The Bass Diffusion Model does not explain diffusion

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Abstract

The Bass Diffusion Model (BDM) is one of the most successful models in marketing research in particular and management science in general. Since publication in 1969, it has guided marketing research on diffusion. This paper illustrates the limitations of the BDM, using mobile diffusion as a context. We fit the BDM to two large developed markets, the USA and Germany, and the emerging markets of Brazil, Russia, India and China. We show that the parameters of the classical BDM may change substantially if the time period considered is changed by a single year. The diffusion of mobile communication does not follow an S-curve in some cases. We do not formulate an empirical alternative, but we suggest the structure of an integrated diffusion mode that treats adoption as one of five phase changes of the diffusion process. We trace the diffusion of mobile communications in India, and show that the integrated diffusion model provides a framework for understanding this case. We show that diffusion is a complex phenomenon, and that simplistic approaches are not equal to the task of explaining it.

Keywords: Bass Diffusion Model, Mobile diffusion

Introduction

The Bass Diffusion Model (BDM) is one of the most successful models in management science in general, and marketing in particular. Rogers (2003) calls BDM "a lightning rod for marketing scholars". Bass (1969) is one of the ten most influential papers published in *Management Science* in five decades (Hopp, 2004). It has however raised criticisms that have not yet been completely addressed in existing reviews of diffusion research.

Sterman (2000) deals with the use of system dynamics to study innovation diffusion, and points out some shortcomings of the BDM. Surveying the logistic model and the BDM, he notes that the BDM addresses the start-up problem of the former because the adoption due to mass media does not depend on an existing adopter population. However, he notes that fit to historical data does not show that a model is valid, and that "(models) should not be treated as exercises in curve fitting using the aggregate data". Ability to fit historical data is not a measure of strength in explaining dynamics. The logistic and BDM approaches appear to work because they account for positive and negative loops that interact to form S-curves. Their advocates are selective about data, and they omit cases where the fit is not good. Also, getting more data does not solve the problem. He has also shown how system dynamics can be used to remove the restrictions imposed by "analytically tractable models". He emphasizes the need for a model to capture the "causal structure of the system".

Meade and Islam (2006) comment that the main models of innovation diffusion were established as far back as 1970. Since then, advances have been made in three directions: introduction of marketing variables in the parameters of the models, considering innovations at different stages of diffusion in different countries, and incorporating diffusion of successive generations of technology.

The objective of this paper is to explain why BDM and its successors that have more "bells and whistles" (Rogers, 2003) should not be used in diffusion research, and how system dynamics (SD) based approaches are more suitable for modelling diffusion from an aggregate—not individual— point of view. We make preliminary suggestions about such approaches.

In the remainder of this paper, we first present the BDM and explain the problems with the BDM approach, using illustrations from the mobile communication market. We develop an integrated view of diffusion in the form of a visual stock and flow model and use this model as a background to explain the case of diffusion of mobile communications in India. Finally, we discuss the failures of prediction in global mobile diffusion and suggest area for further work.

The Bass Diffusion Model

An Introduction to the BDM

Bass (1969) drew on prior work that modelled new product growth as a function of either mass media or word-of-mouth communication. He proposed a model that expressed the new product adoption rate as a function of both. Thus, he created an empirical model, called the classical BDM in this paper, to explain the timing of adoption. He drew on contagion models and provided a framework for long-range forecasting.

According to the classical BDM, the probability of adoption of a new product at time t, given that it has not yet been adopted, depends linearly on two forces. The first force, represented by coefficient p in the literature, is independent of the number of previous adopters.

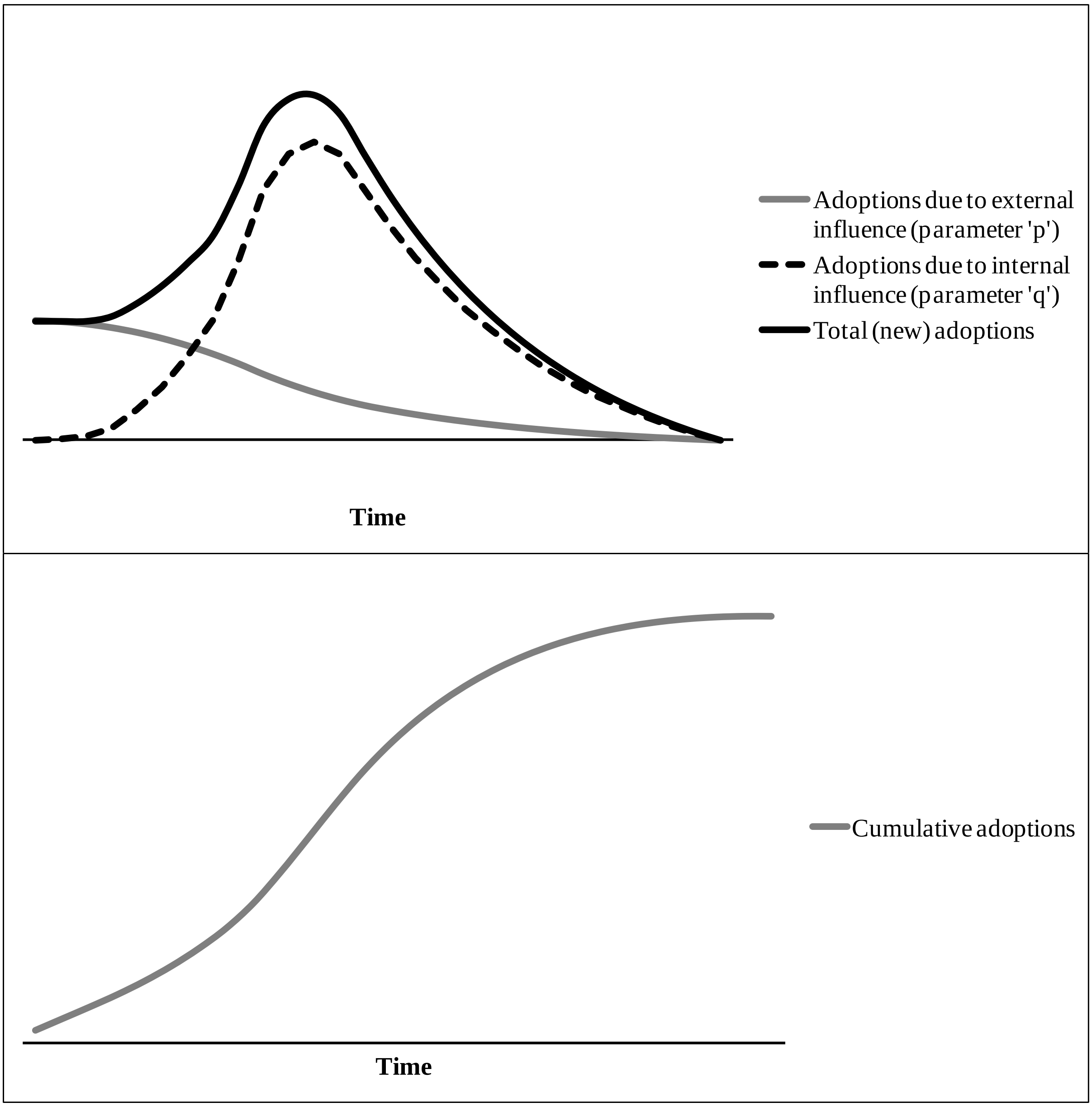


Figure-1: Representation of the Bass Diffusion Model, based on Mahajan *et al.* (1990)

