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Insights

Welcome to the March issue of the *Technology Innovation Management Review*. We welcome your comments on the articles in this issue as well as suggestions for future article topics and issue themes.

Editorial <i>Chris McPhee</i>	3
Underground Innovation: How to Encourage Bootlegging Employees to Disclose Their Good Ideas <i>Kamal Sakhdari and Erfan Jalali Bidakhavidi</i>	5
A Pattern-Based Approach to the Development of Frugal Innovations <i>Anne-Christin Lehner and Jürgen Gausemeier</i>	13
Governing Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship <i>Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez</i>	22
Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs <i>David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søilen</i>	31
TIM Lecture Series – Huge Memory and Collection-Oriented Programming: Less Code, More Speed? <i>Dave Thomas</i>	41
Author Guidelines	44



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Overview

The *Technology Innovation Management Review* (TIM Review) provides insights about the issues and emerging trends relevant to launching and growing technology businesses. The TIM Review focuses on the theories, strategies, and tools that help small and large technology companies succeed.

Our readers are looking for practical ideas they can apply within their own organizations. The TIM Review brings together diverse viewpoints – from academics, entrepreneurs, companies of all sizes, the public sector, the community sector, and others – to bridge the gap between theory and practice. In particular, we focus on the topics of technology and global entrepreneurship in small and large companies.

We welcome input from readers into upcoming themes. Please visit timreview.ca to suggest themes and nominate authors and guest editors.

Contribute

Contribute to the TIM Review in the following ways:

- Read and comment on articles.
- Review the upcoming themes and tell us what topics you would like to see covered.
- Write an article for a future issue; see the author guidelines and editorial process for details.
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Please contact the Editor if you have any questions or comments: timreview.ca/contact

About TIM



The TIM Review has international contributors and readers, and it is published in association with the Technology Innovation Management program (TIM; timprogram.ca), an international graduate program at Carleton University in Ottawa, Canada.



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Editorial: Insights

Chris McPhee, Editor-in-Chief

Welcome to the March 2016 issue of the *Technology Innovation Management Review*. The authors in this issue share insights on underground innovation (bootlegging), frugal innovation, urban living labs, and crowdsourcing.

In the first article, **Kamal Sakhdari** and **Erfan Jalali Bidakhavidi** from the University of Tehran, Iran, examine the factors that encourage employees to reveal previously hidden "bootlegging" activities for innovation within a developing-country context. In their study, they identified five groups of factors at individual, managerial, firm, industrial, and idea levels, explaining the revealing stage of bootlegging behaviour. The findings provide a better understanding of the later phases of bootlegging behaviour and the possible role of context-specific factors such as cultural and religious beliefs.

Next, **Anne-Christin Lehner** and **Jürgen Gausemeier** from the Heinz Nixdorf Institute in Paderborn, Germany, use a pattern-based approach to understand the development of frugal innovations. In their study, they examined 29 selected frugal innovations and the problems they were designed to solve. They deduced six problem categories and identified 56 solution patterns, which they used to analyze the relationships between the abstracted solution patterns, problem areas, and frugal innovations. Their findings illustrate how a pattern-based approach can be used to find comparable – but frugal – solutions to common problems experienced in both developed and emerging markets.

Then, **Bastiaan Baccarne**, **Sara Logghe**, **Dimitri Schuurman**, and **Lieven De Marez** from iMinds – MICT – Ghent University in Belgium, study the urban living lab concept as an inter-organizational design and multi-stakeholder innovation development process to govern the quintuple helix model for innovation. Using a multidimensional case study design that focuses on the concepts of innovation democracy, mode 3 knowledge production, the innovation ecosystem as a system of societal subsystems, and socio-ecological transition, they provide a more profound understanding of such innovation processes to tackle socio-ecological challenges by means of public–private interactions driven by eco-entrepreneurship.

Next, **David Gedda**, **Billy Nilsson**, **Zebastian Sâthén**, and **Klaus Solberg Søylen** from Halmstad University, Sweden, investigate crowdfunding models and associated payout models in search of an optimal combination of models for entrepreneurs and funders. Based on an analysis of the top 10 most visited crowdfunding platforms and surveys of both entrepreneurs and funders, their results suggest that the combination of the "all-or-nothing" payout model with both non-financial and equity crowdfunding models would be optimal. Given that the models used in current platforms are in better alignment with the preferences of entrepreneurs than funders, the authors highlight a potential new market for crowdfunding platforms.

Finally, this issue includes a summary of a recent TIM Lecture presented by **Dave Thomas**, Chief Scientist/CSO of First Derivatives FD Labs, who focused on the disruptive aspects of "huge persistent memory" in terms of the technology shift it represents, the impact it has on how developers write software programs, and the corresponding business opportunities it brings about.

In upcoming issues, we will be examining innovation and entrepreneurship in India and in Australia. We also have other unthemed issues in progress, for which we welcome your submissions of articles on technology entrepreneurship, innovation management, and other topics relevant to launching and growing technology companies and solving practical problems in emerging domains.

A common thread through several of our upcoming issues is our association with ISPIM (ispim.org), the International Society for Professional Innovation Management, which is a network of researchers, industrialists, consultants, and public bodies who share an interest in innovation management. This year, ISPIM Innovation Conference (conference.ispim.org) is being held in Porto, Portugal, from June 19–22.

We hope you enjoy this issue of the TIM Review and will share your comments online. Please contact us (timreview.ca/contact) with potential article topics and submissions.

Chris McPhee
Editor-in-Chief

Editorial: Insights

Chris McPhee

About the Editor

Chris McPhee is Editor-in-Chief of the *Technology Innovation Management Review*. He holds an MASc degree in Technology Innovation Management from Carleton University in Ottawa, Canada, and BScH and MSc degrees in Biology from Queen's University in Kingston, Canada. Chris has over 15 years of management, design, and content-development experience in Canada and Scotland, primarily in the science, health, and education sectors. As an advisor and editor, he helps entrepreneurs, executives, and researchers develop and express their ideas.

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Underground Innovation: How to Encourage Bootlegging Employees to Disclose Their Good Ideas

Kamal Sakhdari and Erfan Jalali Bidakhavidi

“ *Hidden talent counts for nothing.* ”

Nero (37 AD – 68 AD)
Roman Emperor

Employees are increasingly considered as the origin of many corporate entrepreneurial ideas. Research on “bootlegging” posits that individuals often resort to hidden activities to elaborate their initial ideas and bring them to fruition. The origins and causes of bootlegging behaviour are well argued in the literature. Yet, less is known about what drives bootleggers to uncover their hidden ideas. This research uses field data from in-depth interviews with innovators in R&D departments in different industries of Iran to identify factors stimulating bootleggers to reveal their underground ideas. We identified five groups of factors at individual, managerial, firm, industrial, and idea levels, explaining the revealing stage of bootlegging behaviour. The findings provide a better understanding of the later phases of bootlegging behaviour and the possible role of context-specific factors such as cultural and religious beliefs.

Introduction

The corporate entrepreneurship and innovation literature has increasingly highlighted the role of individuals in stimulating entrepreneurial activities within established firms (Amabile, 1988; Kanter, 2000; Turner & Pennington III, 2015). In his seminal article, Burgelman (1983) posits that corporate entrepreneurship is mainly commenced with bottom-up, exploratory activities undertaken by employees at lower levels, in particular those operating at the exploratory departments in R&D units. Yet, where individuals encounter a lack of formal support for elaborating their ideas, they may resort to “underground” (Aram, 1973), “bootlegging” (Augsdorfer, 1996, 2012), or “creative deviance” (Mainemelis, 2010) behaviours. These terms, used interchangeably in this article and the literature (Criscuolo et al., 2013), refer to the process by which employees secretly work on ideas which are not formally supported by their organizations (Augsdorfer, 2005).

The literature on bootlegging has mostly investigated factors causing individuals to follow their underground ideas (Abetti, 1999; Augsdorfer, 2008, 1996, 2012; Glob-

ocnik & Salomo, 2015; Koch & Leitner, 2008; Masoudnia & Szwejczewski, 2012; Salomo & Mensel, 2001). Individuals tend to undertake bootlegging behaviour to reduce uncertainty associated with their ideas (Masoudnia & Szwejczewski, 2012), show the technological and market potential of their ideas (Criscuolo et al., 2013) and establish legitimacy for subsequent resource acquisition (Kannan-Narasimhan, 2014). Yet, there is less understanding of the reasons why bootleggers prefer to uncover their hidden ideas. This lack of attention is unfortunate, given that empirical evidence indicates that bootlegging activities and the subsequent internal pursuit of underground ideas can lead to innovative and entrepreneurial outputs for firms (Augsdorfer, 1996; Burgelman & Sayles, 1986; Criscuolo et al., 2013; Ryan, 2005). Moreover, prior studies have mostly examined such behaviour in developed contexts and said relatively little about how contextual factors may affect bootlegging activities.

