Managing Complexity in the New Zealand software industry

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Abstract

New product development (NPD) needs specialized management. This is especially true for software products where a huge variety of approaches is possible. This study sampled successful New Zealand technology companies to establish how they manage their NPD processes and what influence innovation complexity has.

This study will focus on the following research questions:

How do successful companies manage new product development for software products?

How does complexity influence the new product development approach?

The Cyclic Innovation Model (A. J. Berkhout, Hartmann, & Trott, 2011) was used as the framework to investigate the role of complexity in innovation.

The study found that while there is considerable variation in how NPD is managed, the level of innovation complexity largely determined the approach. Companies with complex innovation challenges had more iterative software development; flexible internal processes; nimbleness in decision-making and re-prioritisation. Companies with lower levels of complexity in innovation had more formal and sequential approaches; less reviewing of process or product experimentation.

Keywords: innovation management, new product development, complexity, software, entrepreneurship
Managing Complexity in the New Zealand software industry

Abstract

New product development (NPD) needs specialized management. This is especially true for software products. This study sampled successful New Zealand technology companies to establish how they manage their NPD processes and to determine the influence of innovation complexity on management style.

The study found that while there is considerable variation in how NPD is managed, the level of innovation complexity largely determined the approach. Companies with complex innovation challenges had more iterative software development; flexible internal processes; nimbleness in decision-making and re-prioritisation. Companies with lower levels of complexity in innovation had more formal and sequential approaches; less reviewing of process and less product experimentation.

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Introduction

This research investigated how New Zealand companies manage the development of innovative software products. Innovation management is about creating the conditions to enable a company to constantly adapt and be creative. New product development (NPD) is more narrowly about the process of taking an idea, turning it into a tangible product and bringing it to market (Annacchino, 2003). Both involve dealing with complexity, accepting risk and making “thousands of decisions” under uncertainty (Pikkarainen, Codenie, Boucart, & Heredia Alvaro, 2011, p. 108).

Two strands came together in this research. The first is the management of NPD with software products. This concerns itself with such things as software development methods; managing developer teams; and the role of experimentation during NPD. The second strand is about how complexity affects the NPD process.

Government and policy makers are interested in how innovation works and how it can best be stimulated. As the global economy changes, innovation will be a key component of the future wealth and prosperity of New Zealand (Callaghan, 2009; Shanahan, 2011). One measure of a country’s capacity for innovation is the Global Innovation Index (INSEAD, 2012). Seven areas are included in the measure: institutional environment, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, and creative outputs. New Zealand’s innovation ecosystem rates well in this index: in terms of its institutions (the regulatory and political environment in particular); creative outputs (e.g. recreation and culture consumption); market sophistication (e.g. ease of getting credit and of protecting of investors); human capital and research (e.g. investment in primary and secondary education).

The Global Innovation Index shows that innovative ecosystems differ between countries and that the exact ecosystem has an impact on the level of business innovation in a given economy. The majority of innovation management research originates in the United States and usually with large American companies (Dodgson, Gann, & Salter, 2008). There is also a strong body of research emerging from Europe (Curzio & Fortis, 2005). There are limitations on how much this research can be applied to other contexts (Pikkarainen et al., 2011; Sundbo, Gallina, Serin, & Davis, 2006) so local empirical studies of innovation management are valuable to furthering understanding of this field.
There is little consensus on how innovation takes place (Sundbo et al., 2006), nor even strong agreement on foundational principles, although recently there have been synthesizing attempts from a variety of disciplinary viewpoints (Loch & Kavadias, 2007; Pikkarainen et al., 2011; Smith, 2007). The focus here is on literature from management studies.

Linear models of innovation have dominated thinking for many decades (Sandberg, 2008). These models consider the innovation process as a pathway, a series of steps: idea generation, concept development, testing and commercialisation (e.g. Barczak, Sultan, & Hultink, 2007; Cooper, 2008; Sandberg, 2008).

Later models found that innovation was simultaneously taking place along six dimensions: theories of change; organisational learning; leadership; new business start-ups; and relationships both inside and outside the organisation (Ven, Polley, Garud, and Venkataraman, 1999). Innovation management was recognized as a broad group of activities set in nonlinear dynamic patterns, inhibited or facilitated by various internal and external factors.

Berkhout et al., (2010) Introduced the Cyclical Innovation Model (CIM). This sees innovation as a complex interaction between four activities: product creation, market transitions, scientific exploration and technological research (see Figure 1). These represent the four poles of industry (the supply), markets (the demand), basic science (exploration) and technology (development). These poles interact in different ways. For instance, markets and products together create customer value;
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Science and technology together create technical capabilities; technology and industry create technical functions; science and markets create what the authors call social insights (and, it is implied, social change). Entrepreneurial skills are needed to negotiate the challenges arising from these poles.