Coefficient *p*, which reflects adoption due to mass media, was originally termed the coefficient of innovation and later renamed the coefficient of external influence. The second force, represented by *q*, is positively influenced by previous adopters. It was originally termed the coefficient of imitation and later renamed the coefficient of internal influence.

As explained in Bass *et al.* (2000), the original model of Bass (1969) postulates that f(t), the likelihood of adoption by an individual at time t, given that he or she has not yet adopted the product, is given by

$$f(t)/(1-F(t)) = p + qF(t), \qquad \text{…. Eq. 1}$$

and Y(t), the cumulative sale of the product (assumed equal to the number of adopters) is given by

$$Y(t) = m(1-e^{-(p+q)t})/(1+(q/p)e^{-(p+q)t}) \qquad \text{…. Eq. 2}$$

where

F(t) = Cumulative distribution function, probability of adoption by time t

m = market potential

p = coefficient of external influence (originally called coefficient of innovation)

q = coefficient of internal influence (originally called coefficient of imitation)

Figure 1, based on Mahajan *et al.* (1990), shows the working of BDM schematically. In the initial periods, adoption is due to external influence. The contribution of external influence decreases, and that of internal influence increases, over time.

BDM has been applied to a number of products over the decades. Bass (1969) studied eleven consumer durables ranging from electric refrigerators (introduced in the USA in 1930) and to recover players (introduced in the USA in 1952). Bass et al. (1994) applied the Generalized Bass Model (GBM) to room air conditioners, colour TVs and clothes dryers.

Reviews of diffusion research

The extensive work done by marketing researchers on refining and furthering the classical BDM is summarized in by Mahajan *et al.* (1990), Bass *et al.* (1994), and Bass *et al.* (2000). Bass *et al.* (2000) classify diffusion models according to the decision variables they incorporate: price alone, advertising alone and both price and advertising.

In a meta-analysis of diffusion models, Sultan *et al.* (1990) studied 213 sets of parameters from 15 articles published from the 1950s to the 1980s. They found that the average values of *p* and *q* were 0.03 and 0.38 respectively, though the values varied considerably. One of their conclusions was that the diffusion process is driven more by word of mouth than by the innate innovativeness of consumers.

Bass *et al*. (1994) develop a Generalised Bass Model (GBM) which enabled the inclusion of decision variables such as price and advertising. The GBM incorporated a term for “current marketing effort”. When this term is a constant, the GBM is equivalent to the classical BDM, and that explains why the classical BDM provides a good fit to adoption data even though it does not incorporate decision variables.

In their multinational analysis of new product diffusion, Talukdar *et al.* (2002) find that developing countries have less penetration potential, and take longer to achieve peak sales. They also investigate the impact of macro-environmental variables on penetration potential and speed, and present an improved methodology for predicting sales and BDM parameter values.

Van den Bulte and Stremersh’s (2004) meta-analysis analyzes diffusion trajectories across 28 countries to study the role of social contagion and income heterogeneity in the diffusion process. They develop hypotheses about the relationship between income heterogeneity and *q*/*p* ratio, as well as between dimensions of national culture and the *q*/*p* ratio.

Hauser *et al.* (2006) identify sixteen topics, grouped into five fields, in their agenda for innovation research. Under the topic of growth of new products, within the field of consumer response to innovation, they note the shortcomings of the BDM. First, the classical BDM did not include explanatory variables. Subsequent inclusions of these variables made specification and estimation complicated. Second, parameter estimates are sensitive to the time period considered. Third, the original estimation by multiple regression is affected by multicollinearity. Fourth, the estimation of parameters requires past data including inflexion points, and this means that parameters can only be estimated once diffusion is history. They state that these and other problems have been addressed by the following research, but it is not clear how the second and fourth problems have been addressed, and the challenges for future research do not seem to include these shortcomings either.

In a review, Peres *et al.* (2010) reiterate that the "main thread" of diffusion research is based on the BDM. They explain that in Bass (1969) the internal parameter represented word of mouth; this understanding needs to be widened to include the two additional social influences of network externalities and social signals. They group past research and their directions for future research into diffusion within markets and technologies, and diffusion across markets and brands.

In summary, the BDM is the foundation of substantial body of research. Several scholars have reviewed and studied patterns in this research. In some cases, these studies acknowledge the limitations of the BDM, but there does not seem to be a thorough study of such limitations. The next section attempts to analyze these limitations with illustrations from the mobile communications market.