This study addresses this gap by posing the question of why bootleggers choose to reveal their elaborated ideas. Data for this research comes from in-depth interviews with bootleggers working in R&D departments in

How to Encourage Bootlegging Employees to Disclose Their Good Ideas

Kamal Sakhdari and Erfan Jalali Bidakhavidi

15 firms in the developing context of Iran. The results indicate that factors at individual, managerial, organizational, industrial, and idea levels can explain the revealing stage of bootlegging.

This study makes at least two important contributions to the bootlegging literature. First, whereas prior literature has largely focused on why employees undertake hidden activities (Augsdorfer, 2005; Masoudnia & Szwejczewski, 2012), this research enriches the literature by investigating the later phases of such behaviour and the reasons behind uncovering hidden ideas. Second, prior studies have been predominately conducted in the context of developed contexts and provided little understanding of how contextual factors may affect bootlegging activities. Selecting the developing country of Iran, we provide valuable insights into context-specific factors driving bootlegging activities.

Theoretical Background

Bootlegging refers to an unofficial way of pursuing innovative activities when facing organizational obstacles (Knight, 1967). Similarly, Augsdorfer (1996) defines bootlegging as a deviate behaviour hidden from senior managers whereby organizational time and resources are used for pursuing innovative ideas that are mainly in line with organisational goals and benefits. Accordingly, bootlegging activities hold three important characteristics (Criscuolo et al., 2013):

1. They are secret and hidden from top management, and not necessarily from colleagues and line managers.
2. They consist of non-programmed and bottom-up activities, often undertaken by employees operating at lower levels of the firm such as those working in R&D units.
3. They represent a kind of constructive deviance, and the resulting goals and innovations are legitimate even though the means may be illegitimate.

Explaining the roots of this behaviour in the theory of “structural strain”, Merton (1968) states that there are valuable goals in any organization and employees attempt to achieve those goals. In a supportive firm where the legitimate means are provided, employees tend to use those means to accomplish internalized goals. On the other hand, when employees are en-

countered with a dearth of legitimate means, and there is the so-called “structural strain”, they may resort to illegitimate means to achieve organizational goals such as entrepreneurial activities. Merton (1968) posits that conformity is an expected behaviour when employees are not faced with structural strain. In this situation, employees follow the rules and use available means to achieve organizational goals. Yet, employees may undertake deviant behaviour when legitimate means are not available for pursuing promoted goals. Meinamelis (2010) argues that structural strain is common in firms due to resource restrictions and the fact that firms often over-promote innovation and creativity and give less attention to available resources for supporting innovative ideas.

Empirical studies have examined bootlegging behaviour and the reasons why employees undertake such activities. A summary of these studies is presented in Table 1. In his seminal article, Burgelman (1983) argues that “hidden innovative activities” are primarily undertaken for elaborating ideas that are beyond the core business of a firm. If the structural and strategic conditions are not appropriate for pursuing innovative ideas, bootlegging occurs and it will continue until the idea can prove its value to senior managers. Augsdorfer (1996, 2008) also posits that employees bootleg to elaborate their immature ideas. When the economic justification and feasibility of the idea is vague, the bootlegging process continues, yet once the feasibility is proven, the process may terminate. Bootlegging is more common in organizations that do not support experimental trial. Employees also resort to bootlegging behaviour in inflexible planning systems where R&D budgets are assigned periodically and ideas appearing between planning periods are not supported (Augsdorfer, 2008).

Abetti (1997) argues that bootlegging can be an effective way of escaping rigid and time-consuming processes, and avoiding interference from managers. It is also considered as a suitable approach for protecting ideas (Koch & Leitner, 2008). Masoudnia and Szwejczewski (2012) find that bootlegging is undertaken to diminish uncertainty associated with ideas. Bootleggers go underground to establish legitimacy and hence acquire needed resources for elaborating their ideas (Kannan-Narasimhan, 2014). Bootlegging can also be affected by formal management practices such as strategic autonomy and rewards as well as employees’ self-efficacy (Globocnik & Salomo, 2015) and creativity (Augsdorfer, 2012).

How to Encourage Bootlegging Employees to Disclose Their Good Ideas

Kamal Sakhdari and Erfan Jalali Bidakhavidi

Table 1. A summary of key prior research on bootlegging

Author(s)	Year	Findings
Burgelman	1983	Bootlegging is a response to non-supportive structural and strategic conditions for ideas outside of a firm's core business.
Augsdorfer	1996	Bootlegging behaviour is undertaken to show the economic justification and feasibility of the idea.
Pearson	1997	Bootlegging can result from curiosity, solving technical issues, and showing the viability of the idea.
Abetti	1997	Bootlegging is an effective way of escaping rigid and time-consuming procedures and rules.
Kanter	2000	Bootlegging is done to gain support for risky projects.
Augsdorfer	2005	The aim of bootlegging is pre-search, product/process improvement and development, and problem solving.
Augsdorfer	2008	Lack of support for experimental trial and inflexible planning are the main reasons for bootlegging.
Koch & Leitner	2008	Bootlegging is a path towards protecting ideas.
Masoudnia & Szwejczewski	2012	Bootlegging is undertaken to diminish uncertainty associated with ideas.
Augsdorfer	2012	Bootleggers can be identified using a diagnostic personality test.
Kannan-Narasimhan	2014	Bootleggers aim to establish legitimacy and hence acquire needed resources for elaborating their ideas.
Globocnik & Salomo	2015	Formal management practices and employees' self-efficacy trigger bootlegging behaviour.

The literature review reveals that prior studies lean more towards the earlier phases of bootlegging behaviour, and less is known about factors stimulating bootleggers to reveal their hidden ideas. Moreover, Abetti's (1999) study indicates that bootlegging behaviour is more common among Japanese employees than American employees because Japanese culture put greater value on long-term employment and loyalty to the firm. As such, cultural and institutional factors may also explain bootlegging activities, but this point has received little attention in prior research. Thus, these gaps in the literature provide the opportunity for this study to further investigate the revealing stage of bootlegging.

Research Methods

This study adopts a qualitative approach to answer the research questions. The qualitative approach tends to

be chosen when the researcher aims to gain a deeper understanding of the phenomenon or identify mechanisms behind it. The nature of qualitative research is essentially exploratory. These studies are conducted for obtaining deep and basic knowledge about a new or complex issue. A case study strategy tends to be applied in exploratory phases when the researcher aims to gain deeper insights into the issue, asking how and why questions (Yin, 2013).

Prior studies indicate that bootlegging behaviour is more common in such industries as information technology, pharmaceuticals, medicine, and telecommunication (Masoudnia & Szwejczewski, 2012). Accordingly, for this study, individuals were selected from companies operating in the field of information technology, software, and pharmaceuticals. Following Kannan-Narasimhan (2014), given that bootleggers are by defini-

How to Encourage Bootlegging Employees to Disclose Their Good Ideas

Kamal Sakhdari and Erfan Jalali Bidakhavidi

tion hidden, we approached top managers to help us identify employees who are more likely to be involved with bootlegging behaviour. They are typically innovators at knowledge-creation units such as R&D and product development units. We interviewed 18 employees in 15 firms, and each interview lasted between 60 to 90 minutes each. Many of the employees were followed up with a second interview, resulting in a total of 33 interviews. Table 2 profiles the companies participants.

Reliability and validity of the research

In qualitative studies, *reliability* refers to the possibility of repeating the same research by another independent researcher and extracting similar results from the same data (Yin, 2013). In this study, following Yin (2013), we documented the data collection and analysis processes so that other researchers could follow and check the process of deriving the results from data. For example, Tables 3 to 7 illustrate open and axial coding, selected quotation, and author's notes. Moreover, we increased the reliability of research by employing two persons for coding the transcript and by re-checking the data with the participants. *Internal validity* concerns the extent to which the results and interpretations are correct and based on reality rather than being the researcher's speculations. There are several strategies for increasing the internal validity of a qualitative study such as triangulating researchers and peer and participant checking, which were all applied in this study. *External validity* refers to the theoretical generalizability of the data, which is substantially achieved through using several case studies for reaching theoretical saturation (Yin, 2013), which was adopted in this research.

Results

Following Corbin and Strauss (2014), open and axial coding levels were used to identify first- and second-order codes. Peer and expert briefing was used to validate emerging codes. The identified categories were classified in five major groups including factors related to the individual, manager, organization, idea, and industry. These factors are shown in Tables 3 to 7. At the individual levels, factors such as persistence, extroversion, practicality, ethics, and self-confidence can be important in revealing underground ideas. The second category is associated with how managers treat their subordinates and manage their units, including the tendency to involve and the development of trust-based relationships. Organizational factors, such as valuing transparency, clarity of organizational values, teamwork and collectivism, and normative enforcement, can also be effective in the revealing stage of bootlegging. Factors related to

Table 2. Characteristics of the companies (N=15) and interview subjects (N=18)

Gender		Unit	
Male	73%	R&D	67%
Female	27%	Product Development	23%
		Software Development	10%
Education Level		Firm size	
Bachelor's	67%	≤49 employees	11%
Master's	27%	50–249 employees	28%
PhD	6%	≥250 employees	61%
Interviewee Age		Industry	
21–30 years	17%	Information technology	4
31–40 years	55%	Telecommunications	5
41–50 years	22%	Medicine	4
>50 years	6%	Pharmaceutics	5

the type of business and the business environment, including the degree of competition and the dynamism of the business environment, can also contribute to revealing hidden ideas. Finally, revealing hidden ideas can be explained by factors related to the idea, such as the relationship to current business and the closeness to implementation.

