NOTES AND INSIGHTS

The value of product development lead time in software startup

Olli-Pekka Hilmola,[a]* Petri Helo[b] and Lauri Ojala[c]

Olli-Pekka Hilmola is an assistant professor in the Department of Marketing (International Business/Logistics) at the Turku School of Economics and Business Administration in Turku, Finland. His current research interests include such topics such as supply chain management, new product introduction, theory of constraints and system dynamics.

Petri Helo is acting as a business unit manager at software startup Wapice Ltd in Vaasa, Finland. His current research interests include supply chain management, technology management and system dynamics. He has previously worked as a lecturer at the University of Vaasa in Vaasa, Finland.

Lauri Ojala is professor of logistics at the Turku School of Economics and Business Administration in Turku, Finland. His previous working experience includes a position as an associate professor of logistics at Linköping University in Linköping, Sweden.

Abstract

This article uses system dynamics simulation to enhance current understanding of the effects of product development lead time improvement in situations where a software company itself is not able to finance its operations with its own cash flow. In these situations, capital markets will provide some rounds of financing for startup at the very beginning, but after a while the company itself should be able to enlarge its operations with its own operational cash flow. However, the delay in the product development process, as well as the decline of R&D productivity within the final product markets, will have their effects. On the basis of the results of this article, it is suggested that the improvement of product development lead time is one of the most important parameters in the software startup environment. In some situations, not only will slightly improved lead time performance require fewer rounds of financing, but also expansion of the company's operations will become less troublesome. Copyright © 2003 John Wiley & Sons, Ltd.

Syst. Dyn. Rev. **19**, 75–82, (2003)

The performance of product development of a software company is a widely discussed topic in the management of research and development (Eisenhardt and Tabrizi 1995; Reinertsen 1997; Brown and Eisenhardt 1997; Quinn *et al.* 1997; Cusumano and Yoffie 1999; Yoffie and Cusumano 1999; Hines and House 2001; von Krogh and Cusumano 2001). Most interesting issues are then related to the following factors:

- Uncertainty and the value of information (Reinertsen 1997; pp. 68–83);
- Lead time performance and its enabling factors, such as project sizes, cross-trained resources and capacity utilization (Eisenhardt and Tabrizi 1995; Brown and Eisenhardt 1997; Reinertsen 1997; pp. 42–67);
- The effect of product architecture on end-product performance (Reinertsen 1997; pp. 144–161; von Krogh and Cusumano 2001).

Traditionally, measures proposed for product development are often lists of success factors, found from qualitative analyses. R&D performance measures, on the other hand, have been used at a more general level. For example, econometric models elaborate the relationship between investment and revenue gained. Direct linkages to company-level financial performance have

[a] Turku School of Economics and Business Administration, Rehtorinpellonkatu 3, FIN-20500 Turku, Finland
[b] Wapice Ltd, Wolffintie 36 F 2/3, FIN-65100 Vaasa, Finland
[c] Turku School of Economics and Business Administration, Rehtorinpellonkatu 3, FIN-20500 Turku, Finland
* Prof. Olli-Pekka Hilmola, Turku School of Economics and Business Administration, Rehtorinpellonkatu 3, FIN-20500 Turku, Finland; E-mail: olli-pekka.hilmola@tukkk.fi

System Dynamics Review Vol. 19, No. 1, (Spring 2003): 75–82
Published online in Wiley InterScience 27 January 2003
(www.interscience.wiley.com). DOI: 10.1002/sdr.255

Received January 2002
Accepted June 2002

His research interests are mainly related to distribution and logistics.

not been studied to a great extent in terms of the relationship between R&D and new product development. Thus, there exists a vast amount of research concerning project-level issues such as costs, resources, scheduling and final completion; for a report of some of the earliest research using system dynamics, see Roberts (1964). However, this kind of research would be especially beneficial for software startups, because at the beginning they do not have any operational cash flow. There is only a sum of money available from capital markets, which is then invested in a hopefully efficient and effective product development process. Sometimes companies may over-value the possible amount of cash generated by the developed products. A good example is provided by the classical development of the Macintosh. According to Kawasaki (1990), Apple was able to achieve its estimated total sales for the year 1984 only four years later (sales objective stated in their product introduction plan, which was given at the end of year 1983). The majority of Internet companies established a few years ago may demonstrate this phenomenon as well (Perkins and Perkins 1999).