Limitations of the BDM

Mobile diffusion curves

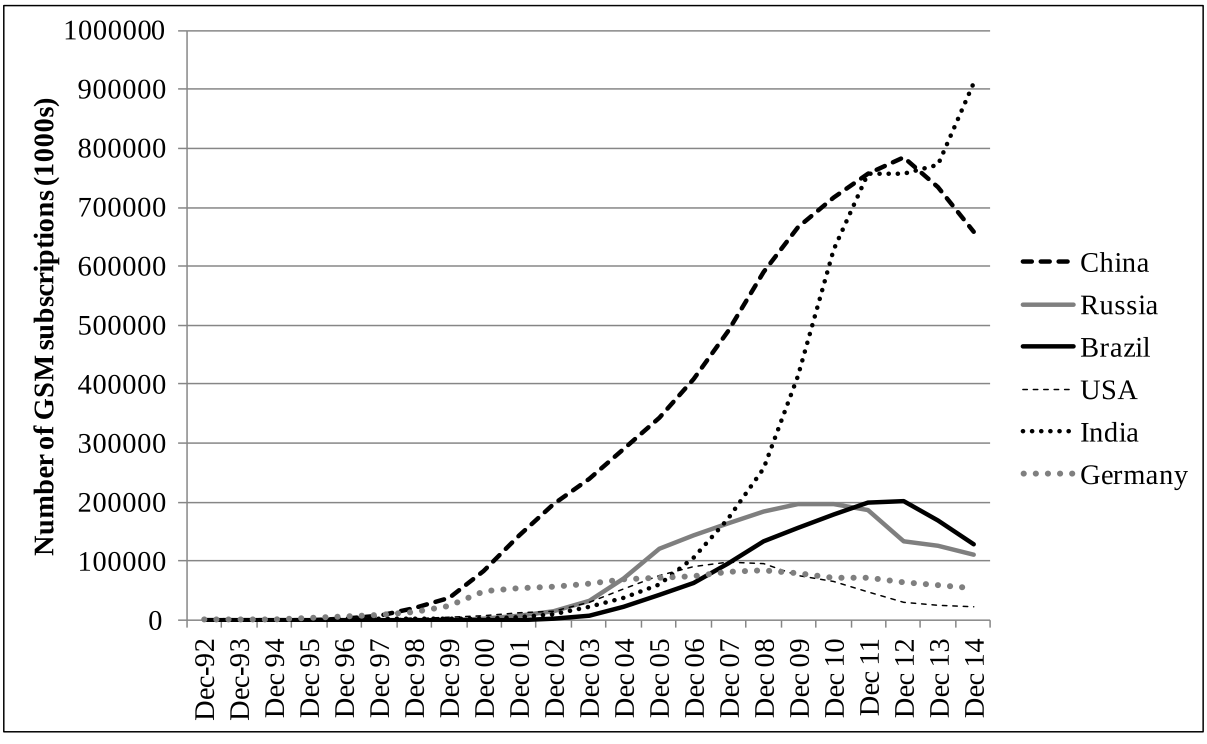


Figure-2 Cumulative adoption curves of GSM in five large markets (subscriptions in 1000s) (Source for data: Informa (2015))

Bass (1995) explains that curves generated by the BDM do not always describe the adoption process, but they usually do. As such, the BDM is an empirical generalization of the diffusion of innovations. Figure-2 shows the adoption curves of second generation Global System for Mobile Communications (GSM) in the large emerging markets of Brazil, Russia, India and China (BRIC) and in the developed markets of the United States of America (USA) and

Germany. First, third and fourth generation technologies, and the second generation CDMA technology are excluded from this picture, so that it shows a single technology. Some observations can be made from this chart. First, a complete adoption model must include de-adoption or abandonment. While diffusion research does account for successive generations of technology, it does not appear to account for products such as pagers being abandoned. Second, it is difficult to accept that a smooth S-curve is the pre-dominant pattern of diffusion in the figure. A more reasonable view seems to be that the S-curve is an idealised representation, while real-life diffusion curves can be markedly different.

Parameter sensitivity to time period

Table 2 summarizes an analysis of GSM diffusion in five large markets—the USA, Brazil, Russia, India and China. Together, these markets had about 1.9 billion GSM subscribers at the end of 2014. We obtained data on historical subscriptions from Informa (2014), and used CurveExpert software, version 1.4 (Hyams, 2015) to estimate the BDM parameters *p, q* and *m* with non-linear regression for each of the five markets. Since the diffusion curves were not S-shaped, we fitted the BDM to data till the year with the maximum subscriptions, or the year of peak subscription, for each market. Thus we analysed a time period in which the diffusion curve was closer to an S-curve. We first estimated the parameters with data till the year of peak subscription. Then, we estimated the parameter with the peak year's data removed—that is, with data for just one year less. The last column of the table shows the effect of removing one year of data from each of the time series, in percentage terms. In most cases, the effect is small. However, there are large changes in the parameter values for Germany, Russia and the USA. If the BDM parameters p and q are indeed representative of the coefficients of internal and external influence of their respective societies, such large changes in the aggregate measures of these influences in a single year are not likely.

Table-1: BDM fit to GSM diffusion in selected markets

Market	Results with data up to peak year					Results with data up to one year before peak year					% change in parameter values as a result of removing one year of data		
	p ($X10^{-5}$)	*q* ($X10^{-1}$)	*m* ($X10^{2}$)	R	S	*p* ($X10^{-5}$)	*q* ($X10^{-1}$)	*m* ($X10^{2}$)	r	s	*p*	*Q*	*m*
India	8.97	5.68	9.64	.9951	34.11	8.94	5.73	9.39	.9942	33.68	0%	-1%	3%
USA	6.15	6.83	1.09	.9981	2.51	9.10	6.92	1.26	.9981	2.17	-48%	-1%	-16%
China	378	3.35	9.08	.9982	18.17	387	3.26	9.34	.9979	18.41	-2%	3%	-2%
Brazil	1315	5.96	2.15	.9992	3.28	1357	5.79	2.19	.9991	3.36	-3%	3%	-2%
Russia	8.50	7.75	2.01	.9980	5.08	10.2	7.55	2.00	.9973	5.36	-20%	3%	0%
Germany	284	5.79	.795	.9923	4.28	204	6.42	.762	.9927	4.04	28%	-11%	4%

The mental model of the BDM

The mental model of the classical BDM is shown in a stock and flow diagram in Figure-3. In essence, given a certain market potential, adoption is determined by the two forces of internal and external influence. As explained earlier, a huge body of research has augmented the classical BDM. For example, the influence of the marketing mix was added to the model. However some key issues in the mental model of the BDM remain unchanged.