Discussion and Conclusion

Prior research shows that the origin of many organizational innovations are "individuals" and primarily reflect a bottom-up and informal process. The literature on bootlegging explains why employees resort to underground activities to elaborate their ideas (Augsdorfer, 1996; 2012; Masoudnia & Szwejcowski, 2012). Yet, less is known about the reasons behind uncovering hidden ideas, in particular in the context of developing countries. As such, this research was designed to shed light on the revealing stage of bootlegging. As depicted in Figure 1, identified factors can be categorized at individual, managerial, organizational, industrial, and idea levels.

How to Encourage Bootlegging Employees to Disclose Their Good Ideas

Kamal Sakhdari and Erfan Jalali Bidakhavidi

Table 3. Individual factors

Open Coding	Selected Quotation	Author's Notes
Persistence	<i>That means I should be creative enough to create a sample of what I want to present, then I can announce it.</i>	Persistence can enable a person to find alternative ways to elaborate and express their ideas.
Extroversion versus introversion	<i>Because of my extroverted attitude, I say whatever comes to my mind easily without using many filters.</i>	Extroverted people uncover their ideas to the public sooner because they are more comfortable speaking up.
Practicality	<i>I am pragmatic and I prefer not to say what I am doing till I have reached a concrete output.</i>	It takes some time for practical employees to reach concrete outputs, so these people unveil their ideas later.
Ethics	<i>When you do not let managers know you are spending your time in unplanned activities, it is against ethics and God's advice.</i>	Believing in ethics, and in particular unlawful (forbidden) and lawful (permitted) religious issues, encourages employees to unveil the idea sooner.
Self-confidence	<i>Lack of confidence caused me not to come and tell you what I am doing.</i>	People who have little self-confidence will unveil their ideas later.

Table 4. Managerial factors

Open Coding	Selected Quotation	Author's Notes
Management involvement	<i>The managers prefer to be informed about what is going on. I think everything should be told them.</i>	Management involvement encourages underground ideas to be revealed sooner.
Trust-based relationship	<i>I know if I tell him the idea, he listens to me, so I'd like to tell him my idea.</i> <i>Well, I have some fear of presenting it to my supervisor and he tells it to top managers as his idea.</i>	The managers who develop relationships based on trust enable employees to reveal their ideas sooner.

Table 5. Organizational factors

Open Coding	Selected Quotation	Author's Notes
Valuing transparency	<i>I have to say everything. We have been told always to do so.</i>	A culture valuing transparency encourages employees to uncover their hidden ideas.
Clearness of organizational values	<i>It is not clear to me what is right and what is wrong. I am often not sure whether to be creative or follow the rules.</i>	Lack of awareness about the organizational values postpones revealing ideas.
Teamwork and collectivism	<i>An individualistic culture makes someone not tell someone else exactly what is they are doing.</i>	In an individualistic culture, hidden things are uncovered later.
Normative enforcement	<i>You work freely and independently. No one asks you what are you doing now or what you did yesterday. Goals are important, not the means to achieve them.</i>	Low normative enforcement encourages revealing hidden ideas.

How to Encourage Bootlegging Employees to Disclose Their Good Ideas

Kamal Sakhdari and Erfan Jalali Bidakhavidi

Table 6. Industry/business environment-related factors

Open Coding	Selected Quotation	Author's Notes
Degree of competition	<i>Because this business is so competitive and other companies might surpass us, it is constantly emphasized to know everyone's ideas.</i>	In competitive environments, employees are more likely to be encouraged to present their ideas, so they uncover their ideas sooner.
Dynamism of the business environment	<i>He (the manager) should be aware of it because if I decide not to tell him today, it might be late tomorrow as everything is changing.</i>	Employees should uncover their ideas sooner in more dynamic and fast-paced business environments.

Table 7. Idea-related factors

Open Coding	Selected Quotation	Author's Notes
Relationship to current business	<i>It solves a challenge we are faced with in our ongoing business activities, so why do they reject it?</i>	Ideas related to the core business of the company will be unveiled sooner.
Closeness to implementation	<i>When I feel like the idea is close to implementation, I go for telling my supervisors.</i> <i>Much money is needed to do it, and if I present it now, it will be rejected for sure, so I decide not to present it for now.</i>	Ideas that are well developed and close to implementation are revealed sooner.

We found that individual factors can be effective in revealing hidden ideas. For example, persistence enables employees to find many alternative ways to follow up their ideas. Extroverted people make their ideas open and public sooner because they are more comfortable speaking up. If morality is important for a person, they may publicize the idea earlier because the hidden work would be against their ethical beliefs. In contrast, employees with low self-confidence may postpone revealing their ideas. Although firms do not have control over many of these individual factors, some of these aspects can be manipulated through human resource practices (Augsdorfer, 2012). An interesting finding of this research is the potential role of ethical and religious beliefs in revealing hidden ideas, thereby opening a compelling avenue for future research to investigate the role of religiosity and ethics in bootlegging behaviour.

The second category is associated with how managers treat their subordinates. For instance, if an employee has the perception that their manager is involved and controls the situation, they may try to publicize the idea earlier. Similarly, managers who listen to subordinates' ideas make them feel comfortable and encourage employees to publicize their hidden ideas sooner. If em-

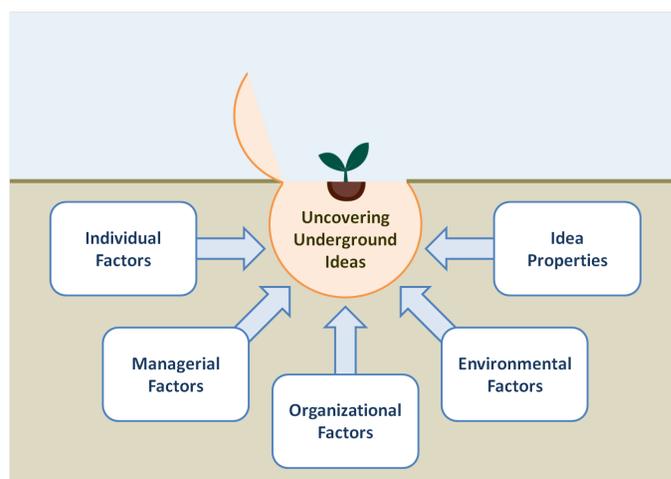


Figure 1. Factors related to uncovering hidden ideas

ployees feel that their managers are likely to steal their ideas (e.g., by presenting the idea to higher level managers without acknowledging the employee's contribution), they may not reveal their hidden ideas. As such, a manager's relational skills and ability to establish relationships based on mutual trust may motivate employees to reveal their underground ideas. Bergelman (1983) argues that middle managers, as intermediaries between senior managers and front line knowledge-

How to Encourage Bootlegging Employees to Disclose Their Good Ideas

Kamal Sakhdari and Erfan Jalali Bidakhavidi

creating staff (e.g., those in marketing and R&D units), play a critical role in facilitating bottom-up initiatives. Our research reveals that such factors as managers' relational skills can be important in creating a suitable strategic context for elaborating and uncovering hidden ideas.

Organizational factors can also be effective in the revealing stage of bootlegging. Theorizing on deviant creative theory, Mainemelis (2010) argues that strict normative enforcement can hinder bootlegging behaviour. Our research acknowledges this proposition by providing qualitative evidence that greater focus on goals than means may better motivate employees to reveal their elaborated ideas. Cultural factors such as the importance of transparency, clarification of organizational values, and the encouragement of teamwork can also trigger employees to reveal their underground ideas.

Factors related to the type of business and the business environment can also contribute to revealing hidden ideas. For example, in a competitive industry, creativity and the presentation of ideas are encouraged and employees are more likely to unveil their ideas easier and faster because the organization encourages them to do so. In some industries, such as information technology, rapid changes may make revealing ideas more important. As such, it seems that, in business settings with more degree of competition and dynamism, there is greater necessity and pressure to reveal hidden ideas.

Finally, factors related to the idea can explain the revealing of hidden ideas. One of the most important factors can be the degree to which an idea has matured. Also, as argued by Burgelman (1983), ideas that are less related to a firm's core business have less chance for organizational attention, enhancing the likelihood of delayed announcement. Ideas far from implementation also need to go underground and take more time to show their market and technological potential, and hence should be revealed later. Failing to support such ideas limits the firm to planned ideas and may restrict their venturing activities (Covin & Miles, 2006). As such, firms may need to prepare a suitable strategic and structural context for elaborating and revealing such ideas.

