Forecasting of Diffusion Pattern: A Case Example of OLED Technology

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***Abstract* - Technology changes create an enormous impact to every company. To survive in this fast-changing environment, companies need to find a proper way to manage their technologies and prepare for new technology investment. One crucial issue for technology managers to consider after determining the strategic timing for technology substitution is to know what diffusion pattern of new technology would be. This issue is important as the management of companies can effectively prepare themselves to be ready for upcoming market opportunity.**

This paper presents the analysis of the Bass diffusion model to forecast the diffusion pattern of OLED technology in portable devices. The analysis indicates that using p and q value derived from analogous product, cellular telephone, results in realistic diffusion pattern (p = 0.008 and, q = 0.421). The result reveals that OLED portable device sales start to boost up in 2013 and increase significantly around 2015 - 2017.

Keywords – **Bass model, display technology, OLED, technology diffusion**

I. INTRODUCTION

Nowadays, new technologies emerge in a very rapid pace. Scientific breakthroughs, engineering development, product innovations incessantly run to the market. Every company needs to find an appropriate way to know what the diffusion pattern of new technology would be in the future. It is very crucial for companies to deal with this challenge and make an appropriate decision because it will significantly impact the status of a company and determine the future of a company as well.

One of the important roles of technology managers after recognizing technology substitution is to forecast the penetration pattern of a new technology which will diffuse through the market as shown in Fig. 1.

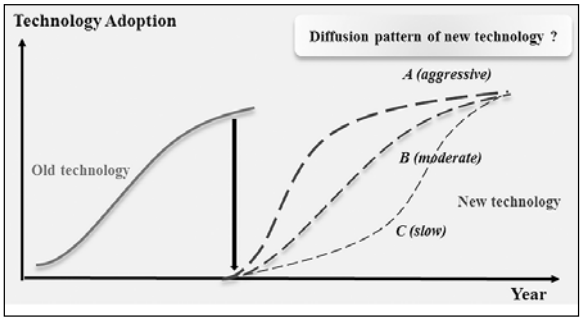

Fig. 1. Prospective result of diffusion pattern.

Gordon emphasized that under tough business competition, companies need to continuously upgrade their technology. Then, forecasting of technology comes to play a role to cope with this challenge and makes companies go beyond its competitors [1]. Porter also explained that forecasting also made any company recognized the possibility and potential of a new technology [2].

History of technology diffusion has been introduced since 1960s. Fourtand and Woodlock (1960), Mansfield (1961), Floyd (1962), Rogers (1962), Chow (1967), and Bass (1969) are the pioneers in this field. According to ISI Web of Science in 2005, the citation numbers of those people are 119, 428, 10, 988, 58 and, 582 respectively [3]. Regarding with these citation numbers, it is obvious that the majority of technology diffusion theories are Rogers and Bass theory.

Bass model has been widely used to illustrate and predict the innovation diffusion pattern in relation with period of time. This model is supported by empirical research with high correlation between perditions by comparing Bass model and actual data report. There are several researches and studies regarding Bass diffusion model. For example, in 2004, there was a study to forecast large-screen TV diffusion pattern in South Korea. The result showed that large-screen TV will boost up sale around 2005. The peak sale is between 2009 -2010 and will saturate in 2015 [4]. Bae and teams analyzed the diffusion of RFID in US retail market by using Bibliometric analysis and Bass diffusion model. The result indicated that the adoption rate of RFID in retail application increased slowly from 2005- 2017 and then significantly increased during 2018-2029. Finally, after 2030, the rate of adaption slowly declined [5].

Therefore, this research emphasizes on applying Bass model to analyze how new technology penetrate thought the market.

II. METHODOLOGY

Bass diffusion researches are reviewed [3, 6-19]. All relative data of OLED (Organic Light Emitting Diodes) and LCD (Liquid Crystal Display) are collected such as the market potential, the feasible value of parameter p and q of OLED and analogous technologies [25-29]. Finally, the diffusion pattern of OLED portable devices is analyzed. Bass equation is shown in equation 1.

