Critical Mass in Collaborative Hypertext Environments

Wybo Wiersma
King's College London
mail@wybowiersma.net

1 Introduction

In this essay we will be examining what exactly critical mass is, and how it affects collaborative hypertext environments. In short critical mass is the minimum number of users required for an application to make it worthwhile for new visitors. While, generally, the effect of critical mass on hypertext applications is that it makes them fail because it cannot be attained.

However there is more to it, and in order to be able to give a more precise answer, we will first be examining some of the terminology used to denote critical mass, further delineate the problem, and specify some limits of this essay. The foremost of these limits is that we do not attempt to provide a magical recipe for obtaining critical mass. The essay merely tries to clarify the notion in the context of hypertext applications.

Then, under the heading of network effects, we will investigate what advantages the presence of other users can bring to an application. Following, we will be discussing four different conceptions of critical mass. We will continue by exploring various aspects and properties of critical mass thresholds. Finally, we will discuss the factors that are important for collaborative hypertext applications in relation to the attainment of critical mass.

1.1 Terminology

Across various disciplines different words are used for denoting critical mass and a set of very similar and loosely related concepts. Terms used are the *startup problem*, the *accelerative dilemma*, and the *community paradox*. The same concept is also referred to in a variety of contexts. In physics critical mass is the minimum amount of uranium required to sustain a nuclear reaction, at parties we speak of critical mass if there are enough people to raise the atmosphere, and in economics the concept of *network effects* denotes an important market reality for network-related products.

The concept of network effects, while slightly different from critical mass, is the most important concept related to it. It refers to a network or an application being more valuable if it has more users. Even more terms refer to this phenomenon, than to critical mass thresholds, such as: the *bandwagon effect*, *winner takes it all*, *tippy markets*, *network externalities*, *positive consumption externalities*, *positive size externalities*, *demand-side economies of scale*, and more remotely the *Mattheus effect*, and even the *snob effect*.

1.2 Problem

All these terms sketch out the same problem. Namely that of initiating a successful network or (here) web-community. If there are no users it is not useful for newly arriving visitors, but unless it is useful, there are going to be no users to make it useful. John Platt described such problems as *social traps*. A social trap is a situation in which behaviour that brings small personal advantages, but greater social or long-term disadvantages, is perpetuated nevertheless. The opposite case, in which personal disadvantages keep people from engaging in behaviour which would have greater collective benefits, is called a *social fence*. In order to attain critical mass, a social fence is what has to be overcome.

Platt identified three kinds of social traps (and corresponding fences): *individual traps*, where, for the same person, the benefits work in the short term, and the disadvantages in the long term (smoking with risk of cancer is an example); *missing hero traps*, where a collective problem can be alleviated by the (for him disadvantageous) actions of a single individual; and *collective traps*, where the collective disadvantage can only be alleviated if most actors cooperate (a tragedy of the commons such as the overgrazing of a common pasture is an example). Critical mass problems are social fences that can be classified in between the missing hero and collective trap types.

The existence of social traps indicates that the free market, or even free choice, can sometimes lead to sub-optimal or even detrimental outcomes. A particularly hard to tackle type of social trap are nested social traps; what Platt calls *social chains*. These are situations in which multiple social traps interlock and reinforce one another. An example of this is gang violence in poor neighbourhoods (poverty induces crime, crime makes police appear dysfunctional, gangs offer some protection, but perpetuate crime and violence and thus poverty). In case of academic hypertext applications there might also be adverse social chains such as those between career-advancement and journal-publications.

1.3 Assumptions and Limits

In this essay we assume that individual interests are the deciding factor for whether people adopt a hypertext application. We exclude situations in which the usage of an application would be part of the users job description, or would be enforced in other ways. Yet we do consider social traps and fences as a possibility (e.g. the users perceived interest can differ from his real, long-term interests, or from collective interests).

We will also limit our definition of hypertext to page and link hypertext, as opposed to stretch-text hypertext (unfolding text, as one clicks on phrases) and visual forms of hypertext such as found in mind-mapping and visualisation software. Page and link hypertext is the traditional kind of hypertext that makes up most of the web. In line with this we will be limiting ourselves to web-based applications with regard to application-types.

