# CRITICAL MASS AS AN ANTECEDENT TO STABILITY IN ONLINE COMMUNITIES

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**Abstract**

This research examines the major antecedents of sustainable web-based communities. The topic of why people contribute to online fora has been studied from economic, sociological and biological perspectives. One significant contribution derives from game theory which incorporates an individual's expected return from their contribution (Axelrod & Hamilton, 1981; Nowak et al., 2010; Nowak & Highfield, 2011). However, these theories take insufficient account of the scale of social networks relative to their population in influencing growth rates. Rewarding or punishing individuals according to game theoretic approaches can be inefficient for promoting cooperative behaviours because of incomplete information about cooperative and non-cooperative individuals (Oliver, 1980; Marwell et al., 1988). Critical mass theory encompasses incomplete information issues, and focuses on production function and network structure (Marwell et al., 1988; Westland, 2010). A series of hypotheses are tested within a conceptual framework linking individuals' motivations underpinned by altruism, reciprocity and desire for commitment as antecedents of contribution to a forum. It is these small segment of group of initial volunteers who contribute to the critical mass at which the forum becomes stable.

**Key words:** Social Dilemma, Voluntary Contribution, Critical Mass, Online Communities

**JEL Code:** M20, M31

## Introduction

Online fora have been created extensively within communities of individuals having a shared interest, from very specialized niche interests, such as historic steam railways to much larger general interest communities, characterised by mass collaboration. One of the more notable forms of online fora is Wikis (eg www.wikipedia.org), whereby very large numbers of individuals contribute their knowledge voluntarily to the community and which are accessible to everyone.

Open access online fora represent a form of social dilemma, characterised on the one hand by individuals gaining maximum personal payoffs for making self interested decisions, but on the other hand, collectively receiving a lower payoff if everybody acts in a selfish manner (Dawes, 1980; Weber et al., 2004). Social interaction can generate social dilemmas in many contexts, for example in the use of water resources, alleviation of traffic congestion and organisation of collective labour union activities (Ostrom, 2010). Social dilemmas can be recognized as the antonym of cooperation and have been documented in many situations for the supply of public goods and services which involve no rivalry in consumption and for which it is not possible to exclude users, giving rise to “free riders”.

More recently, social dilemmas have arisen in the context of online fora. Participants must make explicit or implicit assessments about the consequences – to themselves and others – arising from their involvement in an online forum. Such evaluations have been studied through games, and the most classic example is the Prisoner’s Dilemma (PD) game (Romp, 1997; Xie, 2006). Other examples include public good games (Andreoni, 1988; Ostrom and Ostrom, 1999; Wasco et al., 2009), communication games (Rode, 2010); game of trust (Ba, 2000), psychological games (Battigalli and Dufwenberg, 2009), and evolutionary games (Geng et al., 2004). Collective actions and social dilemma are compelling issues, since both are about the tension between selfishness and cooperation.

There has been extensive research into individuals’ motivation to cooperate, drawing on theories based in the disciplines of sociology, psychology, and biological sciences. However, each discipline has distinct language which may inhibit further integrated understanding and there have been calls for more integrated, multi-disciplinary approaches (Gintis (2007). Across disciplines, a number of theories and conceptual frameworks have been developed to understand individuals’ motivation to co-operate, including theories of altruism (Wright, 1922; Groson, 2007; Alger, 2010), commitment (Laffont, 1975; Harsanyi, 1978; Groson, 2007),and reciprocity (Sugden, 1984; Croson, 2007).These theories highlight individual’s decision making system and suggest the mechanisms for contribution as solutions to cooperate. For every constellation of contribution, each decision is associated with the expected payoff.

Cooperative actions are informed by study of population characteristics. In the context of virtual organisations, an implication of many studies has been the existence of a dynamic, heterogeneous population (Gen et al., 2005). However, theories of altruism and commitment generally deal with homogeneous populations, and theories of reciprocity consider group heterogeneity but requires simultaneous contributions by all. The above mentioned theories are helpful in understanding individuals' motivation to cooperate, but are insufficient to explain online collective actions. In contrast, the theory of critical mass (Oliver et al., 1985) discusses group heterogeneity and sequential decision making systems, while shedding light on the power of a small, typical group of contributors who can provoke the mass collective actions. In this paper, we describe this group of contributors as "critical mass contributors".