The CIM provides a useful way of thinking about complexity in innovation and emphasises that NPD is an interconnected, iterative process. For example, consider cloud services: the product is built on new software technology which in turn creates additional capability for new on-demand products using the cloud. The market decides which products are desirable and what role customization plays in this new product. In this way, products change the market and influence social behaviour which in turn leads to theories of online behaviour. Scientific advances in data compression yield new capabilities for software in cloud computing. This type of analysis could equally apply for robotic automation, mobile applications or game consoles. The point is that there is a cycling between the technology and product poles representing engineering; between the product and the market poles, representing product customization. There is also cycling with the science pole which provides both behavioural and social science knowledge which can be applied to market/customer behaviour and physical and natural science knowledge which can be applied to technology. In this way, the CIM usefully demonstrates how the development of a new software product can emerge within a complex environment. New ideas may begin anywhere on the model and influences cycle around in unpredictable directions.

![CIM analysis of cloud computing](image)

Figure 2. CIM analysis of cloud computing.
Product Development of Software

Software products have distinctive NPD challenges: the models of NPD which apply to manufactured products do not easily fit. Pikkarainen et al. (2011) outline five reasons why software innovation is different:

1. Malleable. Software can be incrementally changed, it can be delivered in small chunks, to some types of users first, and there are almost endless ways of achieving functional goals.

2. Intangible. It cannot be inspected except by using it.

3. Accessible. Barriers to entry, upfront investment and cost of distribution can be very low.

4. Consumerization. The user typically becomes co-creator.

5. Productivity. A particular software engineer or team can have a decisive impact on product success.

So software production demands its own kind of NPD approach and this research sought to discover how that is managed.

Method

Population

The research studied high tech companies whose primary revenues are from commercialised software products. They all had a proven track record of software success and were primarily based in New Zealand. Twenty-four companies were invited to participate, eight agreed to take part. Their identities are commercially confidential (see Table 1).

<table>
<thead>
<tr>
<th>Participant</th>
<th>Interviewee</th>
<th>Size</th>
<th>Growth</th>
<th>Ownership</th>
<th>Customers</th>
<th>Product/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digitaldeal</td>
<td>Head of product development</td>
<td>Large</td>
<td>Established</td>
<td>Listed</td>
<td>C, B</td>
<td>Online trading</td>
</tr>
<tr>
<td>Webfabrik</td>
<td>Founder</td>
<td>ME</td>
<td>Start up</td>
<td>Private</td>
<td>B, C</td>
<td>Tools for manufacturing</td>
</tr>
<tr>
<td>Cloudway</td>
<td>Founder, CTO</td>
<td>ME</td>
<td>Start up</td>
<td>Private</td>
<td>B, C</td>
<td>Middleware &amp; cloud services</td>
</tr>
</tbody>
</table>
Table 1. Characteristics of participants

<table>
<thead>
<tr>
<th>Company</th>
<th>Role</th>
<th>Size</th>
<th>Sector</th>
<th>Ownership</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medimage</td>
<td>Founder</td>
<td>SME</td>
<td>Start up</td>
<td>Private</td>
<td>B, PS</td>
</tr>
<tr>
<td>Cybersoft</td>
<td>Head of product</td>
<td>Large</td>
<td>Established</td>
<td>Private</td>
<td>PS, B, C</td>
</tr>
<tr>
<td></td>
<td>development manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financialware</td>
<td>Prod. development</td>
<td>Large</td>
<td>Established</td>
<td>Private</td>
<td>B, C, PS</td>
</tr>
<tr>
<td></td>
<td>manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bizware</td>
<td>Founder</td>
<td>SME</td>
<td>Growth</td>
<td>Private</td>
<td>B</td>
</tr>
<tr>
<td>Infotree</td>
<td>Founder</td>
<td>SME</td>
<td>Start up</td>
<td>Private</td>
<td>B</td>
</tr>
</tbody>
</table>

† B=business, C=consumer, PS=public sector

Procedure

Semi-structured interviews were conducted either in person or via phone. All interviewees were senior product development managers, heads of development, Chief Technology Officers, or company founders close to the development process. The interviewees were all male, mid-career, and from mainly technical backgrounds. Most had international experience (such as working or training overseas). All companies had some business presence overseas but were Wellington or Auckland based.

The Cyclic Innovation Model (Berkhout et al., 2010), states that innovation involves negotiating four poles of influence. These poles feed into each other and essentially represent challenges for the organisation to manage. In the original analysis Berkhout et al. (2010) used the concepts of a 2-level company – where there are two levels of challenge (e.g. product and science) or a 3-level company where there are three challenges (e.g. technology, market and science). However this research felt that classifying a company as ‘2-level’ did not adequately reflect the level of difficulty. In this research a more fine grained a measure was sought based on the degree of complexity.