Finally, as already noted, exploring ways to attain critical mass is not the primary aim of this essay, though they are mentioned between the lines where they help to explain aspects of, or factors involved in, critical mass. We will also not be arguing for the advantages of web-based hypertext applications over journals and other media. This has been done elsewhere already (such as Wiersma et al.). The essay also is mostly qualitative in its approach. No explicit empirical data has been collected or analysed.

2 Network effects

2.1 Basics

Applications intended for a community, such as collaborative hypertext applications, connect people by gathering them around the texts they produce, review, rate and remark on. The value that these connections create is a network effect. The simplest example of a system that exhibits network-effects is that of a phone network: If you were the only person in the world having a phone, it would be completely useless to you (except as a status-object). So why would anyone buy the first (few) phones? In the beginning of the 20th century this was a real issue, but as more people acquired phones, and thus could be called, having a phone became increasingly valuable. Similarly, *Facebook* probably is valuable to you because your friends are on there.

When discussing network effects, it is important to maintain a clear distinction between network effects and a few seemingly similar concepts. The first is that of something being mainstream and introduced to many people through word of mouth. You probably joined Facebook in response to a recommendation, but the same could be true for any other product, such as using scissors for cutting paper because you saw your mother do this. While obviously scissors don't have network-effects. Finally it is important to keep network effects separate from (production side) economics of scale. Mass-produced scissors may be cheaper, but there is again no effect of others using scissors on your cutting.

2.2 Interrelationships

Network effects can be direct and indirect. Direct network effects are network effects from increased usage that directly leads to increased value (our example of being able to call more people as more of them own phones). Indirect network effects on the other hand, are derived from the availability of complementary goods and services. A good example of this is the fact that *Mediawiki*, the software running *Wikipedia*, is made more useful because many plug-ins have been developed for it by third parties.

Indirect network effects can be one- and two-sided. Most network-effects are one-sided, where the complementary product does not become more valuable as more of the primary are sold. An example are the now widely available protective covers for mobile phones. In two-sided network-effect the complementary product does become more valuable. For example in the case of on-line Journal-publications, which have not only been made more useful because of websites such as *Scopus*, *IngentaConnect* and *Google Scholar*, but as more articles appear on-line, these websites will also become more valuable. Cross-compatibility is the central issue here. In terms of social traps, two-sided network-effects are social chains.

2.3 At different scales

Network effects can function at different scales as well. The most important distinction is that between global and local effects. Local network effects appear in relation to the people in your immediate surroundings, such as your friends, colleagues and acquaintances. Because connecting with them is most important to you, you likely will use the application that they are already using, not the one most popular in the greater population.

An example of local network-effects is the usage of Apple computers in arts and design, while (until recently) basically everybody else used IBM-compatible PC's. Another example are social networking sites restricted to the employees of certain companies, such as *Beehive* within IBM (which has 50.000 users). Finally, the system of invites (that people can give out to friends) for *Google Wave* hopes to bring in pockets of befriended users (displaying local network-effects). As the variation in scale between these examples shows, the difference between local and global network-effects is relative, not absolute.

3 Conceptions of critical mass

3.1 Threshold

The first conception of critical mass we are going to discuss is that of a simple threshold. That is; the minimum number of users required for an application to display (sufficient) network-effects. It is the most minimalistic of the concepts under discussion, as it does not include any notion of runaway growth or relapse, nor applies to things other than the application itself, such as the user-base attained by competing applications.

This threshold can be pictured as a portal that an application has to move through before it is of any value to newly arriving users. Alternatively, the minimum number of other people that should be using an application can be imagined as a necessary feature of the application (for getting others on board).

In relation to this latter picture, Jacob Goldenberg has even considered network-effects to be a constraint, rather than something which adds value to an application, and can help spur its adoption-rate. In his model the value of the product is assumed to be fixed, while network effects prevent adoption before a threshold of users is met. Though this way of putting things is rather artificial and does not acknowledge the positive value derived from the network.