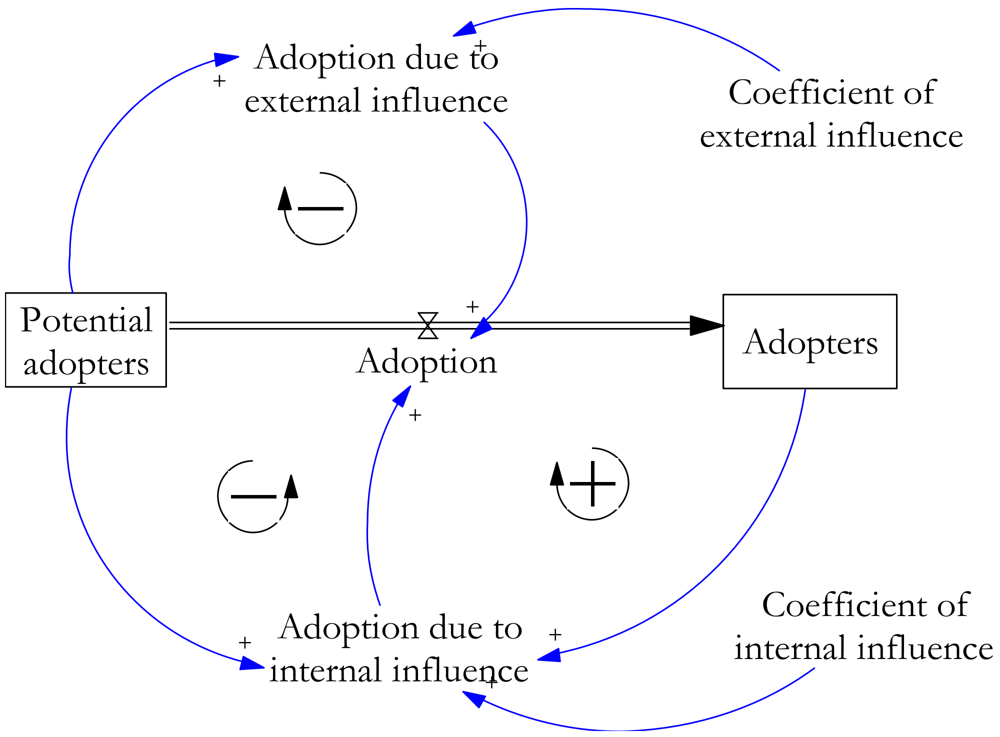


Figure-3: Diagram of the BDM

First, the mental model of the BDM assumes that a person in Singapore can understand and predict the diffusion path of a durable in Papua New Guinea or Canada with just past sales data and without any insights into consumer behaviour, the economy or society, and without any interaction with people from these countries. It is enough to estimate the parameters of the BDM based on the geometry of the past diffusion curve.

Second, there is the issue of predicting the future from the past. In his popular book, Taleb (2007) explains that a black swan is an event which has three characteristics: rarity, extreme impact, and retrospective (though not prospective) predictability. Taleb notes that “(the) highly expected not happening is also a black swan”. In the case of the mobile industry, the initial failure of third generation (3G) Wideband Code Division Multiple Access (WCDMA) services in Europe from a business viewpoint, and the collapse of mobile handset brands such as Motorola and Nokia are examples of events that were unexpected a few years before they occurred. In the concluding section, we explain with more examples how predictions have been wrong by large margins when it comes to mobile communications, though the diffusion of the industry has been rapid and successful.

Third, as explained above, there is evidence that diffusion curves are not necessarily S-shaped and—more importantly— that BDM parameter values estimated are not reliable. The vast research done on adding the marketing mix, technology generations, newer modes of communication between consumers, and other variables to the classical BDM does not overcome these difficulties.

Fourth, the logic behind the acceptance of the BDM is not sound. The logic is roughly this: if adoption were explained by the internal and external forces of the BDM, then adoption curves would follow a particular shape. Since adoption curves do follow the shape, it follows that the BDM does explain adoption. The flaw here is that if *a* implies *b*, and *b* is true, that is not enough to prove that *a* is true.

In spite of its unsuitability to predict or explain retrospectively, the BDM does provide model fit with the extremely parsimonious construct shown in Figure-2 and we need to understand why. A possible reason is that the S-curve is a widely occurring construct. It is also found in project management and in the learning effect, and is an outcome of a reinforcing and balancing loop interacting with each other (Sterman 2000). As shown earlier, once de-adoption kicks in, the diffusion curve does not look like an S-curve any more; however observers who focus on the growth part of the product life cycle will see a shape resembling an S-curve.

The parsimony of the classical BDM derives from its focus on communication between consumers as the driving force of adoption. Other models have taken more comprehensive views of the diffusion process. We use these models to outline the structure of an integrated diffusion model in the next section.

An Integrated View of Diffusion

Rogers' Diffusion of Innovations theory

Everett Rogers started practical research on the subject of diffusion as an agricultural sociologist in 1954. The first edition of his book *Diffusion of Innovations* was published in 1962. The following discussion of the vocabulary of diffusion of innovations is based on the fifth edition (Rogers, 2003). An important point is that many publications (*e.g.* Moore and Benbasat, 1990 and Hsu *et al.*, 2007) state that they use Rogers' Diffusion of Innovations (DOI) theory, but they only use one of the many important constructs (perceived characteristics of the innovation) of DOI theory.

There are four elements in Rogers' model of the innovation diffusion process. First, there is the *innovation*: It is an idea, practice or object that is perceived as new by an individual or other unit of adoption. The characteristics of the innovation, as perceived by the adopter, are relative advantage (the extent to which it is better than what it replaces), compatibility (the extent to which it matches the values and beliefs of the adopter and his or her social system), complexity (the extent to which it is easy to use), trialability (the possibility of experiencing its use without paying upfront) and observability (the extent to which non-adopters can see the benefits to adopters). Second, there are *communication channels* (that are modelled in the BDM). Communication is the process by which participants create and share information with one another in order to reach a mutual understanding. Third, there is the element of *time*. This element is involved in the process in three ways. The individual's decision process consists of a series of stages, from knowledge about the innovation to confirmation of its use. Then, there are differences in the relative innovativeness of individuals. For example, some individuals are "innovators" who are the first to adopt, and some are "laggards", who are the last to adopt. Finally, there are differences in rates of adoption of different innovations. The fourth element in the diffusion process is a *social system*, that is, a set of inter-related units that are engaged in joint problem solving to accomplish a common goal. Depending on the context, it may be a single village or a national market.

Rogers' DOI model clearly shows that adoption is a step in the diffusion process. Diffusion does not end with adoption. As an interesting example, Japan, Egypt and Armenia have similar mobile penetration figures of 118%, 116% and 114% respectively (Informa 2015), but it is quite possible that the drivers, services, device preferences and usage patterns of mobile communication in these countries are different.

Design dynamics

Rogers' DOI theory takes a multi-faceted view of the dynamics of a particular innovation. However, while it recognizes many more variables than the BDM and its successors , it treats the innovation itself as a rather static entity. Rogers does include the phenomenon of reinvention of the innovation by consumers (providing the example of short message service, SMS, in the mobile industry), but does not study the linkages between product design and diffusion. This area is addressed by Rindova and Petkova (2007), who explain that the specific properties embedded in products reflect the producers' intended values. The perceptions of these intended values generate cognitive and emotional responses from consumers, and these responses contribute to the perceived value of the product. Like Bower and Christensen (1995), Utterback (1996) focuses on changes in the innovation product itself, as it morphs through different popular designs until a "dominant design" is established.