Since the 1990s', the theory of critical mass has been adapted and applied in communication studies (Monge et al., 1998), influence models (Kim and Bearman, 1997), social networking studies (Westland, 2010; Wasco et al., 2009) and others fields. Despite assumptions, there is a lack of empirical data that supports the critical mass model. In the context of social networks, the point of critical mass, expressed in absolute numbers or percentage penetration, has not generally been empirically determined in contexts of online fora. This study seeks to make a contribution by attempting to understand why individuals are motivated to contribute to a forum, and more specifically to explore the critical mass at which patterns of motivation may change do that an online forum becomes self-sustaining by groups of highly motivated contributors.

This study is developed as follows. First, we introduce social dilemma problems in the context of social networking. Next, we explore motivations to cooperate online and the probability of critical mass contributors for online fora being self sustainable. This paper discusses conceptual frameworks and methodologies which are being applied to current ongoing research.

## 1 Problem Identification

Online fora play an increasingly important role in business and society (Füller et al., 2008; Dholakia et al., 2009; Demange, 2010). One challenge faced by a sustainable electronic forum is the availability of knowledge/ information (Chiu et al., 2006; Harris and Rae, 2009; He and Wei, 2009; Levy, 2009; Payne et al., 2009). A sustainable electronic forum is understood as "live", i.e. one where members exchange information continuously and consult information frequently.

Digital information can be described considered a public good. Four dimensions that characterize public goods are nonrivalry, non-excludability, the production function and jointness of supply (Wasco et al., 2009). In other words, public goods are outputs of collective contribution, and all individuals are able to access public goods regardless of their own contributions (Snidal, 1979). Furthermore, public goods such as public open spaces and public radio are not used up after consumption (Samuelson, 1954). The cost of joint production of public goods is lower than would be the case if the good was produced separately (Buchanan, 1966). A classic example is theatre performance, which through television or digital broadcast, individuals can see at home, satisfying the four criteria of a public good. (Wasko et al., 2009). In parallel, digital online fora provides intelligence of a collective, whose usage will neither exclude nor diminish the capability of access or usage by other users who follow. Once a message is published, the cost of jointly supplying is the same no matter how many members review the message (Wasco et al., 2009).

One obvious problem associated with public goods is social dilemma (Ostrom, 2000; Ostrom, 2010). According to Gintis (2007), the individual decision making model (named as rational actor model in economics) indicates that decisions are made to optimise a preference function subject to informational and material constraints. In other words, when every individual is rational and enjoys a public good for free, the public good will never be produced. Similarly, members of an online forum who benefit from this network but who wish to make little or no contribution, are called free riders.

The classic linear public good is illustrated through the utility function: $U_i = U_i[(E-X_i) + A^* P(\sum X_i)]$, where "E is an individual endowment of assets; $X_i$ is the amount of this endowment contributed to provide the good, A is the allocation formula, and P is the production function. A is specified as 1/N and $0<1/N<P<1$, where N is the number of individuals (Ostrom, 2000, p.139)". So long as contributing to the collective good is never an optimal strategy for a fully self-interested player. However, one of the specific characteristics of digital public goods is that it is indivisible, i.e. the information online remains the same however many times it has been read. Thus, the utility function of the digital public goods is expressed as $U_i = U_i[(E- X_i) + P(\sum X_i)]$, with $0<1/N<P<1$.

The above models indicate that overcoming the public goods problem requires collective actions that are specifically embedded on voluntary cooperation (Ostrom,2000; Wasko et al., 2009). Research about individual motivations to cooperate is a history of fantasy. Most recently, the biologists Nowak and Highfield (2011) propose the "five ways to solve the dilemma". These five ways are direct and indirect reciprocity, skin, spatial and group selection, which are compatible with classic theories such as theory of reciprocity, altruism and commitment. The following sections will give an overview about the mentioned theories.