3.2 Core group

Another concept of critical mass is that of a minimum core group of active users needed to sustain the community. This concept adds the possibility of a relapse in activity levels that brings an application under its threshold of active users again (as opposed to signed up users). It is analogous to the concept of critical mass in physics: the smallest mass that will sustain a reaction.

Sometimes it is also pictured as a core of users that are (much) more active than others. Such as for example the 5% of Wikipedias contributors that have done more than a hundred edits. But there is little to say for this conception, as a community could of course also be maintained with a bigger group of people that don't contribute that often. Though, as Jan Marco Leimeister has found, most people seem to prefer smaller (150 active members), and relatively intensive, web-communities over larger ones (featuring sub-groups). In any case a core group does not need to grow to remain stable.

3.3 Self-sustained growth

Then there is the concept of critical mass as a phase of self-sustained growth. In this view the point at which critical mass appears is akin to a tipping point, that, once passed, leads into runaway growth. According to this conception, before an application reaches critical mass, its growth has to be sustained by things such as advertising and price cuts or even gifts. In another variation of this concept, critical mass is a size beyond which an application becomes profitable (advertising costs drop and one can start charging).

A related, but unusual property of the economics of network effects pointed out by David Allen, is that network effects apparently make the supply and demand-curves bend in a direction opposite to those they normally take. Whereas normally, as more of something is produced, demand goes down, and the cost of supplying the product goes up (due to scarce resources), with applications that exhibit network-effects demand goes up as more people use it (network effects), and piece-wise costs go down (due to it being a virtual good). See figure 1.

This effect can, however, be explained away if, with Hugh Fullerton, we assume that the number of users using an application, besides influencing demand in the normal direction (down), also improves an important feature of the product (its uptake), thus drawing a new demand-curve above the previous one (figure 2).

3.4 Saturation

The final conceptualization is that of saturation, introduced by Christopher Westland. Imagine a porous material on which water is poured. In the material, which can be modelled as a two dimensional grid, there are a limited number of random connections between its cells. Using something called *perlocation theory* it can be calculated that only when connections occur with a probability of 50% in such a material, a pathway will be formed, and the water will be able to run out at the bottom.

Now if we see an application (say a social networking application) as forming the pathway between the points, we can say that inside it a so called giant cluster (pathway connecting most users) appears when it connects 50% of its target population (the cells). At this point critical mass is attained. Before this happens, there will be many small separate clusters. So that when people receive invites from their friends, they only receive invites from a few of them, which is not enough to cause them to sign up.

Regardless of its mathematical rigour, this conceptualization does not apply well to hypertext applications. As both invites and a monolithic cluster connecting all users, are not central to them. Thus it is not considered further in this essay. We will mostly be working with the first two minimalistic conceptions of critical mass: a threshold and the minimum size of the core-group of active users required.