An integrated view of diffusion: mobile communication in India as a case study

Figure 4 is our attempt to show selected aspects of the diffusion of innovations, based on Rogers (2003), Rindova and Petkova (2007) and Utterback (1996). We have made some modifications to the original models. While Rogers showed communication channels as having an impact in each of the five stages (from knowledge to confirmation), he showed the perceived characteristics as a determinant only in the persuasion stage. In our initial model, the perceived characteristics drive each diffusion stage, and are themselves a function of communication channels, changing design characteristics and reinvention. We explain this integrated model with a case study, the diffusion of mobile communication in India. Figure 5 shows the history of mobile subscription numbers in India. Key events are superimposed on the chart.

A complex set of inter-related factors—including regulatory actions, intended design characteristics, dominant design evolution and the strategic manoeuvring of firms—shaped the diffusion of mobile communication in the years 1995-2005. The first mobile call in India was made in 1995, in the city of Kolkata. The mobile phone was then a "gizmo of the rich" (*India Today*, 2005), with a handset costing (at 2015 exchange rates) at least US$400, and a minute of a voice call costing the caller 26c and the receiver 13c. Mobile operators had overestimated the market and bid for a total of US$ 6.25 billion to be paid over ten years as licence fees (French, 2009) for operating Global System for Mobile (GSM) services. By 1999, the arrears in license fees were US$ 680 million, for an industry whose revenue was roughly US$ 300 million. In 1999, the Indian government rescued the industry by converting the license fee to a revenue sharing regime through a new telecom policy. The new policy was used as a basis by two conglomerates, Reliance and Tata, to offer Code Division Multiple Access (CDMA) services with minor limitations, in the face of opposition from

GSM operators who stated that the CDMA service was a “back door” entry into mobile communication. The chairman of Reliance stated that its mission was to provide cellular telephony at the price level of a postcard, about 0.2 US dollar cents. This simple statement was a part of functional and symbolic positioning of the new service, which included bundled handsets that were much more affordable than their predecessors. Cheap handsets helped to make mobile telephony affordable for marginal adopters. Many observers including Prahalad (2004) trace the mobile boom in India to the price war that resulted after one particularly aggressive 2003 offer from Reliance, called “Monsoon Hungama” (literally “Rainy Season Commotion”). Mobile services also became more user-friendly with the introduction of the Calling Party Pays (CPP) model in 2003. GSM and CDMA operators were brought under a single licensing policy in 2005 (Telecom Regulatory Authority of India, TRAI, 2007). The existence of prepaid plans remains crucial to the Indian market, as the mechanisms required to enforce post-paid contracts are limited. By 2005, the effective charge per minute had reduced to about two cents a minute, with incoming calls being free.

Mobile diffusion was reaching consumers who did not have access to many basic amenities. The use patterns of these consumers reflected their resource-constrained environments. For example, it became common to make use of the Calling Party Pays model by “leaving a missed call” to convey a message such as “Call me” (Donner 2007). Consumers would use their phone just for receiving calls once their prepaid balances expired. However, Subscriber Identity Module (SIM) cards would expire after a while, and such users were then cut off from mobile communication till they could afford new SIM cards. In 2006, one operator, Bharti Airtel, responded to the unmet need of such users by launching “lifetime validity” plans that were positioned as prepaid plans without an expiry date. There were some glitches around the definition of lifetime, but Telecom Regulatory Authority of India, TRAI (2006) found that when the industry adopted these plans, within about six months 15% of all mobile subscriptions were of lifetime validity plans, and 51% of lifetime validity subscriptions were new adopters of mobile telephony. One of the pillars of the rapid diffusion of mobile communication was the use of e-refills, or over-the-air micro refills. These systems enabled prepaid users to buy airtime in small denominations that were within reach of consumers with low disposable incomes, and cost-effective for mobile operators to deploy. They were pioneered in Philippines (Milne, 2006) but they were perfectly suited to Indian market conditions. In 2007, the Indian mobile industry took its first steps towards site sharing. Under this arrangement, a form of coopetition (Brandenburger and Nalebuff, 1995), while operators competed for end users, they collaborated to share and save costs of towers and electrical equipment. Starting in 2004-2005, several operators outsourced the operation of their networks to global network manufacturers. A challenger mobile operator shook up the industry in 2009 by launching prepaid plans based on per-second billing (*Business Today*, 2014). The incumbent operators responded, and mobile penetration surged from 29% to 43% within a year, and the Indian market started adding 15 million subscriptions a month, more than the Chinese market. The sizzling growth continued till it was checked by market uncertainty. In a corruption scandal uncovered in 2010 (but perpetrated in 2008), popularly called the “2G scam” and counted by *Time* magazine (2011) as one of the top ten abuses of power in history, politicians and officials colluded with some bidders to arrange for them to get frequency allocation licenses at prices well below fair levels. A Supreme Court verdict in 2012 ordered this allocation to be cancelled, and the resulting uncertainty told on the market. In 2012, mobile subscriptions declined for the first time in Indian history. However, in the intervening years, third generation (3G) and fourth generation (4G) auctions were conducted transparently.

Today, mobile phones are deeply embedded in the social fabric of the country. As the end of 2014, there were 924 million mobile subscriptions in India. According to the public quarterly results of the largest mobile operator, Bharti Airtel, in October-December 2014 the average revenue per user (per month), ARPU, was INR 202 (about US$ 3.30), and 95% of its subscriptions were prepaid. In January-March 2002, the operator had reported an ARPU of INR 910 and 63% of its subscriptions were prepaid. The average use level per subscription per month was in October-December 2014 was 417 minutes of voice and 622 megabytes of data (the latter being calculated only for users of data), up from 193 minutes of voice and negligible data in the quarter January-March 2002. Thus, the increase in the number of adopters is accompanied by major changes in the patterns of use. Not only did more people adopt mobile communication, the average use of voice more than doubled, and in addition new services were developed and used. Caller Ring Back Tones (CRBT) were always a popular service in India, given the popularity of films. SMS-based shows became an integral part of Indian TV. Some researchers have studied developmental aspects of mobile communication. For example, Jensen (2007) shows that mobile phones help fishermen to get access to market information to plan their activities so that they get better prices and minimise waste. Balasubramanian *et al.* (2010) study the use of mobile phones for life-long learning among rural women in South India. Lokanathan and de Silva (2010) assess the use of value added mobile services for agricultural market access. An interesting aspect of mobile consumption is that ownership, or subscription, and usage do not exactly overlap. TRAI (2015) reports that in January 2015, the nationwide peak percentage of "active" users versus registered users (those with valid subscriptions) was 89%. However, this figure was in the 50s for some mobile operators. Thus, there were owners who did not use their registered mobile subscriptions. On the other hand, Kalba (2007) states that in emerging markets including India, usage of mobile phones may be shared by "anywhere from two to a dozen users". So there are mobile users who do not own mobile phones.