# 2 Exploring motivations to voluntary contribution

Gintis's (2007) Individual Decision Making Model suggests that individuals encounter informational and/or material loss in contemplating contribution decisions. Furthermore, the potential loss differs according to different preference functions. It is commonly agreed that an online forum differs from other traditional social networks major in that participants are more heterogeneous and have limited or non physical contacts between each other. In addition, online fora that are studied in this paper are interest-oriented. In other words, an interest-oriented online fora gathers individuals who share the common interest or theme, and it deals primarily with knowledge or information sharing rather than making financial transaction, establishing relationships or playing out fantasies. Aspects mentioned above indicate that potential losses rewarded by online contributors are particularly about online discussions.

For instance, a devoted member contributes lot of time participating in online discussions, which leads to less time for enjoying something else. Furthermore, members may process their private information through Internet channels, where anxieties could occur if the capacities of online fora to treat such information are questioned. Again, members' opinions are influenced by others. An individual who belongs to a social group is unwilling to be excluded and/or to take related social risks (de Valck et al., 2009).

Although perceived loss, some individuals are keeping on contributing to communities. In this study, this behaviour is named e-voluntary contribution, which is defined as contribution in the form of online knowledge-sharing by members who overlook associated losses such as time, psychological and social risks.

## 2.1 Altruism

Altruism theories assume that individuals take care directly of others' welfare or utility (Becker, 1974). In eusocial species such as ants and bees, some adults sacrifice their lives in order to save the young. A bird gives a danger alert, thereby exposing itself to danger. Frohlich (1974) uses an example to explain altruistic behaviours in the human world. When "one loves one's neighbor as one loves oneself", and "one's neighbour reciprocates one's feelings", one could be indifferent from the possible resource allocations.

One of the areas of research that can shed light on the nature of altruism comes from evolutionary biology and social behaviour. One influential approach refers to "The Selfish Gene" (Dawkins (1976). The "selfish gene" suggests that genes desire to be described accurately as they are. In natural selections, it is understood as a concern about the quality of being copied. In a broader understanding, parents are altruistic to their offspring in order to take care of their own genes. In fact, the theory of kin selection (Hamilton, 1964) acknowledges that a gene can proliferate itself mainly through the increasing possibility of duplication of a familiar or reproduction of close relatives who carry also the same gene. It is understood that the relationships between genes could be an important factor behind "altruistic behaviour".

Wright (1922) determined a coefficient of relationship (r) between two related individuals while considering the external relationships associated with each[1]. In such a setting, Hamilton's rule (Hamilton, 1964) is applied to explore conditions under which an altruistic action will be taken – if and only if $rb>c$, where c is the giver's cost, b represents the benefits to the recipient's fitness. Hence, Hamilton's rule explains that an altruistic action will be taken depending on the weight of r: an altruistic action will never happen between two heterogeneous (unrelated) individuals ($r=0$), and is more likely to occur when two individuals are related ($r\rightarrow 1$). Smith et al. (1987) have examined Hamilton's rule through a study of probated wills. Their results indicate that in the context of wealth inheritance, close relatives who are favoured over distant kin receive the most inheritance. Smith et al. (1987) name this human behaviour as maximising "inclusive fitness".

More recently, Alger (2010) has argued that the degree of altruism can be developed stably while the degree of selfishness can't be so, if given a positive level of assortativity match to population. Hamilton's rule involves also the idea that individuals' behaviours are the responses to the changes of one's own and others' behaviours. If one contributes, the matched other will contribute as well in order to enjoy a bigger benefit. In contrast, a selfish individual, assuming that the matched other is selfish, will make a higher effort in order to increase his/her benefit. It is interpreted as the "between-pair" effect of altruism: the equilibrium material welfare increases as the result of the increase in the common degree of altruism. Alger's solution to free-ride is about the incentive to altruism: if the incentive is important, the undermined effect of own altruism on material welfare is small, which leads to a large stable degree of altruism. In the former, neighbours help each other and $r\rightarrow 0$ but not equals to 0, and the disadvantages of altruistic actions (c) are very slight. Hence, altruism behaviours are not only associated with the coefficient relationship ( r ) but also the benefit of

[1] Wrighter's $r=(R_{XY}) = \Sigma\ (1/2)^n$

helping. According to Nowak and Highfield (2011), "inclusive fitness" is the compelling rather than a standard explanation for altruism behaviours.