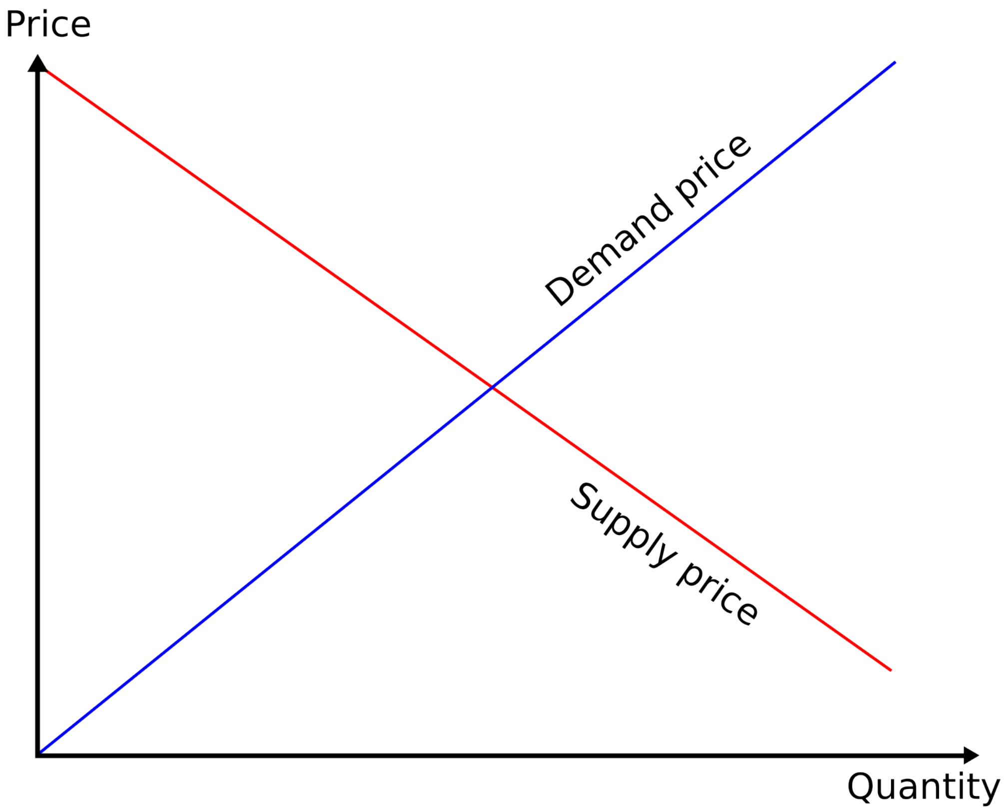

Figure 1: *Reversed supply and demand curves (illustration)*

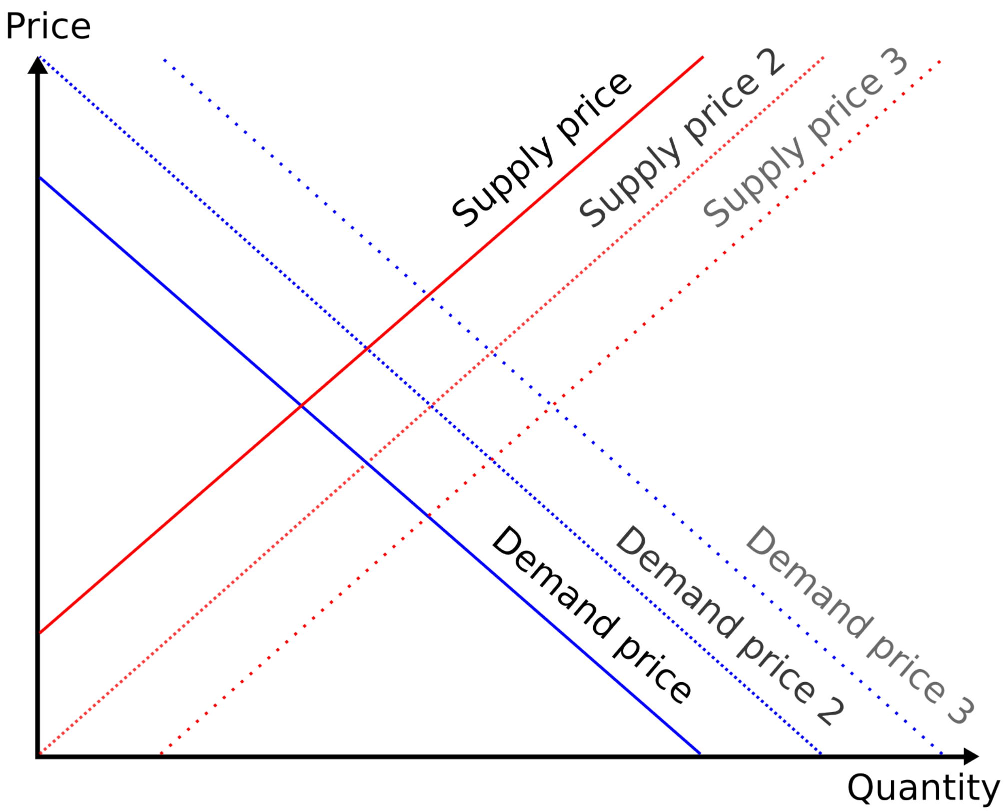

Figure 2: *Multiple supply and demand curves (illustration)*

4 Thresholds

4.1 Production function

The first thing in relation to critical mass thresholds to reckon with, is that of the shape of the production function of the application, which can be accelerating or decelerating. In case of hypertext applications it delineates where the problem of producing texts, links and other community assets lies.