Overall, this research, as one of the first studies on the later stage of bootlegging in the novel context of a developing country, provides valuable insights into why bootleggers choose to uncover their hidden ideas. Greater understanding of this behaviour waits for future research.

About the Authors

Kamal Sakhdari is an Assistant Professor in the Faculty of Entrepreneurship at the University of Tehran, Iran. He received his PhD in Business and Entrepreneurship from the Queensland University of Technology (QUT) in Brisbane, Australia. His main research interests are corporate entrepreneurship, innovation management, institutional theory, and international business. He is also a member of the Australian Centre for Entrepreneurship Research (ACE) at the QUT Business School.

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How to Encourage Bootlegging Employees to Disclose Their Good Ideas

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A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

“Creativity and insight almost always involve an experience of acute pattern recognition: the eureka moment in which we perceive the interconnection between disparate concepts or ideas to reveal something new.”

Jason Silva

Television personality, filmmaker, and public speaker

The economic rise of emerging markets induces a rapid growth of the global middle class. This new mass market demands products and services adapted to the needs of the local population – so called "frugal innovations". Engineers often face similar challenges while developing products and services for these markets, and therefore may develop similar solutions. By the abstraction of these solutions to transferrable solution patterns, the efficiency of the development process could be increased. In this article, we introduce a systematic approach to develop a pattern system for frugal innovations. Based on 29 selected frugal innovations, we derived the problems that led to the development of the analyzed frugal innovations. By categorizing these problems, we deduced six problem categories: education, environment, culture, infrastructure, regulation, and finance. We stripped down the solutions to these problems to their core principles, and in our subsequent analysis, we identified 56 solution patterns. Moreover, we analyzed the relationships between the abstracted solution patterns, problem areas, and frugal innovations. By using a pattern-based approach, the efficiency of the product development process could be improved significantly. As well, patterns may generate new impetus and increase creativity.

Introduction

The economic rise of emerging and developing countries induces a rapid growth of the global intermediate layer, which will grow from 4.9 billion humans in 2010 to nearly triple that number by 2030 (Credit Suisse AG, 2010; Ernst & Young, 2011, 2013). Eighty-five percent of this increase will come from the Asian continent (OECD, 2010; Roland Berger, 2013), and 40% of the consumption is predicted to be generated in China and India in 2030 (Ernst & Young, 2011).

The emerging mass markets demand low-cost products and services that are adapted to the needs of the local populations. In the literature, such market services are named "frugal innovations" (Basu et al., 2013; The Economist, 2010). Frugal innovations are distinguished by a high robustness, functionality, user

friendliness, and low price (Roland Berger, 2013). However, the concept of frugal innovations is not limited to developing countries and newly industrializing countries: the number of price sensitive customers in industrial countries demanding frugal products will also increase (A.T. Kearney, 2012; Bhatti & Ventresca, 2013).

Companies often face several problems in developing market services and business models for these markets; in particular, they lack knowledge regarding local conditions and customer needs. Their developed solutions are often too costly and do not fit into the environment. Patterns provide solutions for recurring problems. Based on the hypothesis that many of the problems a developer faces in emerging markets are recurrent, patterns can make a substantial contribution to the development process.

A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

In this article, we explain our pattern-based approach to the development of frugal innovations. We start with a short introduction to the concept of frugal innovations. Afterwards, the transmission of the pattern approach onto the development of frugal innovations is explained. In the main section, we describe how we derived frugal innovation patterns and developed a frugal innovation pattern system. Finally, we summarize the results and provide conclusions.

Defining Frugal Innovations

Frugal innovations are a relatively new field of research, which has been gaining in importance in practical and academic discourse during recent years (Bhatti & Ventresca, 2013). The roots of frugal innovation can be traced back to Carlos Ghosn, Chairman and Director of Renault-Nissan, who in 2006 introduced "frugal engineering" as "achieving more with fewer resources" (Kumar & Puranam, 2012). The term frugal innovation became established by the article "First Break All the Rules – The Charms of Frugal Innovation", which was published in *The Economist* in 2010. In that article frugal innovations were described as products that are "stripped down to their bare essentials" and "take the needs of poor consumers as a starting point" (The Economist, 2010). In the course of the increasing academic interest, more definitions of frugal innovations were developed. The differences between the existing definitions can be understood with the help of three questions (Lehner et al., 2015), which are described in the subsections that follow.

1. What are the characteristics of frugal innovations?

An essential difference between the definitions are the assigned characteristics. Price is the main characteristic of many definitions (Bound & Thornton, 2012; Tiwari & Herstatt, 2014). Zeschky, Widenmayer, and Gassmann (2011) define frugal innovations as products with an external cost advantage in comparison to conventional

solutions. In addition to the cost advantage, the scientists of the Frugal Innovation Lab of Santa Clara University define frugal innovations as "appropriate, adaptable, affordable, and accessible" (Basu et al., 2013). According to Bhatti (2012), frugal innovations are characterized by sustainability. Bound and Thornton (2012) point out that frugal innovations often offer a social benefit. Accordingly, a bulk of the common definitions refer to characteristics of frugal innovations that go beyond the cost advantage.

2. Which application areas do frugal innovations address?

The existing definitions differ in the application areas. Whereas the definition of Zeschky and colleagues. (2011) only considers products, Basu, Banerjee, and Sweeny. (2013) and Bound and Thornton (2012) add services. George McGahan, and Prabhu (2012) as well as Bhatti and Ventresca (2013) consider a frugal innovation as a type of business model innovation. The most extensive definition is used by Tiwari and Herstatt (2014): frugal innovations are "products (both goods and services), processes, or marketing and organizational methods". Table 1 shows the three main application areas and exemplary frugal innovations.

3. Where are frugal innovations developed and sold?

A further differentiating factor is the development site and the key market. Some researchers restrict the development site to developing countries and newly industrializing countries (e.g., George et al., 2012; Eager et al., 2011). Others argue that frugal innovations are also demanded by consumers from industrialized countries (e.g., Bhatti & Ventresca, 2013).

For the purposes of this article, we define a frugal innovation as a new or significantly changed product, market service, or business model that is based on the local conditions and customer needs in developing and emerging markets.

Table 1. Application areas and exemplary frugal innovations

Application area	Frugal Innovation	Description
Product	ChotuKool	ChotuKool is a portable, battery-operated fridge, designed for the rural Indian population. It costs about 75 US-Dollar.
Service	M-Pesa	M-Pesa transfers money via SMS (text messages). The service enables its users to remit money with their mobile device to other people, who also have a mobile device.
Business Model	Aravind Eye Care Clinics	In these clinics persons with cataract got operated. By a tiered-pricing business model, poor and rich people can use this service.

A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

Transmission of the Pattern Approach onto the Development of Frugal Innovations

The pattern approach can be traced back to the activities of the architect Alexander. In the 1970s, he developed 253 patterns to design cities, buildings, and constructions. His idea was to document recurrent solution principles in form of patterns. According to Alexander, a pattern “describes a problem that occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice” (Alexander et al., 1977).

A pattern generally does not stand alone. A bulk of patterns is called a pattern catalogue. If patterns are related to each other, we speak of a pattern system, which describes the dependence between the patterns, their implementation, and the process of finding solutions (Buschmann et al., 1996).

To this day, the pattern approach is still used by many different disciplines, including software engineering, product design, and business model development. With the aid of patterns, solutions can be externalized, structured, and documented; complexity and input are reduced and a uniform communication is created (Amshoff et al., 2014).

The transmission of the pattern approach to the development of frugal innovations is based on three hypotheses (Lehner et al., 2015):

1. Product developers face similar problems while developing market services and business models for developing and newly industrializing countries (e.g., insufficient infrastructure, adverse climatic conditions, missing financial resources).
2. If the problems are similar, the solutions will also be similar.
3. By abstracting the applied solutions to patterns, they can be used to develop market services and business models with similar problems.

Besides the derivation of patterns, the insight of the underlying problems is one of the main aims of the analysis. One question is for example: Which problems necessitate the development of a frugal innovation, and how are these problems interconnected?

Development of a Pattern System for Frugal Innovations

To validate the first and second hypotheses and to deduce a pattern system, we used the procedure, described in Figure 1. It consists of four phases, which are explained in the following subsections.