Figure 4 shows the diffusion of mobile subscriptions juxtaposed with some of the driving events, categorized in terms of the integrated diffusion model presented earlier. We hope that this discussion conveys a sense of the complexity of real world diffusion. The impact of pricing innovations provides just one example. Innovations such as "Monsoon Hungama", lifetime validity and per-second billing were not only about how much customers were charged, but how. They cannot be categorized as price reductions. In some cases, the unit cost of usage actually increased (TRAI, 2006), but the value to the marginal, deprived user still increased and the rate of diffusion still rocketed.

Against this background, research based on plotting diffusion curves and estimating parameters from those curves chooses to ignore rich material on diffusion. Unfortunately some of the drivers discussed above do not figure at all in diffusion research. It is a separate shortcoming that, as explained earlier, the estimated parameters can exhibit large changes on adding just one year of data.

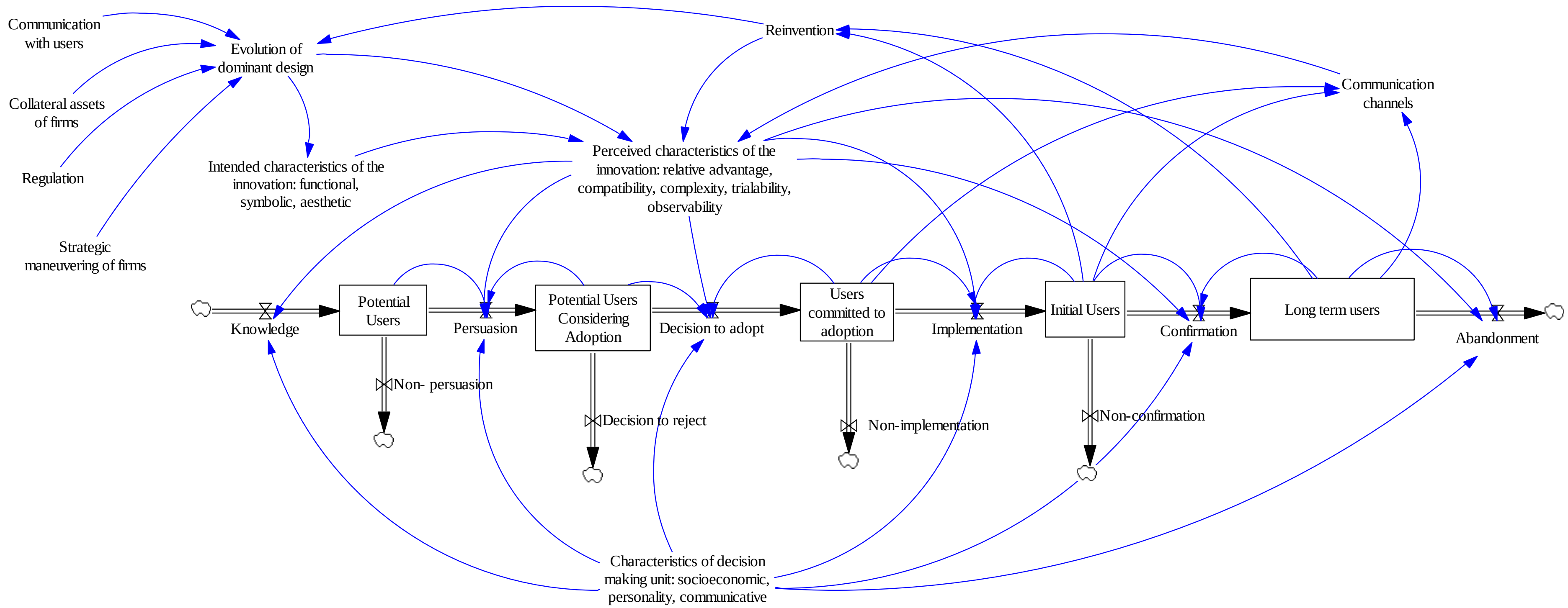
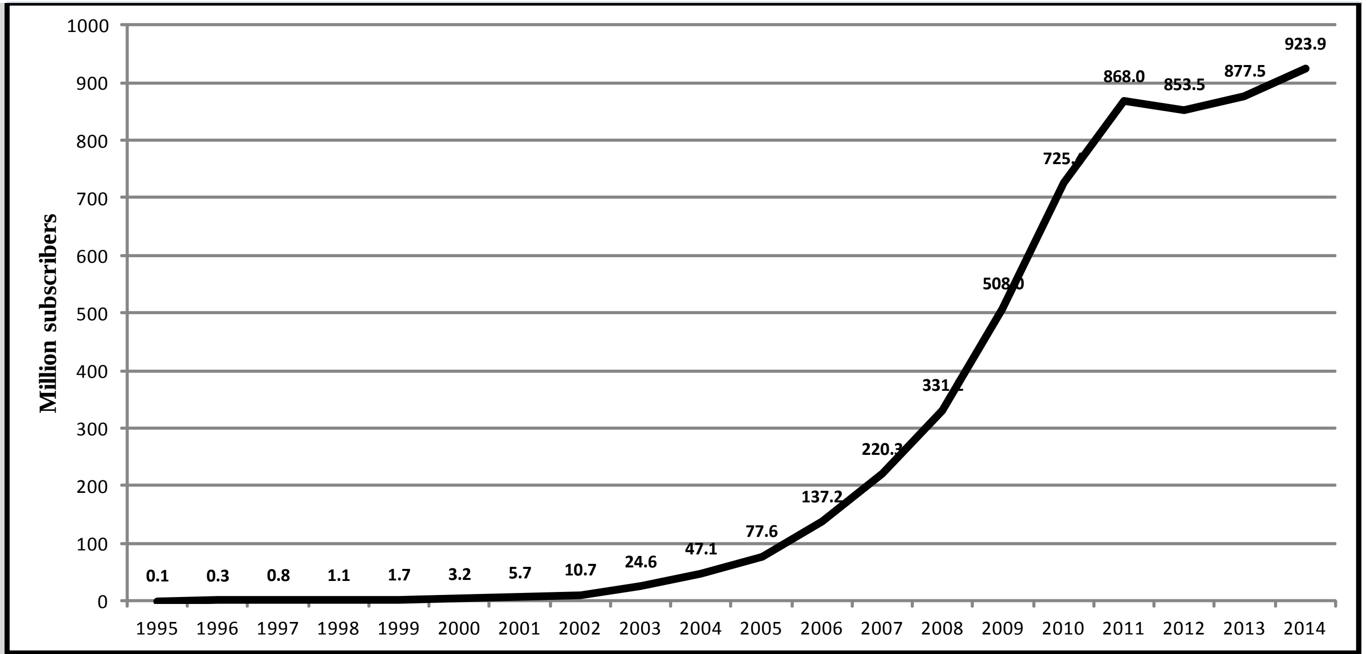