Jaques defined complexity in terms of time span (Brown, 2011): a complex task requires a long time span to be completed and will require many decisions along the way. Creating a complex piece of software, perhaps one which will need to be patented, will take time to plan, develop and make the “thousands of decisions” (Pikkarainen et al., 2011, p. 108) needed until it yields results. Less complex
tasks are shorter, require fewer decisions and hence are less ambiguous: they are less challenging to manage.

Accordingly, each company in the study was rated in terms of its overall level of complexity for the four CIM poles *product creation, market transitions, scientific exploration* and *technological research*. Ratings of *low, medium* and *high* complexity were assessed from interviewing key staff.

<table>
<thead>
<tr>
<th>Company</th>
<th>Technology</th>
<th>Science</th>
<th>Product</th>
<th>Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bizware</td>
<td>Med</td>
<td>Low</td>
<td>Med</td>
<td>High</td>
</tr>
<tr>
<td>Webfabrik</td>
<td>Med</td>
<td>Med</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Financialware</td>
<td>Med</td>
<td>Low</td>
<td>High</td>
<td>Med</td>
</tr>
<tr>
<td>Cloudway</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Medimage</td>
<td>Med</td>
<td>High</td>
<td>Med</td>
<td>Low</td>
</tr>
<tr>
<td>Cybersoft</td>
<td>Med</td>
<td>High</td>
<td>Med</td>
<td>Low</td>
</tr>
<tr>
<td>Digitaldeal</td>
<td>Med</td>
<td>Low</td>
<td>High</td>
<td>Med</td>
</tr>
<tr>
<td>Infotree</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 2. Companies rated low, medium, high innovation complexity according to product, market, science and technology.

The rating represents a snapshot in time for the company. These ratings would be expected to change over time as markets, products, science and technology all change.

**Sources of Complexity**

*Technology* – all companies in the sample except one scored medium or high in terms of technology complexity. One company (Cloudway) stood out as currently having more complexity than the others and so rated high. This company is also at the leading edge globally in terms of its patented technology. One company scored low on technology complexity as much of the software is comprised of off-the-shelf components (Infotree).

*Science* – two companies (Cybersoft and Medimage) stood out as having high complexity ratings in science. Both companies have products which are commercialised spin offs of world-leading
scientific research. The science is highly specialised. Ensuring that they have the science correct and staying abreast of any developments in the science is a focus for both.

*Product* – half of the companies scored high complexity in terms of their product creation. This was reflected in much concern by interviewees in differentiating and constantly improving their products

*Market* – four of the nine companies were in dynamic and fast-paced markets. They were all creating or proving their markets and optimising their strategy. There was a lack of certainty around what was going to happen next. Two companies scored low on the complexity of their current markets. This was because they had secured markets and customers for their current major products. They had market pull for their products and were outpacing their competition.

**Comparing Management Strategies**

Medimage and Cybersoft both rate high on the complexity of their science challenge and low on the complexity of their market challenge. Both companies are developing new software products which are spin offs of world-leading academic research. In terms of business maturity, the companies are very dissimilar: Cybersoft is a large and well-established company with a whole range of products, while Medimage is a market newcomer, a SME and has one product. However, both have large customers and market pull for their new products. Their customers require very high levels of quality and reliability of product. The process of product development is prescribed by the customer to an extent for Cybersoft and to a high degree for Medimage. Both companies use a formal and specification-driven software development process.

Digitaldeal and Financialware both scored low for science but high on product. Science impacts each company mainly in terms of understanding online behaviour and optimising design accordingly. Development focused on constant extension, optimisation and modification of the main product. Both innovate by creating new spin off products.

Cloudway and Cybersoft are the most dissimilar pair. Cybersoft scored high on science, Cloudway low; Cybersoft scored medium on product and low on market, while Cloudway scored high on both. While both companies work intensively on their new product development, it is the challenge from the market pole which was most revealing in the interviews. The Cloudway data demonstrated a huge focus on the complex challenge of creating, proving and keeping up with an international and fast paced market. The more niche market in which Cybersoft is operating with its new law enforcement product offers a different level of complexity. Both companies have relatively new products, so have a focus on product development currently.
**Analysis**

The first point which became clear during the data analysis is the extent of variation in the management of NPD. Four broad themes emerged from the data: the customer; workflow management; development teams; and managing the build.

The Customer: In software development the customer has a special role. Negotiating priorities with the customer is necessary for all companies but especially so when the company is still developing the product. One participant described the challenge as being one of mutual discovery. Nobody knows what to build: you have to discover what you can deliver and the customer has to discover what it is they want.

Workflow management. Working through iterations was one of the key themes in all the interviews. Regardless of whether the participants said they were working to a waterfall, agile or stage gated model, all discussed running through several product iterations. The outcome of this process is a set of lightweight specifications which are improved upon as the build starts. In this way, specifications evolve over time, rather than being fixed early.