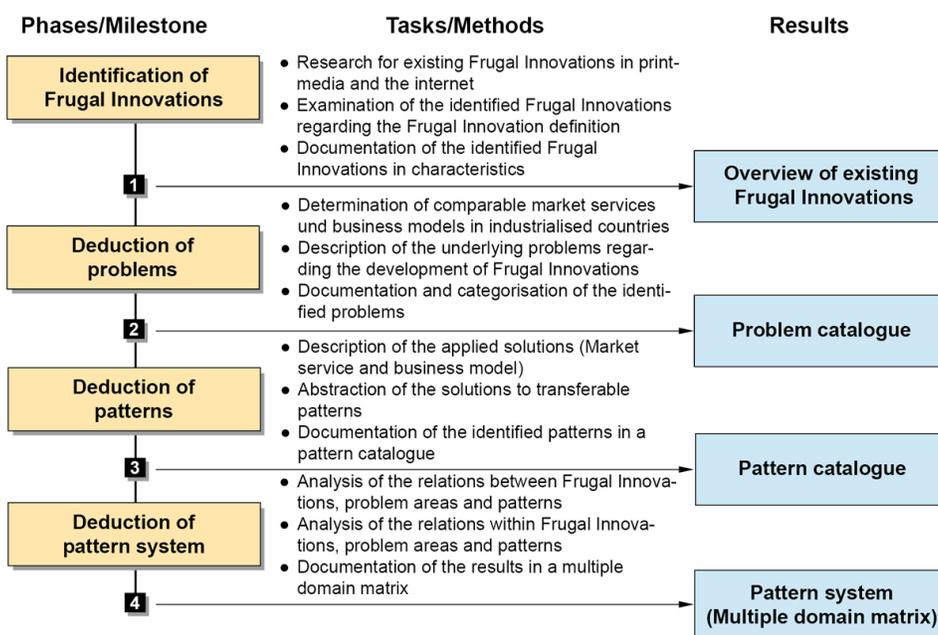


Figure 1. Procedure to develop a pattern catalogue for frugal innovations

A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

Phase 1: Identification of existing frugal innovations

In the literature, there are many market services and business models that are labelled as frugal innovations. First, we researched existing frugal innovations on the Internet and in print media and analyzed them according to our definition of frugal innovations. Market services and business models that were found to conform to all criteria (characteristics, application areas, development site, and key market) were selected and documented. Altogether, we used 29 frugal innovations in our analysis (Lehner et al., 2015). Table 2 shows an extract of the analyzed frugal innovations.

Phase 2: Deduction of problems

In this phase, we analyzed the reasons for the development of a frugal innovation. In the first step, we identified comparable products, services, and business models for each selected frugal innovation. These are market services and business models that are placed in industrial countries and have a similar benefit or value proposition as the considered frugal innovation. For example, a comparable product for the Indian Tata Nano city car is the Volkswagen Up. And, the Aravind Eye Care Hospital is comparable to the eye clinics of the Charité in Berlin. Based on the comparable products and business models, we answered the question of why these products cannot be placed in developing countries. The determined problems were transferred to a list. Besides the obvious problems, such as differences in income, other problems were identified, such as different family structures. After the derivation of all problems for all selected frugal innova-

tions, the results were collected and categorized. In total, six problem categories were identified: environment, infrastructure, education, culture, regulation, and finance.

Phase 3: Deduction of solution patterns

In order to identify the applied solution patterns, we analyzed the applied solutions to solve the problems identified in phase 2 (see Figure 2). The solutions can be an adaption of the market services (e.g., a reduction of the functionality), an adaption of the business model (e.g., an adaption of the revenue model), or both an adaption of the market service and business model. An example of the combined case is the communal use of a market service, which results in a modification of the market service concept as well as the concept of the business model. Afterwards, the identified solutions were abstracted until they just describe the core of the solutions. The number of times a pattern occurred had no influence: each abstracted solution for a problem was documented.

Figure 2 shows the results of the procedure using the example of frugal innovation number 8: the GE MAC 400, which is a portable, user-friendly, battery-powered electrocardiogram (ECG) machine. Due to its characteristics, it offers adequate services during home visits of patients in rural areas. Concrete problems relating to the use of a conventional ECG machine in an emerging country are counted amongst other problems, such as differences in income, differences in temperature, as well as insufficient power supplies in outlying areas.

Table 2. Extract of the analyzed frugal innovations

No.	Frugal Innovation	Description	Country
FI 1	Aravind Eye Hospitals	The Aravind Eye Care hospitals are specialised on eye operations. The price of an operation depends on the income of a patient.	India
FI 2	Bharti Airtel	Bharti Airtel is a mobile phone provider, which offers the worldwide cheapest mobile phone call (1 US-Cent per minute).	India, Africa
FI 3	Chamak Laundry Service	Chamak Laundry Service builds laundry kiosks with washing mashines, dryer and independent water supply. The clothes are cleaned within 24 hours at a price of 0,72 € for 1 kg clothes.	India
FI 4	ChotuKool	ChotuKool serves the local Indian population with a portable, battery-based fridge at a price of 75 US \$.	India
FI 5	Danimal Yoghurt	Danimal's Yoghurt is enriched with vitamin A, iron and zinc, in order to reduce malnutrition in South Africa.	South Africa
FI 6	Dial 1298	Dial 1298 runs an armada of emergency ambulances. The cost of the transport depends on the hospital selected by the patient.	India
FI 7	Eko Financial Services	Eko Financial Services enables low-wage foreign workers access to simple bank accounts and mobile banking. By this, workers have the possibility to send their wages to their families at home.	India
FI 8	GE MAC 400	GE offers a portable, user-friendly and battery-operated ECG-maschine, in order to provide medical care in rural areas.	China, India

FI: Frugal Innovation

A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

The printer that is built into a conventional ECG machine is designed to be used in a climate typical of an industrialized country, but cannot be used in the relatively high temperatures and humidity levels found in a developing country, in this case India. Instead, the frugal innovation adopted a printer that is used to print tickets in Indian bus terminals (Tiwari and Herstatt, 2014). The core of this solution is the transfer of existing solutions from other sectors to the problem under consideration. Accordingly, the pattern is called *Use of existing technologies from other sectors*. Further problems in this case were the absence of distribution and finance infrastructure. These problems are solved by General Electric (GE) in collaboration with the State Bank of India. The bank offers a widely ramified network in rural areas of India. Through this arrangement, GE could use the network of the bank for distribution and could simultaneously offer the solution at low cost. In addition, the confidence in the market services is strengthened by the cooperation with a regional company (Singh & Lillrank, 2015). The derived patterns are *Cooperation with financial institutions* and *Distribution channel sharing*.

All in all we identified 56 patterns for frugal innovations, which build together the pattern catalogue illustrated in Figure 3. In the pattern catalogue, the solutions are sorted by their underlying problem categories. A summary of all determined patterns for the problem category “Infrastructure” is shown the first index card in Figure 3.

Each pattern is briefly described by its characteristics. It consists of a short description of the solution pattern and its underlying problems. Furthermore, best practices are presented. Figure 4 shows an exemplary characteristic of solution pattern 26: *Distribution channel sharing*.

Phase 4: Deduction of the solution pattern system

The targets of this phase are statements about the correlation between the solution patterns as well as the frugal innovations and problem areas. The correlations are visualised with the help of a multiple domain matrix (MDM). The domains, which are illustrated in the matrix in Figure 5, are frugal innovations, problem areas, and solution patterns. The description of the pattern system in this way is somewhat unconventional, but it indicates dependencies between patterns as in the “normal” network descriptions.

The filling of the matrix takes place in two steps. Based on the analysis of the earlier phases, the upper right tri-

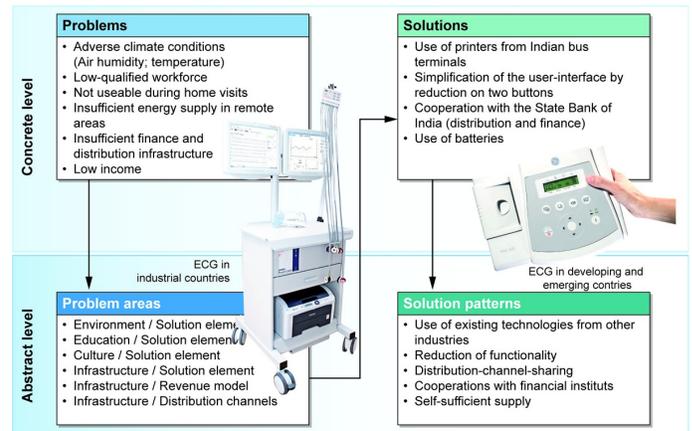
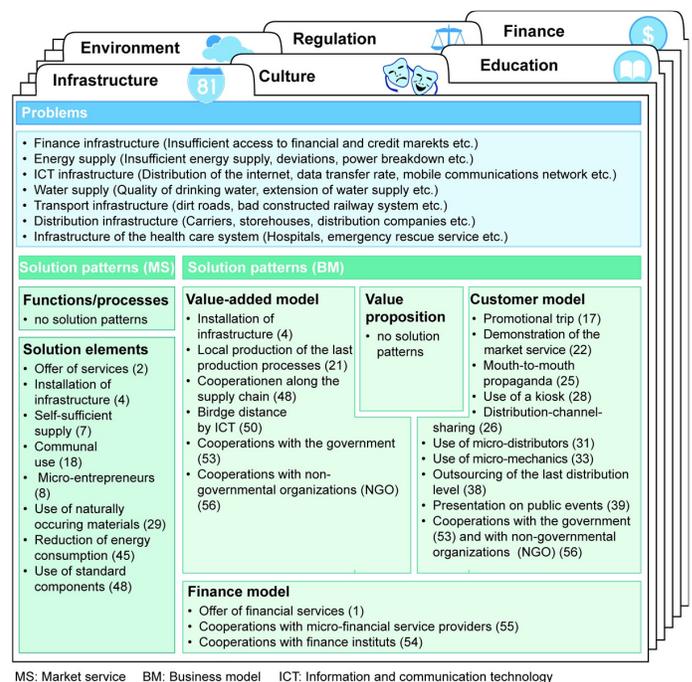