Moreover, the ideal diffusion pattern is demonstrated in Fig. 2 [10].

$$S(t)=[p+(q/m)(N(t-1)][m-N(t-1)] \quad (1)$$

S(t) = a number of adopters new product during the time period t

N(t-1) = a cumulative number of adopters for the new product through the previous time period

p = the coefficient of innovation

q = the coefficient of imitation

m = total potential market

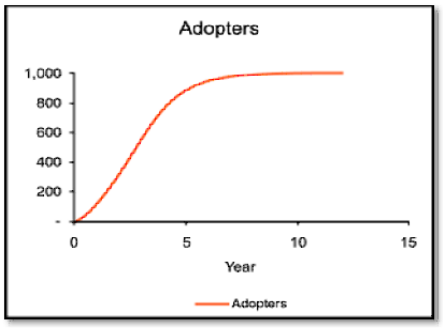

Fig. 2. Cumulative number of adopters.

The procedure to extrapolate Bass diffusion pattern is summarized step by step as followed.

1) Finding the p and q values by using values of analogous product.
2) Finding the m value by estimating the total market potential from reliable source.
3) Bass equation will be used to extrapolate the diffusion pattern.
4) The diffusion pattern should be confirmed with the actual cumulative sales (even at the early stage product lunch) to check the reliability the diffusion pattern. If the pattern is reliable, it can be used for the further analysis. If the pattern does not fit with the amount of cumulative sales over time, then the value of p and q need to be recalculated).

III. RESULTS

To analyze Bass diffusion model, there are 3 parameters needed to identify which are p, q, and m as shown in equation 1.

In most of Bass model studies, p and q values are derived from analogous products. For example, analyzing diffusion model of RFID (Radio-frequency identification), p and q values of barcode were used [20]. Actually in case of OLED, the product that has similar characteristic is LCD, however the p and q values of LCD are not available. Through the initial development, OLED technology has been applied for portable electronic devices like mobile handset, digital camera et al. [21]. Then, the most applicable product with p and q values is a cellular telephone as analogous product. With this case, p value is 0.008 and q is 0.421 [22].

Next step is identifying m which is total potential market size. It is estimated that smartphone and tablet possessions in 2017 will be around 4,000 million units [23]. Therefore, the m value is 4,000 million units.

After p, q and m values are determined, we put all of those values to Bass equation.

The Bass equation will generate the remainder values and extrapolate the diffusion pattern of OLED portable devices as shown in Fig. 3.

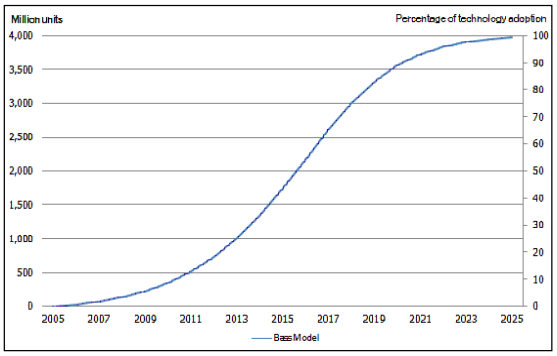

Fig. 3. Diffusion pattern of OLED portable devices.

Fig. 3 shows that the initial phase of diffusion pattern occurs around 2005-2013. Companies producing display products should prepare themselves for investing in OLED portable devices in this period. After that, the market will grow rapidly. Later on, it will go to saturation phase around 2019.

In order to know whether that p and q values obtained from previous research are suitable and reliable to use, data comparison by mapping the graph pattern (Fig. 3) with cumulative actual sales of portable devices in 2005-2012 (Table I) is applied. The table shows actual sales of portable devices of PMOLED (Passive Matrix OLED) and AMOLED (Active Matrix OLED) [24].

Fig. 4 shows the actual cumulative sales along the diffusion pattern. It is clear that the p and q values of analogous product, cellular telephone can be used to forecast future trend of OLED portable devices which both share similar characteristics.

TABLE I
The small/medium size of PMOLED and AMOLED sales in 2005-2012

Year	PMOLED (million units)	AMOLED (million units)	Total sales (million units)	Cumulative sales (million units)
2005	55	-	55	**55**
2006	69.2	0.6	69.8	**124.8**
2007	70.9	2.6	73.5	**198.3**
2008	68.9	7.1	76	**274.3**
2009	Not available	Not available	79.7	**354**

Year	PMOLED (million units)	AMOLED (million units)	Total sales (million units)	Cumulative sales (million units)
2010	Not available	Not available	111	**465**
2011	Not available	Not available	152	**617**
2012	Not available	Not available	191	**808**

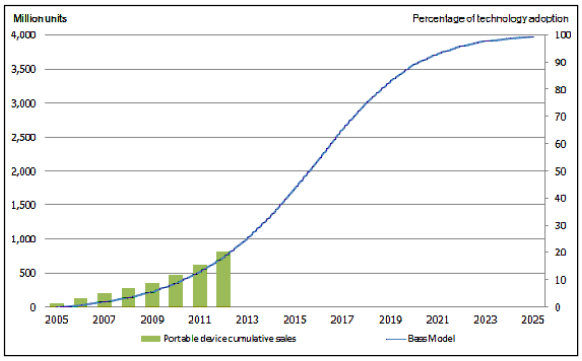

Fig. 4. Diffusion pattern vs cumulative sales.