If it is decelerating, it is easy to get people to create the first few texts, but then as there are more texts, people see less value in adding new content. In this case there will be no start up problem, but a maintenance problem. While, if the production function is accelerating, then gaining critical mass is hard, but once it is attained, more and more content will be added (self sustained growth).

In Wikipedia, for example, the production-function most likely is accelerating. As the quality of articles increases, there will be more visitors, and more people motivated to add or improve articles. While in threaded web-forums a new reply to a thread that already is very long, is less likely to be read or valued, and thus in forum-threads the production function is expected to be decelerating (at least above a certain size).

4.2 Diversity of motives

Another important property of critical mass thresholds is that of diversity between people in terms of their reasons to contribute. For Wikipedia, for example, Pattarawan Phrasarnphanich found widely diverging motives: some work on Wikipedia because it is fun, others because they learn from it, some do it for altruistic reasons, and yet others to give something back to the community. Besides this, means and skills can also vary between visitors.

Diversity allows for peoples personal critical mass thresholds to vary; e.g. the number of users that will make the community an engaging place for them. Which makes it possible to start off with the most willing contributors, and then grow as the application gradually meets the expectation-thresholds of others. A good feature of Wikipedia related to this is that it allows visitors to start out with very small contributions, such as fixing a spelling error.

4.3 Shape of network-effects

This brings us to an interesting question with regard to the shape of the function of network-effects, as opposed to the production-function for content. Namely, how will the perceived value of network-effects change, as more people join an application? As it is unlikely that they will look the same to all (prospective) users.

Peter Swann noted that if we assume people to differ in their predispositions towards new technology, it is likely that there are local network effects with regard to such preferences as well. In other words, pioneers are most likely to want to call other pioneers, and thus for pioneers, a small network of early adopters will have critical mass. In figure 3 you can see the different utility functions as set out by Swann.

Strategies such as introducing an application in a high-tech region first or featuring certain topics on the main-page, can all help to pull people together that value working together (on a certain topic). Starting out an application in a scalable way will also offer a good start. Even a very small Wikipedia, for example, could already be considered a success as encyclopedias come in varying sizes. In addition, as Wikipedia is written by its readers, its content reflected their interests from the start (at least of readers that became contributors).

4.4 Bifurcation points

A bifurcation point (Philip Ball, but a notion from physics) is a point at which a process can seemingly randomly go into one of two directions. The bifurcation point is unstable, while the other two extremes of zero users, and full coverage are stable (self-reinforcing). Competing web-applications that display network-effects and have similar market-shares can be