Proposition 1: Altruism is a motivator to voluntary contribution online.

## 2.2 Commitment

Ravens often give a food call when they find animal carcasses. Ravens will then share the food with recruited others. This behaviour helps ravens to monopolize the food in the newly discovered territory, which is otherwise unavailable (Heinrich, 1989). However, why do recruited ravens not keep foods for themselves but give it back to others, and then enjoy what is allocated to them? There are two important factors: First of all, "the whole is greater than the sum of its parts' (Aristotle,1045). An individual raven could better benefit from collected welfares. Secondly, it appears that all ravens contribute, which further guarantees a bigger benefit. In fact, the recruitment reflects the general principle of "group selection" and "spatial selection" (Nowak & Highfield, 2011): the clustered benefits and the adaptation in a given group. Similarly, the theory of commitment notes that a group of individuals commit to contribute seeking a bigger private payoff.

The theory of commitment considers the possibility and the consequences of collective actions under macroeconomic constraints (Laffont, 1975). Traditionally, the essential macroeconomic constraints are limited resources, which allows that the only consideration of the transfer or allocation cost is sufficient to achieve the pareto-optimal. This consideration is inconsistent with the constraint of self-interested decision making behaviours, therefore, individuals are merely studied as selfish creatures. In Laffont's model (1975), an additive externality is the aggregated consumption, in which non-cooperative economy is no longer efficient. In other words, individuals' utility function[2] is affected as well by all others' contributions. Kantian behaviours, which reflect the ground of Kant's ethical "categorical imperatives", are hereafter introduced to optimise one's utility function. According to Kant's philosophy (1948), individuals will contribute even though they don't want to, but they do so because they believe others contribute. As a result, social welfares are increasing as long as the increase of contribution.

[2] Supposing there are two commodities X and Y in the economy. The price for the commodity X is 1 for normalisation. It is possible to transform commodity X to commodity Y through a process $y \leq \alpha x$. As a result, the utility function of an agent is Max U (X, Y), subject to x+(1/a)y = 1+ (1/a) 1; If the aggregate consumption of y : $\int A\ \Upsilon d\mu$ were the additive externality, the optimisation problem of a selfish agent is then Max U( X, Y, $\int A\ \Upsilon d\mu$). (Laffont, 1975, p.432, p.433)

Different to only pareto-optimal oriented models, Laffont (1975) introduces the population behaviour concept (Kantian behaviours) into social dilemma research. Likewise, in the realm of evolutionary biology, the population structure has long been acknowledged as one important cause of evolutionary dynamics (Nowak et al., 2010). According to the results of spatial games and group selection, co-operators and defectors are clustered in different spaces, and clusters of co-operators can prevail over defectors (Nowak & Highfield, 2011). In other words, the population structure influences the pattern of cooperation evolution. Although population structure is the dominant factor in both spatial and group selection, spatial selection is distinct from group selection (Novak et al., 2010). Group selection has between and within groups selections, while spatial selection has only one clustering selection.

The important assumptions are that individuals can go beyond selfish behaviours and have faith in others fellows, which highlights the importance of ethical norms and homogenous population. Furthermore, the group size should be sufficient large which ensures the number of cheating behaviours negligible.

Similarly, Harsanyi (1978) proposed a utilitarian ethical model embedded in Bayesian rationality postulates together with a Pareto optimality requirement giving the following equation:

$W_j(A) = \sum_{I=1}^{n} \alpha_i U_i(A)$, Where αi represents the coefficients of individual j's value judgement, and strictly positive for I=1,2,3….n; Wj is the social welfare function of individual j; Ui refers to the utility function over all social situation A. In other words, the bigger the ai, the larger the Wj. When n individuals expect the equal weight to the utility functions U1….Un, the axiom of equal treatment of all individuals refers to a1=a2=….=an. …. Groson (2007) concludes that the theory of commitment has an important hypothesis that individuals contribute to public goods in a level that they believe others will choose, and this level is constant.