Figure 2. Excerpt of the procedure to develop the solution pattern catalogue using the example of the GE MAC 400 electrocardiogram (ECG) machine



MS: Market service BM: Business model ICT: Information and communication technology

Figure 3. An excerpt of the deduced solution patterns (Lehner et al., 2015)

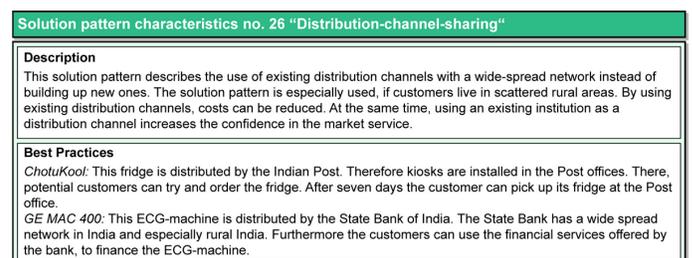


Figure 4. Exemplary characteristics solution pattern number 26: Distribution channel sharing

A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

angle is filled. The diagonal matrices are derived from the matrices of the upper right triangle in the second step. The matrices of the upper right triangle are explained as follows:

- The frugal innovation problem-area matrix indicates which problem areas apply to which frugal innovation. The required data is discussed in Phase 2. For example, problem areas 1 (Environment/solution elements) and 56 (Finance/market services and business model) apply to frugal innovation 1 (Aravind Eye Hospitals).
- In the frugal innovation solution-pattern matrix, the determined solution patterns are assigned to the considered frugal innovations. This information is available from Phase 3 of the procedure. For example, frugal innovation 1 (Aravind Eye Hospitals) uses solution pattern 16 (*Tiered pricing*).
- In the problem areas solution-patterns matrix, indicates which patterns can be used to solve which problem areas. This information can also be derived from the results of Phase 3. For example, for problem area 56 (Finances/market services and business model), solution patterns 16 (*Tiered pricing*) and 33 (*Pay per use*) can be applied.

The three diagonal matrices are described as follows:

1. *Frugal innovation matrix*: This matrix indicates the degree of similarity between two frugal innovations. The degree depends on the existing problem areas and used patterns of two compared frugal innovations. The frugal innovation matrix is a so-called diagonal mirrored matrix. Therefore, just the upper right triangle is calculated. In order to calculate the missing values, the matrix is mirrored on the diagonal. Two frugal innovations have the same problem areas and use the same patterns by a correspondence of 100%. The highest correspondence grade exists between frugal innovations 1 (Aravind Eye Care) and 28 (Narayana Health). These frugal innovations are two Indian hospital chains, which are specialized in different disease patterns. The predominant problems are solved with a similar pattern combination. Beside these frugal innovations, which are from the same industry, there are other frugal innovations with a high agreement grade, which are resident in different sectors: the fridge ChotuKool and the ECG machine GE MAC 400.

Frugal Innovations- problem areas- solution patterns- matrix	no.	Frugal Innovations (FI)			Problem areas (PA)					Solution patterns (SP)				
		FI 1	FI 2	FI 29	PA 1	PA 2	PA 55	PA 56	SP 16	SP 33	SP 54	SP 27		
Aravind Eye Hospitals	FI 1	100%	24%	10%	X	X	0	X	X	0	0	X		
Bharti Airtel	FI 2	24%	100%	8%	0	X	X	X	0	0	0	0		
Zhongxing X-Ray Machine	FI 29	10%	8%	100%	X	0	0	X	0	0	0	0		
Environment / Solution elements	PA 1				100%	33%	45%	98%	0	0	0	X		
Infrastructure / Solution elements	PA					100%	2%	98%	0	0	X	X		
Regulation / Solution elements	PA						65%	100%	94%	0	0	0	X	
Finance / MS and BM	PA 56						12%	65%	3%	100%	X	X	X	X
Tiered-Pricing	SP 16									100%	0%	14%	19%	
Pay-per-use	SP 33									0%	100%	23%	22%	
Cooperation with financial institutions	SP 54											100%	33%	
Use of existing technologies from oth. industr.	SP 27											46%	100%	

Figure 5. Matrix of frugal innovation problem areas and solution patterns

2. *Problem area matrix*: This matrix indicates how often a problem area j (column) appears when a problem area i (line) exists. In contrast to the frugal innovation matrix, it is a directional matrix. An evaluation of 100% implies that the problem area j (column) always exists together with the problem area i (line).
3. *Solution pattern matrix*: In this matrix, the correlations between the patterns are analyzed. It indicates how often a pattern j (column) appears when a pattern i (line) exists. This matrix is also a directional matrix. A value of 0% means that a pattern j (column) is never used in cases where pattern i (line) exists. For example, this is the case with solution patterns 1 (*Tiered pricing*) and (*Pay per use*).

The pattern system provides an essential input to the development of frugal innovations. The choice of suitable patterns by given problem areas will be supported through the matrices of problem areas and solution patterns. Accordingly, conclusive pattern combinations can be identified.

A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

Analysis of the Results

Based on the presented procedure, 56 solution patterns could be deduced from 29 selected frugal innovations. The most popular solution patterns are number 18 (*Training of local talents*) at 21%, number 34 (*Use of natural resources*) at 21%, and number 52 (*Cooperation with the government*) at 17%.

An analysis of the determined problem areas shows that the reasons for the development of a frugal innovation are based on financial (90%), infrastructural (72%), cultural (38%), and educational (38%) differences. In more than 74% of the analyzed frugal innovation, more than one problem category applies.

According to the allocation of the frugal innovations to the problem categories, 75% of the solution patterns deal with financial problems and approximately half deal with infrastructural problems. Just a few solution patterns support regulatory problems. However, 89% of the solution patterns focus on multiple problem areas; just 9% of the solution patterns address only financial problems.

The solution of the determined problems are solved by an adaptation of the market service or the business model: 60% of the analyzed solution patterns lead to changes of the business model, as seen in the solution pattern for *Tiered pricing*. The change of the revenue model seldom comes along with changes to the market service. And, 30% of the analyzed solution patterns are based on changes to the market service, as seen in the solution pattern *Biometric identification*, for example. Around 10% of the solution patterns lead to changes to the market service as well as the business model, as

seen in the solution pattern *Communal use*. Regarding all frugal innovations, it becomes clear that it is not sufficient just to change the market service or business model. In most of the cases, it was and will be necessary to change both elements. Therefore, all of the analyzed frugal innovations use a combination of different solution patterns.

Conclusion

The pattern approach is already used successfully in many disciplines, and so its application to the development of frugal innovations seemed promising. The validation of the developed hypothesis confirms this expectation. Based on the presented procedure, 56 solution patterns for frugal innovations were identified. The high reutilization of the patterns shows that a transfer of pattern is reasonable and possible. In further research, it would be helpful to elaborate a pattern-based systematic approach to the development frugal innovations. This approach would require systematic derivation of the problem categories for a given market services and business models, the selection and combination of suitable solution patterns, as well as the transfer of the solution patterns to new application areas.

For practitioners, this article shows the relevance of existing knowledge regarding the development of frugal innovation. The article underlines that, whether using patterns or not, a glance beyond one owns business broadens the horizon and creates new ideas. The problems companies face in emerging markets have parallels to each other, and so we expect a pattern-based search to yield comparable solutions that are both fruitful and frugal.

A Pattern-Based Approach to the Development of Frugal Innovations

Anne-Christin Lehner and Jürgen Gausemeier

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A Pattern-Based Approach to the Development of Frugal Innovations

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Governing Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

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“Cities are never random. No matter how chaotic they might seem, everything about them grows out of a need to solve a problem. In fact, a city is nothing more than a solution to a problem, that in turn creates more problems that need more solutions, until towers rise, roads widen, bridges are built, and millions of people are caught up in a mad race to feed the problem-solving, problem-creating frenzy.”

Neal Shusterman
Author of young-adult fiction
In *Downsiders* (2001)

Growing urbanization puts pressure on both social and ecological systems. This pressure raises complex and multi-faceted challenges that can only be tackled by collaborative and distributed innovation development processes. However, theoretical frameworks that assess such collaborations are often very conceptual, with little focus on the actual governance mechanisms that facilitate them. This article studies the urban living lab concept as an inter-organizational design and multi-stakeholder innovation development process to govern the quintuple helix model for innovation by means of an action research based multidimensional case study design, which focuses on the concepts of innovation democracy, mode 3 knowledge production, the innovation ecosystem as a system of societal subsystems, and socio-ecological transition. In this way, we provide a more profound understanding of such innovation processes to tackle socio-ecological challenges by means of public-private interactions driven by eco-entrepreneurship.