Figure-4: Stock and flow diagram of an integrated diffusion model. Based on Rogers (2003), Rindova and Petkova (2007) and Utterback (1996)

Growth in subscriptions



Drivers and characteristics of diffusion

Regulation	GSM licenses operational	License regime changed to revenue share	Calling party pays	Unified access policy		2G scam uncovered	
Collateral assets of firms			CDMA services launched				
Strategic maneuvering				Network outsourcing	Site sharing		
Communication with users			Monsoon Hungama	E-refills, Lifetime validity plans		Per Second Billing	
Intended characteristics	Prepaid						
Reinvention		Missed call culture	Shared use				
Characteristics of adopters			ARPU US$22.80, 63% prepaid, usage 194 minutes per month				ARPU US$ 3.30, 95% prepaid, usage 417 minutes per month, data usage 622 MB per month

Figure 5: A Simplified View of Mobile diffusion in India (source for subscription data: Informa (2015))

Concluding Remarks

The Difficulty of Prediction: the Global Mobile Industry as a case study

The mobile phone is the most successful consumer appliance in history, if we measure success either by the number of users or by the speed of diffusion. There were 7 billion mobile subscriptions (not subscribers, as multi-SIM usage is common) in the world by December 2014 (Informa 2015). Yet, it is interesting that even in the relatively short period of diffusion of mobile communications, several predictions were spectacularly wrong. These mistakes underline the difficulty of predicting diffusion.

One commonly repeated anecdote on this subject (see, for example, Fransman, 2003) is the consulting firm McKinsey's advice to AT&T, in the early 1980s, that mobile communication had a potential worldwide market of 900 thousand users by 2000 (there were actually 400 million). To be fair to the analysts, this advice must have been based on the then current knowledge about designs and capabilities of mobile phones. A leading communications scholar (de Sola Pool, 1990) also predicted wrongly that rural communications in India would be mainly based on broadcast technologies. While the growth of terrestrial network based mobile telephony was underestimated, the prospects for satellite telephony on the other hand were vastly overestimated. The Iridium network that had five billion US dollars invested in it turned out to be a failure (Olson *et al.*, 2000).

Management literature often cites 3M's "Post-It" notes as a case of serendipitous success. Another messaging innovation, the Short Message Service (SMS) is, however, an even more striking example of serendipity. Mobile operators intended to use SMS primarily to tell subscribers that they had voice mail waiting for them. SMS uses available excess capacity in the "signalling" channels, without burdening the revenue generating "voice" channels. Hillebrand (2010), Trosby (2004) and Agar (2003) describe aspects of the evolution of SMS, including its "accidental" nature and its growth after teenagers discovered it could be used to communicate with a low and fixed cost. From uncertain beginnings, SMS grew to become one of the most successful mobile services ever, in terms of usage, before declining as a new generation of mobile applications took over.

On the other hand, Multimedia Messaging Service (MMS) was launched with the objective of overtaking SMS usage. Le Bodic (2003) suggested that MMS could represent for radio-based personal services what colour television is to radio-based broadcast services. Hsu *et al.* (2007) reflect the mobile industry's view that MMS could overtake SMS. Yet till 2008, MMS had an estimated 1.36% of the usage (number of messages) of SMS (Strategy Analytics 2008).

In summary, several diffusion successes were underestimated, and failures overestimated over a period of two decades. The difficulty of prediction suggests that researchers need to approach diffusion studies with humility, to first increase the explanatory power of diffusion models and then apply the improved understanding of past to make conjectures about the future.

Scope for further work

The integrated diffusion model shown in Figure 4 is only a preliminary work. Two interlinked areas obviously need further development. First, the structure of the model needs to be tested and verified for different kinds of products. For example, defining the exogenous and endogenous boundaries is an area that requires more research. The characteristics of the decision-making units, shown as exogenous variables, may themselves be impacted by changing social norms. Second, the relationships need to be quantified so that the conceptual model is developed into an empirical model.

Implications

We have shown that the BDM cannot explain diffusion, in spite of its ability to fit historical data. The parameters obtained from model fit are not reliable. The incorporation of additional variables into the BDM does not solve the problems that we have listed. The preliminary integrated diffusion model that we present shows the complexity of the diffusion phenomenon. The integrated diffusion model retains a key drawback of the BDM—the need to fit a model to the past, and then use it to make projections about the future. However, in terms of approach, it brings in a much wider set of explanatory variables, and it avoids the use of the time period as an explanatory variable.

It is easier to say that the BDM is flawed than to suggest a replacement. However, the convenience of applying models to historical data should not override the need for reliability, validity and attempted causal understanding.

Diffusion is much more than adoption. Especially with the rise of the services economy, there are many more use cases in which post-adoption diffusion is of interest. Shih and Venkatesh (2004) have studied the determinants, patterns and outcomes of use-diffusion or post-adoption diffusion. However it would be useful to integrate pre- and post-adoption behaviour together with the adoption phase itself.

Marketing research into diffusion needs to diversify and also to start afresh, and we hope to have added to the body of work that will help in these steps.

References

Agar, J. 2003. *Constant Touch: A Global History of the Mobile Phone*. Icon Books, London.

Balasubramaniana K, Thamizolib P, Abdurrahman U, Kanwara, A. 2010. Using mobile phones to promote lifelong learning among rural women in Southern India. *Distance Education*, **31**(2): 193–209

Bass FM, Jain D, Krishnan T. 2000. Modeling the marketing-mix influence in new product diffusion. In Mahajan V, Muller E, Wind Y. *New-Product Diffusion Models*. Kluwer, Boston, 99- 122.

Bass FM. 1969. A new product growth model for consumer durables. *Management Science* **15**(5): 215-227.

Bass FM. 1995. Empirical generalizations and marketing science: a personal view. *Marketing Science* **13**(3): G6-G19.

Bass FM, Krishnan TV, Jain, DC. 1994. Why the bass model fits without decision variables. Marketing Science **13**(3): 203- 223.