*Proposition 2*: Commitment is a motivator to voluntary contribution online.

## *2*.3 Reciprocity

Hauser et al. (2003) observed that a cotton-top tamarin could supply food, without leaving any food for itself, to an unrelated other who has the opportunity to pull a tool within a shorter time interval between trials. Observations indicated meanwhile that tamarins often help individuals who always pull a tool but rarely those who never work. The tamarins therefore follow a similar pattern of cooperation: individual pulls a tool for another and then receives helps from the receptor.

In human behaviours, the "giving and receiving helps" pattern has been described as direct reciprocity or indirect reciprocity (Nowak & Highfield, 2011). Direct reciprocity has been largely studied in repeated PD[3] games (Axelrod, 1984 ; Nowak & Sigmund, 1990; Romp, 1997; Xie, 2006; Nowak & Highfield, 2011). It requires a certain cognitive skill to recognise repeated interlocutors and their behaviours patterns. Popular sayings such as "tit for tat", "an eye for an eye", and " the blood for the blood" are acknowledged as one kind of direct reciprocity. Other forms of direct reciprocity including grim tit for tat, generous tit for tat and win-stay losing-left strategies. The grim co-operators switch to defectors permanently once the opponent players play defecting. Called tit for tat, a player plays cooperation from the beginning and mimics the last move of the opponent player thereafter. Generous tit for tat players could keep on playing cooperating with a certain probability for mistakes or forgiveness, even though the opponent played defecting in the past tournaments. A criticism of tit for tat strategies comes from the "noise" interactions generated by trembling hands or fuzzy minds because they can undermine cooperation dynamics (Nowak & Sigmund, 1990; Romp, 1997; Xie, 2006; Nowak & Highfield, 2011). In contrast, win-stay lose-shift strategy follows a simpler logic: sticking with the current choice if it is doing well, otherwise switch to another. The results of repeated PDs show that generous tit for tat is lasting longer than tit for tat that is more forceful than grim tit for tat. However, win-stay lose-shift is the better strategy for repeated PD games (Nowak and Highfield, 2011).

While direct reciprocity depends on personal experiences, which brings to the donor an immediate benefit, indirect reciprocity considers both personal as well others' experiences, which could lead to a delayed but more generous return (Alexander, 1985; Nowak & Highfield, 2011). According to Alexander (1985), reciprocal behaviours will flourish under two realisable conditions: One is the appearance of a promise that joint similar efforts are worth more than the total sum of separate contribution. The other is the variation among

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[3] The payoffs awarded to co-operators and detectors in a standard PD satisfy the conditions: $S<P<R<T$ and $R<(S+T)/2$, where R for mutual cooperation, P for mutual defection. S and T are payoffs generated by unequal moves, in which S to the co-operator and T to the defector. The first constrain indicates that the defecting strategy is evolutionary stable in a single turn play, while the second condition suggests that mutual cooperation is favoured over unequal moves. In the context of repeat games, reciprocal cooperating strategies are evolutionary stable (Nowak & Sigmund, 1990; Nowak & Highfield, 2011). An evolutionarily stable strategy (ESS) is defined by Axelrod (1984) as, for two strategies A and B, B is an ESS relative to A, If $Val(A/B)<Val(B/B)$ or $Val(A/B)=Val(B/B)$.

individual resources or capacities. As a result, given is relatively inexpensive to return when every individual in a society contributes. This kind of asymmetrical reciprocal interactions, also called indiscriminate social investment by Alexander (1985), can be multiplied in a complex, large society. That is, direct reciprocity works well in a small society while indirect reciprocity, depending largely on the power of reputation, can be operated even in a heterogeneous and larger network (Nowak & Highfield, 2011).

Either direct or indirect reciprocity is sufficient for players in repeated PD games to forecast the next moves by rivals. The principle of reciprocity described by Sugden (1984) refers to an obligation that any individual of a group has to follow. In general case, if other members of a group contribute at least ε (individually) to the public good, one must make an effort of at least ε. If one is the only person in a group, one must make an effect that maximises one's self-interest.