Introduction

Society is confronted with challenges of an increasingly complex and global nature. It is hard for a single societal actor to come up with the right solutions, given that knowledge and resources are distributed among a wide network of stakeholders (Bogers & West, 2012). Thus, innovation actors must reach out to external knowledge. Among the most pressing and interesting challenges are those involving public value and market failure. As urbanization continues at a rapid pace, socio-ecological systems are put under heavy pressure, inducing ecological issues such as global warming, decreasing air quality, increasing hazardous emissions, and geological instability. Although a sense of urgency for solutions is widespread, society is still struggling to find an adequate, sustainable, and agile way to react. It is clear,

however, that these challenges need to be dealt with by a diverse ecosystem of private actors, universities, civil society, and politics.

Nevertheless, in innovation management theory, the question is not *why*, but rather *how* such challenges can be tackled. In the collaborative knowledge production and innovation management literature, one of the frameworks that attempt to take the natural environment into account is the "quintuple helix model" for innovation (Carayannis & Campbell, 2010). Although this rather recent analytical framework is very promising, only little empirical evidence exists that explores its possibilities and limitations. On top of that, this model is mainly applied to assess larger innovation ecosystems such as national or regional innovation systems, and to a lesser extent to the innovation development process.

Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

Therefore, this article focuses on the specific governance mechanisms that can facilitate quintuple helix innovation at the level of the individual innovation development process. More specifically, the "urban living lab" concept is explored as an inter-organizational R&D design and multi-stakeholder innovation development process to govern the quintuple helix model for innovation. Hence, this article contributes to a more profound understanding of local collaborative innovation processes that are designed to tackle socio-ecological challenges by means of public-private interactions, driven by eco-entrepreneurship. In other words: How can urban living labs be a way to put quintuple helix innovation into practice?

First, we discuss the urbanization process to better understand the context in which these challenges occur. Next, we relate this evolution to collaborative innovation literature, and elaborate on the (urban) living lab concept as a way to put this into practice. Finally, we develop an analytical framework, which is structured along the concepts of innovation democracy, mode 3 knowledge production, the innovation ecosystem as a system of societal subsystems, and socio-ecological transition, and apply this framework to two urban living lab cases.

Background

Urbanization, socio-ecological challenges, and urban innovation

The speed of urbanization is overwhelming (Bocquier, 2005). This rapid evolution puts pressure on social, physical, and ecological systems as city populations continue to grow and more and more people are live in densely populated areas. This pressure, in combination with the associated emergence of grand societal challenges and rapid technological evolutions, forces cities to look for new ways to reinvent themselves (Atkinson, 1998; Foth, 2009; Viitanen & Kingston, 2014).

In practice, however, local governments often lack the capability and resources to tackle these challenges in a flexible way (O'Flynn, 2007). In the search for new ways to cope with this tension, transparency and close interaction with grassroots initiatives are increasingly put forward as solutions to overcome this gap (Buscher et al., 2010). This approach involves a wide variety of urban stakeholders (e.g., citizens, universities, enterprises, non-governmental organizations), thereby potentially leveraging the distributed knowledge in the urban environment.

Nevertheless, these interactions need to be governed and in some way be able to connect the traditional top-down approach with a grassroots or bottom-up approach. This strategy is in line with the open or distributed innovation approach (Bogers & West, 2012; Chesbrough, 2003), causing city governments to question the dominant paradigm of top-down innovation development, and implementation, and to experiment with innovation processes together with, and even by, citizens and other organizations in the urban environment (Paskaleva, 2011).

Understanding collaborative innovation processes

A useful framework for the analysis of such complex collaborative innovation networks is the "triple helix" model for innovation (Etzkowitz & Leydesdorff, 1995), which originally focused on collaboration and knowledge production in university-government-industry partnerships (Etzkowitz & Leydesdorff, 2000). It was later expanded with a fourth helix to incorporate civil society (Carayannis & Campbell, 2009).

However, from a socio-ecological systems point of view, the urban evolutions described above also need to be studied as changes in human-environment systems (Young et al., 2006).

Hence, a socio-ecological systems approach integrates social and ecological systems thinking in a holistic way to assess "system threats" (Berkes et al., 2000). Such socio-ecological systems can be considered complex units in which resources are exchanged and regulated by social and ecological systems (Berkes et al., 2002; Machlis et al., 1997), which makes them interesting conceptual frameworks to assess socio-ecological innovation in an urban environment. They also encourage the integration of this logic and analytical dimensions in the innovation ecosystem literature. Therefore, a fifth helix should be added to the quadruple helix model, to also take the natural environment into account (Carayannis & Campbell, 2010). This is what makes the quintuple helix model for innovation an interesting and valuable model to analyze innovation ecosystems.

To explain processes of knowledge exchange that take place in such collaborative innovation ecosystems, these models apply the concepts of "mode 3" knowledge production and "open innovation diplomacy". Mode 3 knowledge production is conceptualized as an extension of mode 1 knowledge production (traditional research by universities) (Godin & Gingras, 2000) and mode 2 knowledge production (knowledge that is gen-

Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

erated when mode 1 knowledge is applied and put into practice) (Gibbons et al., 1994; Nowotny et al., 2003). Mode 3 adds a third component to this representation of knowledge production by highlighting the overarching system in which this knowledge is produced and exchanged (i.e., innovation networks and knowledge clusters). "Open innovation diplomacy", on the other hand, is used to describe the way in which different organizations and ecosystem are able to collaborate and bridge the divides that exist between traditionally separated domains (this can be social, organizational, cultural, or technological) (Carayannis & Campbell, 2011).

Living labs and the urban environment

Triple, quadruple, and quintuple helix models have a strong theoretical nature. One approach that tries to facilitate such models in a structured way is the "living lab" approach, which can be defined as an ecosystem approach in which end users and other stakeholders are involved in the development of an innovation over a long period of time, in a real-life environment, following an iterative process (Niitamo & Kulkki, 2006; Schuurman et al., 2012) applying multi-method, user-centric innovation research with a strong focus on user empowerment and real-world experimentation (Følstad, 2008; Schuurman et al., 2013; Ståhlbröst, 2008). Furthermore, it offers a structured process and environment to govern input from a wide variety of stakeholders and research methods (Eriksson et al., 2006; Ståhlbröst & Holst, 2012).

In the urban environment, living labs gain importance as a way to govern (complex) urban collaborative innovation processes (Buscher et al., 2010; Paskaleva, 2011). Although the process is similar, *urban* living labs have a distinct nature because the focus is on civic participation, and the output is aimed at increasing quality of life in the city rather than the development of a commercial product or service (Baccarne et al., 2014). As such, urban living labs are an instrument to include a wide variety of stakeholders (citizens, municipalities, entrepreneurs, etc.) in the search for innovations that meet local socio-ecological challenges (Franz, 2014). Juujärvi and Pessa (2013) define an urban living labs as "a physical region in which different stakeholders form public-private-people partnerships of public agencies, firms, universities, and users collaborate to create, prototype, validate, and test new technologies, services, products, and systems in real-life contexts".

However, despite strong European support, this research and development concept is still struggling for an adequate and more profound theoretical anchoring

and remains too much of a "practice-based" concept (Kviselius et al., 2008; Schuurman, 2015). Quintuple helix (-related) concepts provide potentially valuable tools and assumptions for the assessment and theoretical foundation of the more practical oriented living lab literature, embedded within a broader socio-ecological system. On the other hand, the living lab literature might provide a practical framework to put quintuple helix innovation into practice. Furthermore, exploring the quintuple helix model in the context of urban innovation contributes to a more profound understanding of urban innovation in relation with socio-ecological transition in urban areas.

Methodology

Research design

To investigate quintuple helix innovation in relation to urban living labs, we conducted an action research study (Reason & Bradbury, 2001) in which we purposefully designed and participated as researchers in two urban living lab projects. This approach allowed us direct access and control over the projects, as well as more profound insights on the observed phenomena. The analysis is structured following the principles of a multi-dimensional case study design (Eisenhardt, 1989; Yin, 1984). The unit of analysis in this design is the individual project-centric innovation ecosystem.

The two cases had to: i) focus on eco-entrepreneurship, ii) target the urban environment, iii) be open for the researcher team to shape and mold (cfr. action research), iv) be collaborative in nature, and v) encompass an innovation development process. The two selected research projects were instigated by start-up organizations with socio-ecological goals in the urban environment, and they were both incubated by a regional incubating organization (funded by the Flemish government in order to stimulate innovation in ICT). Both projects involved the set-up of an ad hoc collaborative network of stakeholders and a structured, semi-formal adaptive iterative product development process. Project A was set up around the development of an interactive platform to engage, collaborate, and communicate on the topic of air quality. Project B concerned the development of a peer-to-peer car sharing initiative for electric vehicles.