Finally, the result in Fig. 5 indicates that during 2005 – 2013, it is initial phase of diffusion pattern. Companies should prepare themselves for investing in OLED in order to be ready for huge market opportunity in growth phase which occurs in 2013 – 2019. In this phase, the number of OLED portable device sales are forecasted to boost up around mid of 2013 and sharply increase around 2015-2017. Finally, it will come to saturation phase around 2019.

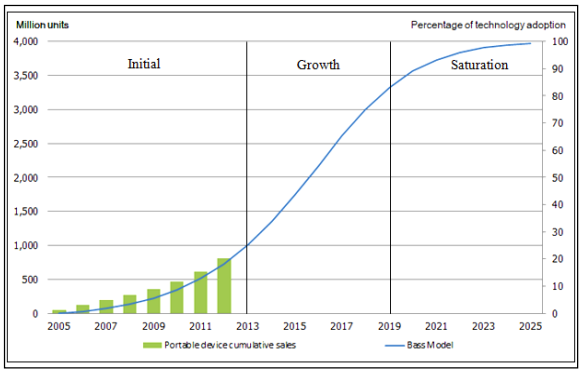

Fig. 5. The result of diffusion pattern of OLED portable devices.

IV. DISCUSSION

In dealing with new technologies after their substitutions, the important question for technology managers is how a new technology penetrates through the market. Bass diffusion model is applied to answer this question.

Bass diffusion model relies on 3 significant factors in order to create diffusion pattern which are p, q, and m. Regarding to the most common use to obtain values of p and q (obtaining from analogous product; cellular telephone, p = 0.008 and q = 0.421 respectively). The m value derives from the estimation of total potential customers in the future, 2017, which are 4,000 million people. Consequently, 3 parameters are calculated to extrapolate the diffusion pattern of OLED portable devices as shown in Fig. 3.

In order to be sure that this pattern is reliable to forecast the diffusion of OLED, the cumulative actual sales in 2005-2012 of portable devices (smartphone and tablet) are plotted in comparison with the diffusion graph. The result shows in Fig. 4 indicating that the current sales are align with the diffusion pattern. It is obvious that the p and q values of analogous product can be used to forecast future trend of new technology that has similar characteristics. Therefore, p and q values of cellular telephone are appropriate for forecasting OLED portable device pattern.

The result in Fig. 5 indicates that in years 2005-2013, it is an initial phase of the diffusion of OLED portable devices. The sales increase gradually from time to time and the market adoption is just around 20%. This period would be a proper timing for companies acting as a fast-follower to prepare their new investments in OLED technology applications in order to be ready for capturing a huge market potential in 2013-2019 (about 2,400 million units which account for 60% of market adoption). This later period is called growth phase of diffusion which the sales increase significantly. In 2019, the analysis result indicates that the OLED portable market will get into saturation phase in which the substitution of a newer display technology could be threaten. At the last stage, the room for market adoption is almost nothing because the OLED portable devices will have penetrated to the market almost 80%. Any investment decision after 2014-2015 would result in a limited return as the later stage in the growth phase of technology life cycle, the competition tends to focus heavily on pricing which is not profitable for companies. At this stage, if companies would like to do business in this market. They have to focus heavily on process development to lower the cost in order to compete with others.

Using p and q value of analogous products is the most common use to analyze Bass model. This research also reiterates that the use of this approach is reliable and appropriate to forecast new technology which has similar technology characteristics. However, it is very crucial as well to validate p and q values before using them to analyze Bass diffusion pattern because using the values without considering the current business dynamic may lead companies to failure.

The result in this research also affirms that the pattern of technology life cycle is S-shape pattern. At the first period, the OLED technology is in the beginning stage of development which has some limitation of its

performance (little steep of slope of technology S-curve). Later on, the technology will be improved significantly and still continuously being upgraded (sharply-slope of technology S-curve). Finally, the OLED technology capability nearly reaches the maximum potential. The slope of technology life cycle will decline. Afterwards, the newer technology will certainly replace the OLED in which it is forecasted to happen in 2019 based on the result of this analysis.