The principle of reciprocity is complementary to the principle of commitment. According to Sugden (1984), the principle of commitment refers to an expected level of contribution that is irrespective of the actual contribution level (called a non conditional commitment by Sudgen). If one chooses a level of contribution that one wishes others will make, and others don't actually contribute, then psychological barriers will occur, and one will feel unfairly treated. Furthermore, the "group" noted in the principle of reciprocity could be a big group consisting of numbers of sub-groups. It is therefore dealing with a heterogeneous population. However, the principle of reciprocity has an assumption that individuals contribute to some public goods simultaneously but embedded in previous knowledge that is obtained during the interactions with others (Groson, 2007). In summary, this pri le can be expressed as :

$$Wj(A) = \sum_{I=1}^{n} \mathring{a}^{c} iUi\ (A), \text{ subject to } \mathring{a}^{c} I = \min(ai) \text{ under commitment theories.}$$

*Proposition 3*: Reciprocity is a motivator to voluntary contribution online.

## 3 Critical Mass

According to Geng et al. (2004), an e-community is made up of a dynamic-continuous inflow and outflow of members, who have imperfect information and memory. This aspect of dynamic e-communities calls for theories explaining how digital public goods could be contributed to through the collective actions of a large, heterogeneous population. Furthermore, theories suitable for digital public goods should deal with multiple processes rather than simultaneous contribution. That is, theories of altruism, commitment and reciprocity alone are not able to explain mass collective actions in the emerging phenomena. Most recently, Wasko et al (2009) and Westland (2010) suggest that the theory of critical mass is relevant for understanding the digital public goods problem.

Critical mass theory (Oliver et al., 1985) explains how a small number of selected individuals can have a powerful, positive impact on the mass collective production. Similar to threshold model (Granovetter, 1978), it focus on the number or proportion of contributors who lead to a point when net benefit exceeds net cost for any self-interested individual. In biology, this transformation is analysed through contagion model (Dodds & Watts, 2004). In social life, one simple example is about the "fashion", where several selected stars can evoke uniformed massive behaviours.

Critical mass theory is the most compelling argument of Olson's (1965) logic of collective action (Oliver and Marwell, 2001). Olson (1965) points out that rational individuals will not behave cooperatively in order to achieve their common or general interest, without incentive or punishment mechanisms that reward selected co-operators or punish no-co-operators respectively. Oliver et al., (1988) argue that punishment and encouragement are not the solution to the collective action problem, because paying for "incentive" or "punishing" are themselves a sort of "collective action". Therefore, rewarding or punishing that is embedded in a complete information system is merely producing a second collective action problem. Although Oliver (1980) recognises that reward or punishment can be somewhat efficient for cooperation behaviours, these mechanisms are unrealistic in electronic social network circumstances because of incomplete information and memory about cooperative and non- cooperative individuals. Critical mass theory encompasses incomplete information issues, and focuses closely on production function and network structure.

The original critical mass model developed by Marwell et al. (1988) can be employed to illustrate individuals' decisions about contributing to public goods as follows:

$$G = p(\sum r)I - r,$$

where G represents an individual's net gain from contribution. It interprets the relationship between an individual and the group in general, thus, it omits the interactions between individuals but highlights the general exchange pattern; $p(\sum r)$ refers to the production function of the total contribution by all parties to public goods, which specifies the relationship between inputs of total resource contribution and outputs of levels of public goods. Furthermore, the production function in this model is a u-concave[4] or accelerating function, which ensures the increasing marginal returns. In online discussion, for instance, one response to a seed message tells 10% of the truth, the second one contributes to 20%, the third one goes to 50%, and the fourth up to 90%. In other words, accelerating production function encourages individuals to make sequential contributions that are embedded in previous outputs, because additional contributions could accelerate victory to certainty. However, the central challenge is to start collective actions because rational individuals will contribute in the late stage in order to enjoy higher payoffs; I is an individual's interest level in the public good; And r means an individual's contribution resource. That is, when $p(\sum r)>r/I$, .i.e. the total payoff from all contributions to public goods exceeds the individual's r/I ratio, an individual will make a positive contribution decision. In other words, the value of a given public good is subjected to available resources and the willingness to pay: the higher the interest level, the more possible that individual contributes; the richer the resources available, the bigger the outputs.