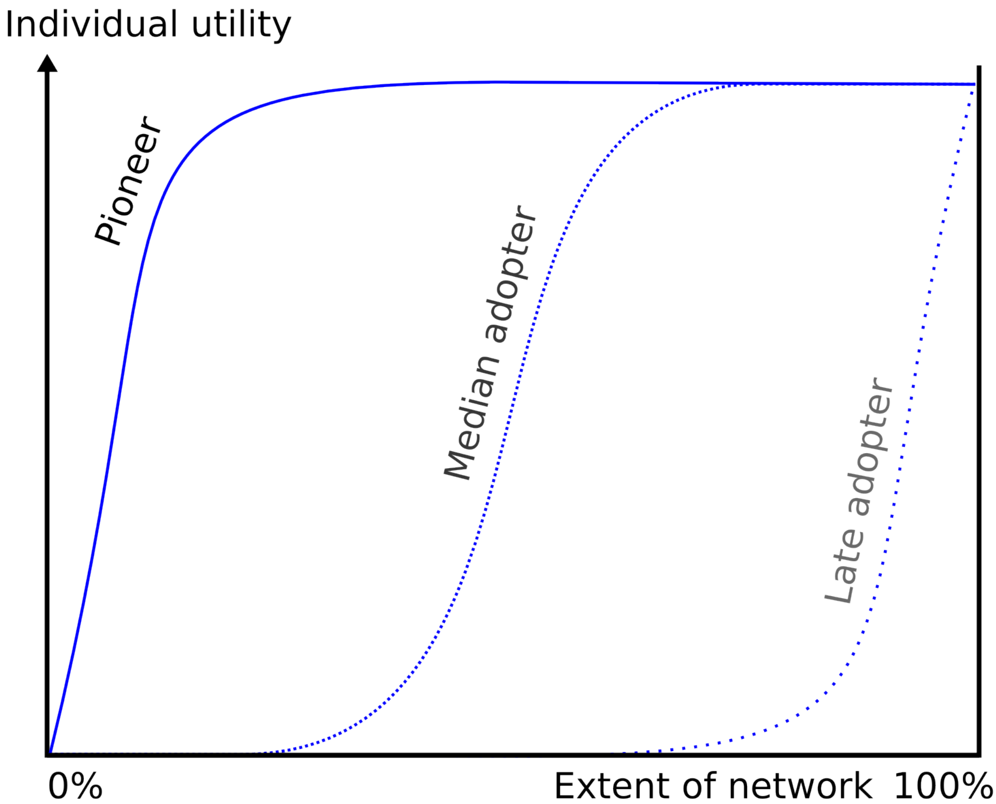

Figure 3: *Shape of the perceived utility of a network*

considered to be at a bifurcation-point. This makes that early leads in take-up can be very important.

When people think about critical mass, often a virgin market is assumed. That is; no product of its kind exists yet, and as one or more new products race to the market, one achieves an entry-deterring monopoly as the bifurcation point is left behind. In most cases however, the ground of a newly introduced application is at least partially covered by something already (for academic hypertexts, by journals, and blogs for example). We also see that network monopolies are overcome in practice (the growth of initially tiny Facebook versus *MySpace* is an example).

For overcoming monopolies it is important that the new application offers a genuine advantage, and preferably also has one or more core features that make it useful on its own, before critical mass is attained. A good example of this is the tagging site *Delicious*, the main feature of which was that it allowed individuals to organize their personal links in one place, and access them from multiple computers. Only later it became a community.

4.5 Meta-stable states

The final important property of thresholds comes from physics (Philip Ball) as well: meta-stability. Meta-stability is a state in which a system that is seemingly stable, is in reality very sensitive to being tipped over into another state. An example of such a system is a busy highway at which all cars move at full speed. Then if one car slows down to take an exit-lane, the cars behind it will brake, likely over-compensating, and a traffic-jam will result. The jam cannot be reversed until much fewer cars are on the road than in the initial stable state (tipping it in one direction is easier than in the other).

Meta-stable systems can be seen as low hanging fruit, as they can stay in their stable state for a long time, ready to be tipped. In terms of social traps they are most comparable to a missing hero type social trap, except that the hero doesn't have to sacrifice much. The existence of meta-stability, more even than bifurcation points, explains why timing and luck can be such important factors in the success of (hypertext) applications.

Of all the properties of thresholds we have discussed, diversity of motives, the shape of perceived network effects, and bifurcation points are normally the most important. The others are less central: knowledge of the production-function of an application is helpful for predicting how hard attaining critical mass will be for it, and metastability can make critical mass appear almost naturally, if one is lucky enough to encounter it.

5 Factors

5.1 Audience

The first important factor that determines whether a hypertext application can attain critical mass, is the audience it targets. A web-savvy audience is more likely to adopt a hypertext application, than an audience of people that distrust the web on principle. Dorine Andrews, for example, found that middle-aged career-switchers don't trust forums, unless they are visibly moderated and backed by a trusted party.

Another maybe obvious, but important thing to consider, is that there must be a need or a desire to use the application among the intended audience. For example a group that already forms a community in the off-line world will likely be interested in communicating after moving their communications onto a (new) platform. Similarly, people that have fewer other outlets for their writings might be more interested in contributing them to a hypertext-community. To speak with Maslow and his pyramid of human needs: if their higher needs are met elsewhere, or if their lower needs are not met, people are unlikely contributors.