The system dynamics simulation model used

The simulation model presented (see Figure 1) and analyzed in this paper is positioned to strategic and tactical decision making situations. On some occasions, important daily and weekly operational decisions are ignored. All the equations and parameter values used in this model are presented in the Appendix. As will be noted, the model can generally be divided into two separate parts. The upper part contains all the financial aspects of a software startup company: productivity factor, capital funding, revenues and expenses.

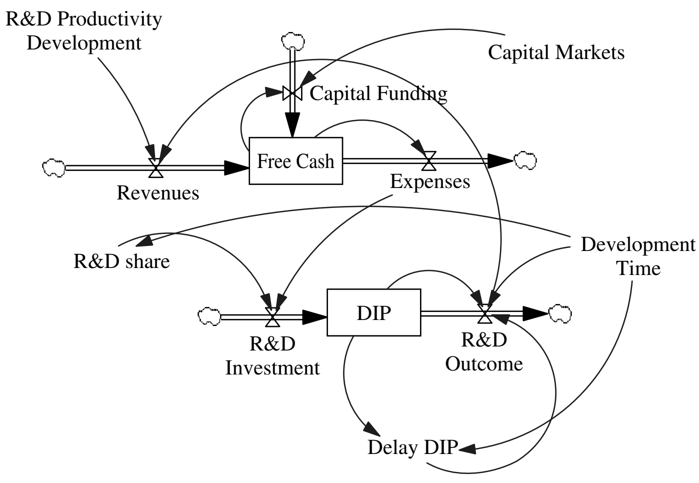


Fig. 1. The system dynamics model used to simulate the life cycle of a software startup (see Appendix for equations and parameter values used)

The lower part presents the value-adding product development process. In a delayed development process, the lower part contains such elements as total share of expenses in efficient and effective development work, as well as the development lead time.

In the model it is assumed that a very small software company starts from a clean slate; it does not have any revenues from current business operations. So at the starting point, capital markets finance all the operations, and expenses depend more on budgetary decisions than on operational revenues. In every situation when the company needs additional finance, capital markets are able to provide it with a fixed amount ($80,000). Until the company's own free cash flow is considered high enough (>$200,000), the total expenses are quite low ($10,000 per month), but after the stated limit, the operations are expanded by a larger amount of cash outflow (to $50,000 per month). These expenses are then linked in the model to the product development process with an R&D share. This R&D share parameter is 20 percent of budget in the scenario, when the development time is 12 months. If development times get shorter, the R&D share will increase along with lead-time improvement. All the R&D investments will remain in the Design in Process (DIP) for the time it takes to develop the product (the model aims to provide a rough view concerning the phenomenon and therefore development delay time is assumed to be fixed). In the model some restrictions on the R&D outcome exist when the DIP is not at a sufficient level. It should be noted that, at the starting point of this simulation, DIP is empty. R&D outcome and R&D productivity development will tie the two stages of the simulation together. Revenue in a particular month is simply the R&D outcome multiplied by R&D productivity development. This latter parameter is assumed to decline from a value of ten to a value of six (see von Braun 1990; Boer 1999; pp. 127–137), because markets will value earlier innovations more.