It can be concluded that there are two important assumptions in the critical mass model: the accelerating production function that highlights the feasibility problem, and the group heterogeneity that allows either highly interested or resourceful individuals to pay the early starting up cost of collective actions. The idea of critical mass is related to exactly these kind of contributors. In this sense, the critical mass members attract numerous others to contribute sequentially, much likely the nuclear metaphor.

However, Oliver and Marwell' (1988) model does not discuss the detailed mathematical and numerical analysis of the ratio of selected individuals and their effects on the general population. It could be one reason why theories of critical mass are surrounded by disagreements. Westland (2010) further defines a formal metric for critical mass in electronic social networks while following the percolation logic[5]. This determines the critical mass probability required for an electronic community to be self-sustaining, i.e. $p \geq pc = 1/(z-1)$. "p the probability that an individual member of the network will form an acquaintance link to another member; pc Critical probability at which a phase change occurs and a "giant" cluster appears, z the maximum number of links that any member may create, Westland (2010, p7)". When $p \geq pc$, the value of social networks is dependent on Log(ňs (p)), Log(ňs (p)), the

[4] Contrast to u-concave or accelerating production function, u-convext or decelerating production function that traditionally studied in economical models fostered initial actions, which leads to strategic action and free-ride problem (Oliver and Marwell, 2001). For a given public good, the benefit to individual A exceeds largely A's cost, thus it worth A to contribute this public good. Individual B knows A will whatever contribute, B could pay little or nothing but enjoy this public good in the future.

[5] The study of probabilistic models that exhibit a 'phrase transition' (Westland, 2010, p7)

logarithm of average number of each member's special interest clusters containing s members. S, the size of the social network, can be the indicator of the level of interesting of the online community.

It is noted that Westland (2010) provides a very sophisticated, pure mathematical model that investigates the social network structural effect. Further empirical studies are necessary. To simplify, we integrate Westland's logarithmical concept into Oliver and Marwell (1988)' model: $Gc = P((\sum r)\ Log(\check{n}sc\ (p))) - Sc*Rc$, Gc represents the gain of the critical mass group; Sc is the size of the critical mass group; Rc refers to the average contribution cost of the critical mass member; $(\sum r)$ is the value of social network; And $Log(\check{n}sc\ (p))$ represents the logarithm of the average number of interest (per critical mass member) containing Sc critical mass members. Logarithmical measure is more robust than simple summarization of number of interest.  It is presumed that human perception logarithmically transforms intensities for obtaining a wider perceptive range that crosses multiple order of magnitude. This ideas is mostly reflected through examples such as human perception of light, sound and other sensory information (Westland, 2010).

It appears that critical mass theory describes a transmission model that leads to the stable and dynamic collective collaboration, which is different to theories of altruism, commitment or reciprocity that discusses the voluntary cooperation. As a result, we propose that altruism, commitment and reciprocity behaviours are antecedents of voluntary contribution. When the proportion of contributors achieves the threshold point , mass collective behaviours become a trend or a belief that shared among individuals, which finally ensure the evolution of collaboration.

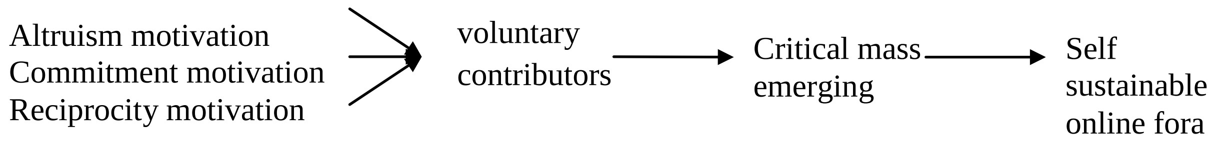
Proposition 4: Individuals' motivation to contribute to an online forum is influenced by the extent to which the forum has achieved a critical mass