Also a small shift in peoples interest in, or perception of, an application, can have big consequences. A good illustration of this is that, as explained by Philip Ball, in a simulation of green and blue agents a strict segregation will be achieved if they have only a slight preference to live near agents of the same colour. Thus while obviously a web-community for digital humanists is more likely to succeed than one for Luddites, the digital humanists group is also more likely to succeed than one for slightly less web-oriented humanists.

5.2 Content

In terms of content it is important, first of all, that there is enough seed-content on the site, and that it is of sufficient quality. A more surprising thing is that the content ideally should also be controversial, or at least something that elicits peoples responses. It was found by Gaowei Chen that unlike in real-life conversations, on the web disagreement triggers increased responses, instead of inhibiting the conversation (which normally happens in face to face contexts).

Secondly, hypertext connects pages through cross-links and thus is not linear. While it is still true that virtually all traditional academic discourse (in the analytic branches of humanities) is linear and argumentative. Thus having a multitude of argumentative lines running through a page that is linked to from multiple places will be necessary, but writing in this way is much harder than writing up a traditional linear text.

Finally, hypertext requiring constant choices between reading on or following links might distract readers from the message. In addition, people will be inclined to memorize the links they have visited, and the pages through which they travelled to the current page, which also incurs cognitive load. And cognitive load comes at a price. Similarly, micro-payments might so far not have become successful because the mental cost incurred by having to decide whether to pay or not, may be bigger than the sum that is paid, or the value that is derived from the content that is received.

5.3 *Usability*

An applications ability to overcome critical mass is closely related to its usability. First of all, because bad usability brings a learning-curve that can incur extra cognitive cost, but more so because it can cause frustration. A lot of research has been done into usability, and things such as the users error-rate, speed of learning to use an application, impediments to access such as sign-ups, and the applications consistency, were found to be important.

The users need to contribute and engage with the community is counter-balanced by the effort he has to go through to do so. Wikipedia in this regard does well, because, while its usability might not be perfect by todays standards, the fact that one can fix small problems easily, without signup, makes the social fence very low (easy to overcome).

An additional aspect of usability that was found to be important is the (speed) performance of the application. If an application feels fast and snappy people interact with it more fluidly. And speed relates to critical mass in the additional way that, as the number of users increases, web-applications often slow down, thus capping or reversing growth. Especially pioneering users can experience an application as going down in value when late adopters clog up the system.

5.4 *Interactivity*

Related to an applications speed, but different from it, is its interactivity. E.g. how much feedback do users get and how much do they feel in control? Wikipedias instant-publication is a positive point in this respect. But Google Wave takes interactivity to a whole new level by making the editing-process itself completely real-time. That is, as people collaborate on a document you see their cursors move through the text, and characters appear as they are typed on everybody's screen.

But besides UI-wizzardry, interactivity can also be determined by whether users are notified of updates through e-mail or other web-media. In this respect *Google Buzz* (a crossover between a micro-blog-post and a forum) is more interactive than Google Wave, as it seamlessly hooks into the users (Google-)mailbox. The constant notifications that Facebook sends out are another good example. Integration can increase an applications stickyness.

Allowing people to moderate, and rate things is an important aspect of interactivity as well. It gives people a sense of control. Finally, commenting, and replying to replies of others through threads, are another form of interactivity. Threaded forums make replying extremely easy. While allowing people to post a few words or a single sentence, instead of a whole post, lowers the threshold for interacting. Being able to directly respond will pull more people into using the application.

5.5 *Sociability*

Sociability is a term akin to usability, which was proposed by Jenny Preece. Instead of being about interacting with the software, it is about interacting with others, across the software. It mostly refers to the degree to which the community is supported and safe-guarded by the application and its policies.

As Preece has formulated it, it encompasses first of all the purpose of the application: What is it for and why would people want to be there? Secondly, the kind of people that are there, their attitudes, or sub-culture, and their mutual support and openness towards newcomers are important. And the third factor are the policies that govern the community (or allow it to govern itself).