Analyzing the results of the simulation

As can be seen in Figure 2, the product development lead time has an enormous effect on the performance of the software startup company during the whole observation period. Available cash from the operations at the end of simulation period is almost eight times higher in the ten-month product development lead time scenario than in the 14-month scenario. However, the differences between five scenarios could be identified earlier from other indicators. For example, the scenarios with the three highest lead times will need one more round of financing than others. Also the expansion of operations is much more difficult with a longer product development lead time. Indeed, in some of the scenarios presented it is not even clear when expansion could be initiated. However, with a shorter development lead time, expansion of operations is less troublesome. For example, the ten-month scenario will have reached its

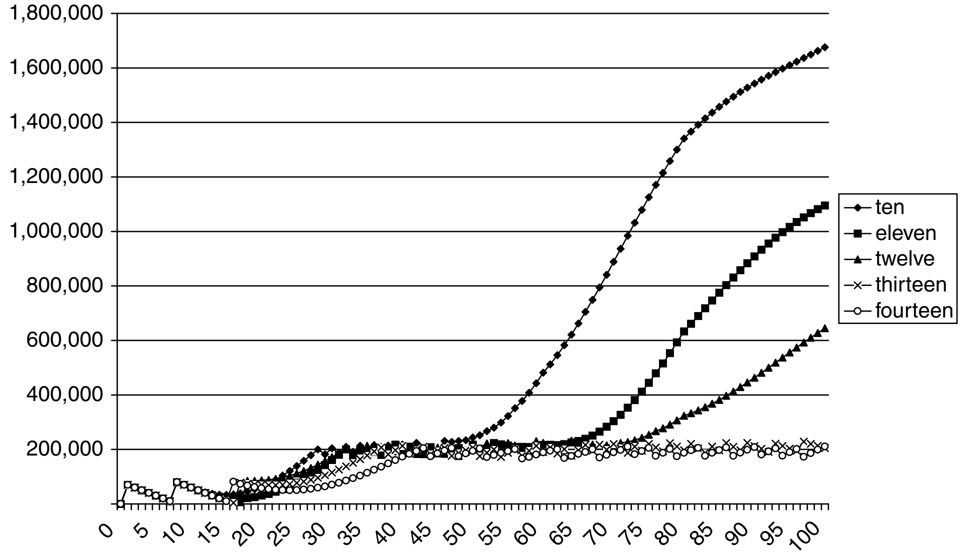


Fig. 2. Amount of free cash in five different product development lead-time scenarios (ranging from 14 to ten months)

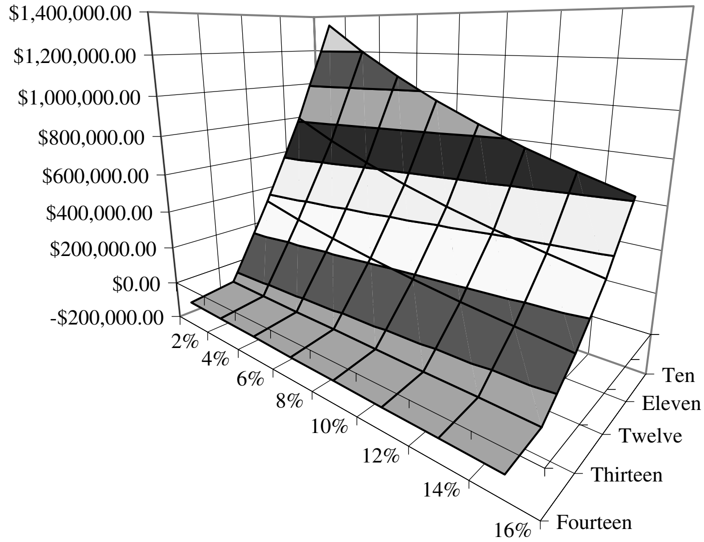
expansion point (where the cash position is well above $200,000) well before the 50th month.