A. Implication of Technology and Innovation Management

The diffusion pattern can lead companies to be well-prepared for a new technology investment. As soon as a company recognizes the diffusion pattern of related-technology, it can properly prepare and adjust business structure and resource allocation in respond to the prospective diffusion pattern. Companies can effectively prepare their human resources, infrastructure, and equipment in order to be prompt with a future technology change and market potential. Companies will have enough time to recruit some expertise to educate their employees to be well-understood and get ready when the time comes. The expansion of factory may be needed; companies can plan and prepare to buy new land, equipment, or build more factories to meet the future demand.

If the diffusion pattern shows strong penetration slope since the beginning, a company should put significant resources in order to capture the opportunity in time otherwise the competitor will seize this opportunity instead. On the other hand, if the penetration pattern proceeds gradually, a company may invest step-by-step rather that dump lot of resources in this technology at the beginning. Definitely, a company applying Bass model will be in a good situation as it can appropriately prepare itself to be ready for the upcoming OLED market opportunity, and has a better chance to success in business.

If any company underestimates this diffusion pattern, the company may not be able to catch up with potential prospective customers. There will be plenty of rooms for competitors to seize market share. Finally, the company may lose the business. In contrast, if any company overestimates this pattern and invests more than necessary. It will turn to be a huge sunk cost because all resources are not used in a maximum potential. New technology is ready, but it is not for the market. Eventually, it will cause the company to fail in this market and may go bankrupt as well.

In the future, if OLED technology is applied to other devices, p and q values will be changed. Then, p and q values of a product which share similar characteristic will be used to extrapolate a diffusion pattern.

Actually, this diffusion pattern can be applied to related technologies or products. For example, plastic molding companies can apply this pattern as guidance to planning for theirs investment on producing smartphone's case cover. They might not have to educate people as much as display technology situation. However, they may have to prepare for buying new machines to product small size of smartphone case. They may have to reconsider the production lines in the factories regarding this market opportunity.

B. Theoretical Contributions

The contribution of this study is to expand the application of Bass diffusion by using OLED technology as another case study. As nowadays this technology is mainly used in portable devices, p and q values of analogous product in the past which is a cellular telephone is adopted to extrapolate diffusion pattern. As a result, it indicates that Bass model is still applicable to use for forecasting the diffusion pattern. Moreover, the result also confirms that the assumption of using p and q values of analogous product is appropriate and can be used as well. Thus, this study reiterates the applicable of Bass model in current technology change.

C. Limitation and Suggestion

Even though Bass model is widely-used in forecasting diffusion pattern of many kinds of product and also has been confirmed to be the useful and acceptable model, using p and q values of analogous product should be considered carefully. The values of p and q may significantly change overtime which will definitely affect the diffusion pattern of that kinds of technology. If current product characteristics are not similar to analogous product in the past, p and q values will be different and create useless model which may lead companies to failure. The value of m is another parameter to analyze Bass model that can be changed over period of time as well. Therefore, it is very important to update and reconsider p, q, and m values regarding market condition in that time.

Secondly, Bass model is based on two basic types of communication – broadcast and interpersonal channels which are very normal in the past. However, there are many types of communication nowadays. Recently, a new type of powerful communication occurs which is online communication or social network communication. Definitely, one of the most powerful communication channels is Facebook. This type of communication has never happened before which can create a significant impact to the diffusion of technologies and innovations.

This prospective model in this research still has limitation in this aspect. Therefore, it is suggesting for other researchers to conduct further study in Bass model including new significant factor which is social network

communication factor to create more accurate diffusion model in respond to business dynamic.

V. CONCLUSION

Bass diffusion model can be used as an effective tool to forecast the penetration pattern of technologies and innovations. This research reiterates that the use of this approach is reliable and appropriate to forecast new technology which has the same technology characteristics. However, it is very important to validate p and q values as well before using them to analyze Bass diffusion pattern. Using the values without consider the current business dynamic may lead companies to failure.

In conclusion, an understanding of technology diffusion pattern is very crucial for any technology-related company. Bass diffusion pattern will definitely provide the guidance for technology managers in companies to prepare themselves for upcoming challenge as well as new market opportunity which will create company competitive advantages in business competition.

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