Development teams. The usual development team was four to seven people. These were either led by a product manager, a lead developer or operated as a self-managing team. Developers usually work with a large degree of autonomy and are expected to work towards set goals without much supervision.

Managing the build: Encouraging prototyping was an important part of management. Two companies gave developers free time to work on projects of their own choice. The developers could work on anything they like, but most actually worked on personal ideas to enhance the functionality of their product. A variation on this theme was running a mini-competition between developers to “prove” that their preferred solution is the best.

All companies except one described adjusting their software development methods to the particular challenges of the emerging product. Medimage was the only company that did not; the method used is dictated by the customer’s regulating agency.

During data analysis many re-occurring themes related to innovation complexity were found. The link between companies with similar levels of innovation complexity and their NPD strategies became clear.

Companies whose innovation complexity was high were more likely to favour an iterative NPD method. They did not create upfront specifications; rather they allowed the details of the NPD to emerge during many iterations. Product development always included the customers as partners.
Agile was the preferred software development method for its ability to embrace changes but there were many different iterative techniques. These included: chunking the project into less complex units, using prototyping, partial builds, upfront design dummies, experimentation; and learning from small and early failures (where appropriate).

Medimage and Cybersoft favoured a more stage gated software development method. This was appropriate to their level of innovation complexity and they were able to focus on process efficiency, but it prevented fast prototyping and development. For these companies it was very clear what their new products needed to do, and the challenge was in ensuring that the software would do this reliably. The complexity of their innovation challenge lay in commercializing the science.

Company maturity was found to have bearing on NPD management. Digitaldeal, Financialware and Cybersoft are all established companies with large workforces. They all have customers from different sectors and at least one established product. The participants all described well established workflows and emphasised that efficiency of development was important. Two companies also spoke explicitly about maintaining the balance between efficiency and creativity. At Digitaldeal and Financialware, the elements of this are company culture (openness, flat hierarchy, self-managing teams) and techniques for exploring new ideas (e.g. experimentation days). When recruiting new team members at Digitaldeal, if a candidate for a role was technically brilliant but there were doubts over team fit, then this candidate would not be considered for the role. Alignment with culture and fit are considered overwhelmingly important. At Cybersoft (and Medimage) the scientific expertise is emphasised in the interview data, and the participants explained that this expertise is necessary to cope with their innovation complexity.

The startups used different strategies. Being nimble and being able to change direction, often if necessary, is part of the innovation challenge. Webfabrik, Infotree and Cloudway all describe chasing an emerging market and the strain of doing so. Their NPD focus is on flexibility, adapting to circumstances, environment scanning and building relationships. Cloudway and Webfabrik focussed on team management, assuming responsibility for staff wellbeing and for maintaining motivation during uncertainty. All three experience complexity on many poles of the CIM (market and product in particular). On the other hand Medimage did not need to constantly shift priorities. Both the market and the product were very clear for this company. Partly this was due to strong personal connections to influential people in the area. The focus of the NPD was on excellence, reliable quality, process driven development and constantly scanning the science for developments. Complexity for this company lay in providing science based solutions for problems and the complexity of the new product is about an achievable – if difficult – execution.

Bizware is a company in growth mode, and provides many new software products to business customers. Good governance is stressed as the key to success in NPD. Working for the customer’s
customer is the measure of success in their projects and complexity in innovation lies in constantly evolving a product which creates value for the customer’s business. For Bizware, NPD is a process of mutual discovery and highly iterative, flexible new product development is favoured alongside developing close, consultative, trusting relationships. Each new requirement is a puzzle to be solved creatively within constraints of value and cashflow.

**Conclusion**

While there are many approaches to NPD in NZ tech companies, the level of innovation complexity is a determining factor of the kind of approach. Complexity is inherent in innovation due to the constant interaction between the market, the technology, the product, and the science. Managing innovation requires a long term view as well as short term nimbleness. Many skills are needed to manage the demands of NPD; the many decisions which need to be made, the flexibility to adapt to changing circumstances, to balance workflow efficiency with creativity and to manage the personal strain when you are a startup founder. This study suggests that this is one of the key principles of innovating with software products: recognizing and responding to innovation complexity with appropriate new product development strategies.

This study has been limited by the amount of data gathered. Further research on a larger cross-section of companies developing innovative products might offer greater insight. Further research in this area could develop a contingency model linking innovation complexity to NPD approach.

It appears that successful companies match the way they do business to the challenges they face. It was found that when companies are under pressure – characterised here by higher levels of innovation complexity – it is inherent entrepreneurship which comes to the fore: making risky decisions, ensuring flexibility, focusing on the right priorities, scanning the environment for changes and opportunities while motivating teams of independent developers.