Bower JL, Christensen CM. 1995. Disruptive technologies: catching the wave. *Harvard Business Review* January-February: 43-53.

Brandenburger AM, Nalebuff, BJ. 1995. The right game: use game theory to shape strategy. *Harvard Business Review* July-August: 57-71.

Business Today. 2015. A matter of seconds. Retrieved 4 March 2015 from http://businesstoday.intoday.in/story/biggest-indian-innovation---tata-docomo/1/205825.html

De Sola Pool I. 1990. *Technologies Without Boundaries: on Telecommunications in a Global Age*. Harvard University Press, Cambridge, Massachusetts. (Note: Edited by Noam EM, posthumous publication).

Donner J. 2007. The rules of beeping: exchanging messages via intentional "missed calls" on mobile phones. *Journal of Computer-Mediated Communication* **13**(1): 1-22

Fransman M. 2003. Knowledge and sectoral innovation systems: the mobile communications industry evolved largely by getting things wrong. Paper presented at the DRUID Summer Conference, Copenhagen, 2003. Retrieved 22 February 2015 from http://www.druid.dk/uploads/tx_picturedb/ds2003-885.pdf.

French, RD. 2009. Governance and game theory: when do franchise auctions induce firms to overbid? *Telecommunications Policy* **33**(3-4): 164-175.

Hauser J, Tellis GJ, Griffin A. 2006. Research on innovation: a review and agenda for marketing science. *Marketing Science* **25**(6): 687-717

Hillebrand, F. 2010, Communication Networks in the Early 1980s and the Portfolio of GSM Services. In Hillebrand F, Trosby F, Holley K. and Harris I, *Short Message Service: the Creation of Personal Global Text Messaging*, Wiley, Chichester (UK), 1-12.

Hopp WJ. 2004. Ten most influential papers of Management Science's fifty years. *Management Science* **50**(12 supplement):1833-1840.

Hsu CL, Lu HP, Hsu HH. 2007. Adoption of the mobile internet: an empirical study of Multimedia Message Service (MMS). *Omega* **35**(6): 715-726.

Hyams DG. 2015. Curveexpert basic: a comprehensive curve fitting system for windows. Retrieved 15 January 2015 from http://www.curveexpert.net/.

India Today. 2005. 1995: Cellphones arrive. Retrieved 20 February 2015 from http://indiatoday.intoday.in/story/bengal-cm-jyoti-basu-made-indias-first-cell-phone-call-to-telecom-minister-sukh-ram-in-1995/1/192421.html.

Jensen R. 2007. The digital provide: information (technology), market performance, and welfare in the south Indian fisheries sector. *Quarterly Journal of Economics* **CXII** (3): 879-924

Kalba K. 2007. The adoption of mobile phones in emerging markets: global diffusion and the rural challenge. *International Journal of Communication* **2**: 631-661

Le Bodic G. 2003. *Multimedia Messaging Service: an Engineering Approach to MMS,* John Wiley and Sons, Chichester (UK).

Lokanathan S, de Silva H. 2010. Leveraging mobile 2.0 in India for agricultural market. Retrieved 15 January 2010 from ttp://dx.doi.org/10.2139/ssrn.1618193

Mahajan V, Muller E, Bass FM. 1990. New product diffusion models in marketing: a review and directions for research. *Journal of Marketing* **54**(1): 1-26.

Milne C. 2006. Improving affordability of telecommunications: cross-fertilisation between the developed and the developing world. In *Proceedings of the Telecommunications Policy Research Conference 2006*. George Mason University, Virginia.

Moore GC, Benbasat I. 1991. Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*. **2**(3): 192-222.

Olson EM, Stanley F, Czaplewski AJ. 2000. The Iridium story: a marketing disconnect? *Marketing Management* Summer: 54- 57.

Peres R, Muller E, Mahajan V. 2010. Innovation diffusion and new product growth models: a critical review and research directions. *International Journal of Research in Marketing* **27**(2): 91–106

Prahalad CK. 2004. *The Fortune at the bottom of the pyramid: Eradicating poverty through profits.* Wharton School Publishing, NJ.

Rindova VO, Petkova AP. 2007. When is a new thing a good thing? Technological change, product form design, and perceptions of value for product innovations. *Organization Science* **18**(2): 217-232.

Rogers EM. 2003. *Diffusion of Innovations*. Free Press, New York.

Shih C, Venkatesh A. 2004. Beyond adoption: development and application of a use-diffusion model. *Journal of Marketing* **68**(1): 59-72.

Strategy Analytics. 2008. Global mobile messaging forecasts (2001-2012). Retrieved in 2009 from https://www.strategyanalytics.com/default.aspx?mod=reportabstractviewer&a0=9907.

Sultan F, Farley JU, Lehmann DR. 1990. A meta-analysis of applications of diffusion models. *Journal of Marketing Research*, **27**(1): 70 – 77.

Taleb NN. 2007. *Black Swan: the Impact of the Highly Improbable*. Random House, New York.

Talukdar D, Sudhir K, Ainslie A. 2002. Investigating new product diffusion across products and countries. *Marketing Science* **21**(1): 97-114.

Time. 2011, Top ten abuses of power. Retrieved 1 March 2015 from http://content.time.com/time/specials/packages/article/0,28804,2071839_2071844_2071846,00.html

Telecom Regulatory Authority of India (TRAI). 2006. Study paper on analysis of tariff schemes with lifetime validity. Retrieved 1 February 2015 from http://trai.gov.in/Content/StudyPaper/1_StudyPaper.aspx.

Telecom Regulatory Authority of India (TRAI). 2007. A journey towards excellence in telecom. Retrieved 1 February 2015 from http://www.trai.gov.in/WriteReadData/UserFiles/Aboutus/History/achievment.pdf.

Telecom Regulatory Authority of India (TRAI). 2015. Press release on telecom subscription data as on 31st January, 2015. Retrieved 17 March 2015 from http://trai.gov.in/Content/PressDetails/32230_0.aspx .

Trosby F. 2004. SMS, the strange duckling of GSM. *Telektronikk* **3**: 187- 194. Retrieved 22 February 2010 from http://www.telenor.com/telektronikk/volumes/pdf/3.2004/Page_187-194.pdf.

Utterback JM. 1996. *Mastering the Dynamics of Innovation*. Harvard Business School Press, Boston.

Van den Bulte C, Stremersch S. 2004. Social contagion and income heterogeneity in new product diffusion: a meta-analytic test. *Marketing Science* **23**(4): 530-544.