848–860.

Gresov, C., Haveman, H., & Oliva, T. (1993). Organizational design inertia and the dynamics of competitive response. *Organization Science, 4*(2), 181–208.

Guastello, S. J. (1987). A butterfly catastrophe model of motivation in organizations: Academic Performance. *Journal of Applied Psychology, 72*, 165–182.

Harmon, K. M. (2003). Conflicts between owner and contractors: Proposed intervention process. *Journal of Management in Engineering, 19*(3), 121–125.

Hartelman, P. A. I. (1997). *Stochastic catastrophe theory*. Amsterdam: Faculteit der Psychologies.

Hartman, F.T. (1993). Construction dispute resolution through an improved contracting process in the Canadian context, PhD Thesis. Loughborough: Loughborough University of Technology.

Herbig, P. A. (1991). A Cusp Catastrophe Model of the adoption of an industrial innovation. *Journal of Production Innovation Management, 8*, 127–137.

Hill, C. A. (2001). A comment on language and norms in complex business contracting. *Chicago-Kent Law Review, 77*(29), 29–57.

Holyst, J. A., Kacperski, K., & Schweitzer, F. (2000). Phase transitions in social impact models of opinion formation. *Physica A, 285*, 199–210.

Latham, M. (1994). Constructing the Team: Final Report by Sir Michael Latham; Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry. London: HMSO.

Liu, M. M., & Fellows, R. (2001). An eastern perspective on partnering. *Engineering, Construction and Architectural Management, 8*(1), 9–19.

Luo, Y. (2002). Contract, cooperation and performance in international joint ventures. *Strategic Management Journal, 23*, 903–919.

Lyons, B., & Mehta, J. (1997). Contracts, opportunism and trust: Self-interest and orientation. *Cambridge Journal of Economics, 21*, 239–257.

Macaulay, S. (1985). An empirical view of contract, Wisconsin Law Review, pp. 465–482.

Macneil, I.R. (1980). The New Social Contract: An inquiry into Modern Contractual Relations, New Haven.

Macneil, I. R. (1981). Economic analysis of contractual relations: Its shortfalls and the need for a rich classificatory apparatus. *Northwestern University Law Review, 75*, 1018–1063.

McKim, R. A. (1992). Risk behavior of contractors: a Canadian study. *Project Management Journal, 23*(3), 51–55.

Newman, P. (2000). Partnering, with particular reference to construction. *Arbitration Journal, 66*(1), 39.

Oliva, T. A., Day, D., & MacMillan, T. (1988). A generic model of competitive dynamics. *Academy of Management Review, 13*, 374–389.

Oliva, T. A., Oliva, R. L., & MacMillan, I. C. (1992). A catastrophe model for developing service satisfaction strategies. *Journal of Marketing, 56*, 83–95.

Piper, B. J. (2001). Partnering: a dream? *Newsletter of the Hong Kong Institute of Surveyors, 8*(10), 22–23.

Ploeger, A., Van der Maas, H. L. J., & Hartelman, P. A. (2002). Stochastic catastrophe analysis of switches in the perception of apparent motion. *Psychonomic Bulletin and Review, 9*(1), 26–42.

Qin, S. Q., Jiao, J. J., & Wang, S. T. (2001). A Cusp Catastrophe Model of slip-buckling slope. *Rock Mechanics and Rock Engineering, 34*(2), 119–134.

Raftery, A. E. (1995). Bayesian model selection in social research. *Sociological Methodology, 25*, 111–163.

Schwarz, G. (1978). Estimating the Dimension of a Model. *Annals of Statistics, 6*, 461–464.

Stewart, I. N., & Peregoy, P. L. (1983). Catastrophe Theory modeling in psychology. *Psychological Bulletin, 94*, 336–362.

Swedberg, R. (1987). Economic sociology: Past and present. *Current Strategic, 5*(1), 1–221.

Tallman, S., & Shenkar, O. (1994). A managerial decision model of international cooperative venture formation. *Journal of International Business Studies, 25*, 91–114.

Tamaki, T., Torii, T., & Meada, K. (2003). Stability analysis of black Holes via a Catastrophe Theory and black hole thermodynamics in generalized Theories of Gravity. *Physical Review D, 68*, 24028–1–24028-9.

Thom, R. (1975). *Structural Stability and Morphogenesis*. Benjamin: Addison-Wesley.

Thorburn, W. M. (1915). Occam's razor. *Mind, 24*, 287–288.

Van der Maas, H. L. J., Kolstein, R., & Van der Pligt, J. (2003). Sudden transitions in attitudes. *Sociological Methods and Research, 32*(2), 125–152.

Wagenmakers, E. J., Van der Mass, H. L. J. & Molenaar, P. C. M. (2004). Fitting the Cusp Catastrophe Model. Available at http://www.psycg.nwu.edu/~ej/ Encyclopediacarastrophe.pdf.

Wong, P. S. P., Cheung, S. O., & Ho, K. M. (2005). Contractor as trust initiator in construction partnering—A Prisoner's Dilemma Perspective. *Journal of Construction Engineering and Management, ASCE, 131*(10), 1045–1053.

Wright, D. J. (1983). Catastrophe Theory in management forecasting and decision making. *Journal of Operational Research Society, 37*, 935–942.

Yiu, T. W., & Cheung, S. O. (2006). A Catastrophe model of construction conflict behaviour. *Building and Environment, 40*(1), 438–447.

Zeeman, E. C. (1976). Catastrophe Theory. *Scientific American, 234*, 65–83.

Zeeman, E. C. (1977). *Catastrophe Theory: Selected papers 1972–1977*. Reading: Addison-Wesley Publishing Company.