A more reliable evaluation of the degree of success of different scenarios can be assessed from Table 1 and Figure 3. All the different scenarios were evaluated according to the NPV investment appraisal method. When this technique is used, the amount of money invested from capital markets, together with positive and negative cash flows in different months, were discounted to the time of the first month. The results are quite interesting, because the two scenarios with highest lead times will produce insufficient (negative NPV) results. These mainly destroy the possible shareholder value. However, the remaining scenarios provide positive results. If interest rates remain relatively

Table 1. Net present value of five product development lead time scenarios, analyzed with varying interest rates (r = from 2 percent to 16 percent per annum)

r (percent per annum)	Lead time				
	14 months	13 months	12 months	11 months	10 months
2	$ −73,190	$ −47,532	$ 365,142	$ 817,284	$ 1,349,706
4	$ −77,808	$ −52,442	$ 308,730	$ 713,590	$ 1,200,696
6	$ −82,120	$ −57,045	$ 260,223	$ 623,881	$ 1,070,288
8	$ −86,139	$ −61,355	$ 218,363	$ 546,008	$ 955,804
10	$ −89,881	$ −65,386	$ 182,111	$ 478,187	$ 854,997
12	$ −93,361	$ −69,155	$ 150,608	$ 418,934	$ 765,979
14	$ −96,594	$ −72,677	$ 123,140	$ 367,008	$ 687,151
16	$ −99,596	$ −75,967	$ 99,115	$ 321,367	$ 617,159

Fig. 3. Net present value of the five product development lead-time scenarios, analyzed with varying interest rates (r = from 2 percent to 16 percent per annum)



low, then relative performance differences between these three acceptable (positive NPV) scenarios will be lower. The absolute amount of profit in any of these positively performing lead-time scenarios is then impressive. However, as option theory has already suggested (Black and Scholes 1973; Amram and Kulatilaka 1999), the higher interest rates will over-favor in relative terms the lowest lead time scenario. Correspondingly, in absolute terms, any of the three acceptable scenarios will yield a remarkably lower level of profit.

Conclusions

According to the presented results, it is evident that the improvement of the product development process and especially its lead time is important and justified. Especially in the software environment, the increasing revenues and R&D outcome are, by many times, more important factors than the possible saving potential of operations. However, several authors, such as Reinertsen (1997), Cusumano and Nobeoka (1998) and Repenning *et al.* (2001), have already pointed out that focusing too much on the problems of one development effort (project) may have discouraging results on company-wide performance, not only now, but also in the future.

Eventually, all decisions related to product development are tradeoff situations. Too much customer orientation and information sharing between different functions could have its side effects. Whole organizations may even fade away from the market, mostly if they fail to achieve rapid technological development. The winners are those companies that are using integrative product architecture and departmental R&D organization structure (Clark and Fujimoto 1991; Allen 1997; Sosa *et al.* 2000).

The evidence provided in this short article is not only essential information for the management of software companies, but it is also useful for investors dealing with software startups. Currently, it is well known that initial public offerings generally do not provide adequate returns for investors in the longer term, and most often speculative valuations suddenly collapse (Siegel 1998; pp. 102–103; Perkins and Perkins 1999). The axiom in this business is not to reduce the expenses, but to generate in the near future a rapidly growing free cash flow. This measure should therefore receive more attention within the evaluation of different investment opportunities. In this article it was also highlighted that the control of the business expansion period is essential. However, it is left as a problem for further research to reveal whether some external financing should also be provided in this situation.

Acknowledgements

The authors wish to express their gratitude to The Third MIT DSM International Workshop for discussions concerning the research topic, and also for anonymous referee comments.

References

Allen J. 1997. *Organizational Structure for Product Development*. MIT Sloan School of Management Working Paper, No. 166–97.

Amram M, Kulatilaka N. 1999. *Real Options: Managing Strategic Investment in an Uncertain World*. Harvard Business School Press: Boston, MA.

Black F, Scholes M. 1973. The pricing of options and corporate liabilities. *The Journal of Political Economy* **81**(3): 637–654.

Boer PF. 1999. The Valuation of Technology—Business and Financial Issues of R&D. Wiley: New York, Chichester.

Braun CF von. 1990. The acceleration trap. *Sloan Management Review* **32**(1): 49–58.