If these things are done wrongly, it is hard for a community to grow, or to continue to flourish. Other things that could go wrong in the social sphere, and put off users or newcomers, are: not responding to e-mails in time, and showing hostility towards (seemingly) stupid questions asked by newcomers. This also ties in with usability, as ideally the software should be self-explanatory.

5.6 Credibility

An application can also be helped a lot by it having credibility. Credibility can come from a project being affiliated with, or subsidised by a reputable institution, as well as from personal recommendations by so called stars (highly respected persons in the relevant community). Credibility is important for trust: the trust that ones contribution will be in good hands with the community.

In addition to trust, credibility is also valuable for generating a shared expectation that an application will be taken up by many people. Critical mass is perceived by potential users in the form of an expectation of how many users an application is likely to have in the near future. If the user thinks that his contribution will generate a return on investment (be noticed, commented on, etc.) he will likely contribute. Critical mass thus often is a self-fulfilling prophecy.

Ways to make an application seem more credible are various, but in general making it look old and traditional, or making it mimic the thing it tries to improve upon, can be a good idea. The French Minitel (fore-runner of the internet) for example, looked like a traditional telephone. But on the other hand an application should also not seem too pretentious. According to Andrew Dalby one reason why Wikipedia attracted many authors was that it started out as an informal drafting-platform for the more daunting *Nupedia* project (which had traditional editors, etc.).

5.7 Rewards

The final factor that is of influence on critical mass in collaborative web-applications, is that of rewards. Publishing in academic journals is tightly integrated with career advancement, and thus brings great rewards to authors. Compared to this, web-communities can offer much less. Though it is likely that this will (or at least can) change, as IT-people already do receive career-benefits from web-communities.

Other forms of rewards are rankings and reputation-points. These can signal the reputation of members, and thereby motivate excellent community-members. In addition, as Gerard Beenen has demonstrated, things such as simply assigning people to teams (even if just in name), and inducing competition between these teams, can make people more productive community members.

Another important way to make virtual rewards more rewarding is making them recognizable. So instead of a karma number that goes up from zero to a hundred, creating a small set of classes of expertise, mimicking those in society (such as layman, student, postgraduate, etc...), is more effective. Making reward-points artificially scarce, or allowing users to re-invest them (to feature their own stories), is another way to make them more valuable. For example in IBMs Beehive they limited 50 (randomly selected) users to rating only three items each week, and this resulted in more, rather than less, ratings.

6 Conclusion

To conclude, we have shown that while a plethora of terms are used to describe critical mass and network effects, for hypertext applications the problem can be clearly phrased in terms of a missing hero-/collective-type social fence: users are needed to make it useful, but there will be no users unless the application is useful already. Among the conceptualizations of critical mass, the threshold and core-group conceptions were here found to be most useful.

For exploring a critical mass threshold it is important, first of all, to know whether the production-function of the application is decelerating, and whether the application tries to tip a meta-stable state. In these cases critical mass might come naturally. If critical mass is a challenge, as it will be for most applications, then targeting early adopters or an existing community are good strategies. Attracting people with a diversity in motives and means might also work, because the thresholds, and local network effects of (potential) users will vary.

In addition to a web-savvy audience, controversial seed-content and good usability are important. Interactivity is another determiner, especially as it can pull people into using an application continuously. Besides these, sociability is central as well: a clear purpose, the right community culture, and clear, agreeable policies. The final two important factors are credibility and rewards. Rewards make it worthwhile for the best contributors, and keep everybody motivated. While credibility creates trust, and can make critical mass a self-fulfilling prophecy. Though if credibility is undermined by competing applications that have a near monopoly (as journals do), it makes for the hardest factor to overcome.

6.1 Future research

Interesting follow-up research would be a more comprehensive study of the ways in which successful hypertext applications have so far overcome critical mass. A more rigorous approach, which would likely enable us to identify the relative importance of the various factors, would be to match the historic growth-patterns as derived from server-logs to a mathematical simulation of the appearance of critical mass. And making comparisons between types of applications, such as forums, wikis and mailing-lists offers another promising branch of research.

Finally, as most collaborative web-applications so far have failed due to problems with critical mass, a better understanding of critical mass is most valuable, it is the key to unleashing the latent potential of the internet.

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