## 4 Conceptual Framework

The review of literature above has suggested that traditional approaches used in the study of individuals' motivation to participate in online fora may provide the necessary, but not sufficient basis for predicting the sustainability of A particular forum. Measures of altruism, commitment and reciprocity explicitly or implicitly use linear scales to predict levels of the dissertation, but critical mass theory would suggest the non linear relationship, manifested by critical points at which individuals' motivation to participate changes significantly. We therefore propose a conceptual framework in which the three widely research motivators for contribution to online for a - altruism, commitment and reciprocity – have an effect on levels of participation in an online forum, but are mediated by a non-linear critical mass variable. Therefore, the sustainability of an online forum is dependent upon the achievement of a critical mass of membership at which motivation of members to contribute becomes sustainable. Below this level of critical mass, the rate of loss of contributors is less than the rate at which new members are gained. Above this level of critical mass, the rate of new membership exceeds the rate of loss.

A proposed conceptual framework is shown in Figure 1.

**Fig. 1: An integrated conceptual framework Title of figure**




The propositions are being explored with an analysis of statistics for a number of online knowledge exchange fora. Four key indicators are being recorded about each forum: i) the community's total knowledge, indicated by the number of message sent and responded by participants, Gc; ii) the maximum number of connections that a critical mass participant can create, z; iii) critical mass participants' interests, Log($\check{n}_{sc}$ (p)) ; and iv) the total cost of critical mass participants, Rc.

For the studied fora, "bulletin board" technology is used, which provides a facility of assembling questions and responses that are connected in a "thread". The first message, called also seed message, is followed by numbers of messages with the title of authors. Therefore, it is possible to know who had published responses. Furthermore, the community's interests can be interpreted by the total number of discussion topics that are published in the area of forums and child forums. A questionnaire was developed using previously validated items used in the literature on altruism, reciprocity, commitment and critical mass, and sent to a sample of forum users, with the cooperation of the moderator.

A typical online forum being studied is one specialising in knowledge exchange about UK railway operations "UK Rail Forum"( http://www.railforums.co.uk/index.php) . In respect of this forum, the following statistics are obtained for our study:

- number of unique participants 9,574
- number of messages posted 581 088 during the last12 month period

From the forum, the following calculations are made:

- the average participation rate (= number of messages posted/ number of unique participants) /12=60, 1/12=5/m
- number of answered seeds (= the total knowledge of community, counted from the column "thread", represented by P(∑r)
- the methodology used individuals' participation patterns to allocate them to one of a number of member categories: lurker (Guests who posted 0 message/ month); seeker (Members who posted 0-5 message/month): Ordinal members (Members who posted messages between 5-10/m): Critical mass (Members who posted more than 10 messages / month).

From this, we count the total number of discussion topics in the area of forum, then we have a

logarithmical expression $Log(\check{n}_{sc}(p))$ – supposing that the average interest of community equals to the average interest of critical mass group. An estimate of Sc*Rc will be obtained through the total number of connections that these critical mass members create, then we can compare if $Gc \geq P((\sum r)\ Log(\check{n}_{sc}(p))) - Sc*Rc$

## Conclusion

In an era of social Network Media, the number of fora through which individuals can obtain or contribute information has increased. Many online fora have failed to attract significant numbers of users from their target population, and many disappear completely. Others go on to achieve sustainable success, based on a large number of contributors relative to users of information, and a rate of attrition that is offset by continuing strong recruitment.

This paper has argued that altruism, reciprocity and commitment may be necessary conditions to be present for individuals to be motivated to contribute to an online forum. However, they are not sufficient to explain why some fora succeed while others disappear. It is proposed that incorporating critical mass into explanatory models of success will overcome limitations of linearity and improve explanatory performance. Ongoing research is seeking to build a model, informed by theories of critical mass, to identify non-linearities in individuals' motivation to participate. A contribution to knowledge in this research will be to identify the factors influencing such "tipping points".

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