Brown SL, Eisenhardt KM. 1997. The art of continuous change: linking complexity theory and time-paced evolution in relentlessly shifting organizations. *Administrative Science Quarterly* **42**(1): 1–34.

Clark KB, Fujimoto T. 1991. The power of product integrity. *Harvard Business Review* **68**(6): 107–118.

Cusumano MA, Nobeoka K. 1998. *Thinking Beyond Lean*. The Free Press: New York.

Cusumano MA, Yoffie DB. 1999. What Netscape learned from cross-platform software development. *Communications of the ACM* **42**(10): 72–78.

Eisenhardt KM, Tabrizi BN. 1995. Accelerating adaptive processes: product innovation in the global computer industry. *Administrative Science Quarterly* **40**(1): 84–110.

Hines J, House J. 2001. The source of poor policy: controlling learning drift and premature consensus in human organizations. *System Dynamics Review*, **17**(1): 3–32.

Kawasaki G. 1990. *The Macintosh Way*. Scott, Foresman and Company: Glenview, IL.
Krogh G von, Cusumano MA. 2001. Three strategies for managing fast growth. *Sloan Management Review* **42**(2): 53–61.
Perkins AB, Perkins MC. 1999. The Internet Bubble. HarperCollins: New York.
Quinn JB, Baruch JJ, Zien KA. 1997. *Innovation Explosion—Using Intellect and Software to Revolutionize Growth Strategies*. The Free Press: New York.
Repenning NP, Goncalves P, Black LJ. 2001. Past the tipping point: the persistence of firefighting in product development. *California Management Review* **43**(4): 44–63.
Reinertsen DG. 1997. *Managing the Design Factory*. The Free Press: New York.
Roberts EB. 1964. *The Dynamics of Research and Development*. Harper & Row: New York.
Siegel JJ. 1998. *Stocks for the Long Run—The Definitive Guide to Financial Market Returns and Long-Term Investment Strategies*. McGraw-Hill: New York.
Sosa MA, Eppinger SD, Rowles CM. 2000. *Understanding the Effects of Product Architecture on Technical Communication in Product Development Organizations*. MIT Sloan School of Management Working Paper, No. 4130.
Yoffie DB, Cusumano MA. 1999. Building a company on Internet time: lessons from Netscape. *California Management Review* **41**(3): 8–28.

APPENDIX

Equations used in the software startup model

(01) Capital Funding=IF THEN ELSE(Free Cash<=10000, Capital Markets, 0)
Units: dollars

(02) Capital Markets=80000
Units: dollars

(03) Delay DIP=DELAY FIXED(DIP, Development Time, 0)

(04) Development Time=10
Units: Month

(05) DIP=INTEG (−''R&D Outcome''+''R&D Investment'',0)
Units: dollars

(06) Expenses=IF THEN ELSE(Free Cash>200000, 50000, 10000)
Units: dollars/Month

(07) FINAL TIME=100
Units: Month
The final time for the simulation.

(08) Free Cash=INTEG (+Revenues−Expenses+Capital Funding,0)
Units: dollars

(09) INITIAL TIME=0
Units: Month
The initial time for the simulation.

(10) ''R&D Investment''=Expenses*''R&D share''
Units: dollars/Month

(11) ''R&D Outcome''=IF THEN ELSE ((DIP-(Delay DIP/Development Time)<0), 0, Delay DIP/Development Time)
Units: dollars/Month

(12) ''R&D Productivity Development''=10+step(−1,20)+step(−1,40)+step(−1,60) +step(−1,80) Units: **undefined**

(13) ''R&Dshare''=0.2*(1+(1−(Development Time/12)))
Units: dollars/Month

(14) Revenues=''R&D Outcome''*''R&D Productivity Development''
Units: dollars/Month

(15) SAVEPER=TIME STEP
Units: Month
The frequency with which output is stored.

(16) TIMESTEP = 1
Units: Month
The time step for the simulation.