Both living lab processes were designed along principles whereby the living lab project had to: i) incorporate multiple iterations (Pierson & Lievens, 2005; Schaffers & Budweg, 2009), ii) involve multiple stakeholders (Feurstein et al., 2008; Frissen & Lieshout, 2004;

Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

Juujärvi & Pesso, 2013), iii) be driven by multi-method research (De Moor et al., 2010; Eriksson et al., 2006; Niitamo & Kulkki, 2006), iv) involve real-world experimentation (Følstad, 2008; Niitamo & Kulkki, 2006), and v) be based on active co-creation by stakeholders (Følstad, 2008; Schumacher & Niitamo, 2008; Schuurman et al., 2012; Ståhlbröst, 2008). In line with the conceptualization of an urban living lab, the local government was a required stakeholder in the innovation development ecosystem. Between each iteration, steering committee meetings were held to evaluate the process and modify it if necessary. These steering committees consisted of the researchers, the project managers, and the project instigators (eco-entrepreneurs) (see also Rits et al., 2015).

Research framework

A beneficial aspect of case study design is the opportunity to include multiple sources of evidence, thus enhancing the validity of the analysis through data triangulation (Yin, 1984). The sources of evidence in this study include ethnographic field notes, in-depth interviews, email communications, meeting reports of steering committees, initial project proposals, project reports, and project deliverables. These sources of evidence were coded and interpreted by the author team following an analytical protocol (Yin, 1984) that encompassed the four dimensions that are key elements in the literature on innovation ecosystems, and in particular the quintuple helix model and socio-ecological systems:

1. *Innovation diplomacy*: the praxis of bridging barriers between traditionally separated actors and fields (Carayannis & Campbell, 2011).

Assumption: properly targeted initiatives are able to connect know-how, tacit knowledge, creativity, and formal knowledge between different domains and nurture entrepreneurship.

2. *Mode 3 knowledge production*: based on a system-theoretic perspective in which knowledge is molded, remixed, shared, and applied within a knowledge-driven society.

Assumption: quintuple helix ecosystems are knowledge production, distribution, and application systems in which knowledge is generated through the exchange of knowledge between actors in the ecosystem (Carayannis & Campbell, 2012).

3. *A system of subsystems*: the quintuple helix ecosystem encompasses the different domains that resonate and collaborate to solve mutual challenges.

Assumption: each ecosystem actor provides unique

resources to the ecosystem, but also mixes, translates, and processes resources from others. The quintuple helix model describes five societal subsystems (Carayannis et al., 2012): i) the educational system, which generates and disseminates new knowledge; ii) the economic system, which controls, possesses, and generates economic capital; iii) the political system, which has political and legal capital (e.g., laws, clearances, policy, public goods); iv) civil society, which has social capital, and is characterized by traditions, values, and behavioural patterns; and v) the natural environment, which has natural capital (e.g., natural resources, climate, air quality, geological stability).

4. *Socio-ecological transition*: the main contribution of the quintuple helix model is the integration of the natural environment, which is conceptualized as a contextualization of the four helices of the quadruple helix.

Assumption: if this context is taken into account, it is possible to achieve sustainable socio-ecological transition, creating synergies between economy, society, and democracy (Carayannis & Campbell, 2011).

Analysis

Quintuple helix innovation in a structured process

An urban living lab follows a structured process in which a central problem, idea, concept, or prototype is at the heart of the collaboration. This innovation development process implements a combination of different methodologies (e.g., for Project A: interviews, focus groups, surveys, co-creation workshops, online crowd-sourcing, and a field trial) to involve a wide variety of stakeholders (e.g., for Project A: different local government divisions, citizens, civil society organizations, large and small research organizations, and startups). As described earlier, this formal but flexible staged process was, in both cases, instigated by the eco-entrepreneurs, was financially supported by the Flemish government, and was managed by iMinds Living Labs, a semi-public living lab organization, embedded in an interdisciplinary and cross-university, technology-driven research centre. The formal living lab process structured the innovation development and governed stakeholder interaction, knowledge production, and knowledge transfer. For example, the process facilitated steering committees, safeguarded the overall planning and resources of the project, leveraged social capital within the different subsystems, provided coaching and implementation resources, and translated knowledge between ecosystem stakeholders.

Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

Innovation diplomacy

The formal commitments within both cases were limited to the eco-entrepreneurs and the semi-public living lab management organization. However, both cases also had semi-formal commitments from their respective local governments. Both projects were unable to convince other key actors in the ecosystem to become a formal partner of the project because these other actors were not willing to commit themselves to an *uncertain* and *open* project. However, once the project gained momentum and tangibility, collaborations were still possible on an ad hoc basis. Not only were key stakeholders eventually attracted to the ecosystem, but also several unexpected smaller institutions (i.e., research institutes, companies, and civic organizations), who were very willing to contribute and share their knowledge. The ad hoc, open-ended, and semi-formal design of these temporal collaboration networks served as a *risk reducing* characteristic and helped to overcome collaboration barriers. As such, the collaborative design of the urban living lab stakeholder ecosystem acted as a *centripetal force* within the urban environment, as acupuncture to congregate urban actors with similar goals. Although every collaborator had their own agenda (e.g., leveraging their own business, connecting with the local government, pushing local change), this did not interfere with the overall goals of the project.

Finally, when it came to the involvement of the local government, the process facilitated access and interaction with different governmental levels. The deployment of a *temporal experimental window*, which was considered "neutral" and "external" to existing organizations, enabled individuals to detach themselves from restraining organizational structures and collaborate in a more agile environment, and to stretch the boundaries of what is generally possible (e.g., temporarily sharing data sources, talking freely outside the governmental organization, providing favourable exceptions on the use of public space).

Mode 3 knowledge production

In the air quality domain (Project A), a lot of knowledge is generated in mode 1. Traditionally, research institutes obtain grants to study atmospheric particulate matter (e.g., as PM_{2.5}) or ozone concentrations. Most of these data remain hidden to the public. However, there are some initiatives that attempt to disseminate these data to civil society. Most of the time, these initiatives are built upon open data principles and are, for example, translated in dashboards showing air quality values. In theory, these initiatives distribute and apply mode 1 knowledge (potentially generating mode 2 knowledge).

However, this information cannot be interpreted by actors outside the knowledge domain (e.g., regular citizens). Even if the raw numbers are translated in visual information (e.g., public visualizations of the air quality have been created in the city of Project A), the academic complexity was not interpretable for citizens and citizens had no idea how to act upon this information.

Through an iterative, multi-method research approach, the (tacit) knowledge of all stakeholders could be captured, exchanged, (re)combined, mixed, and molded. By distributing and translating fundamental chunks of knowledge to actors outside the original knowledge domain, unexpected but valuable interpretations and interactions occurred. However, such "sparks" and often volatile knowledge must be adequately captured and managed to contribute to the project goal. For Project A, this process of knowledge capture resulted in the development a conceptual model for socio-ecological change, which served as the basis for design requirements and the development of the project prototypes. Project B, on the other hand, focused on understanding end-user needs and frustrations in relation to technological evolutions and other stakeholder needs and knowledge, mainly to set-up a field trial experiment that matched the usage context. These insights were necessary for both practical and substantial reasons in order to be able to test the electric-car sharing system.

The ecosystem and circulation of knowledge

In both cases, various exchanges between different knowledge domains took place. Some examples include knowledge transfers from the political system to the economic system (i.e., knowledge regarding policy, internal procedures, the value network, and business model opportunities) and from civil society to both the educational system (e.g., the interpretation of complex data by citizens and the relation to their everyday behaviour) and the economic system (i.e., regarding needs and adoption potential). Furthermore, for the local government, the urban living lab projects also bridged different divisions and individuals *within* the organization (e.g., different divisions were working on open data and air quality for some time, but it took the project to connect them and expose the overlap between their efforts). This bridging can be conceptualized as an *intra-organizational centripetal force*, which is the mobilizing effect of an urban living lab *within* an organization to connect like-minded individuals beyond organizational structures. As such, the projects facilitated horizontal and agile collaboration and knowledge exchange on an ad hoc basis, largely bypassing traditional structures and processes.

Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

Socio-ecological transition

As for the "natural context", both projects aimed to interact with the socio-ecological environment through their environmental goals. Against this backdrop, it makes sense to conceptually model the innovation ecosystem using the quintuple helix model. Using this framework, it is clear that (urban) innovation is related to issues regarding the socio-ecological context in which we live and (co-)develop our common socio-technological future. Neglecting this dimension is a failure to contextualize innovation development in a broader environment. Although this model fits with the theoretical understanding of urban living labs, they in turn offer an implementation approach for the quintuple helix model for innovation.

Concerning sustainability, both projects exposed the difficulty of designing viable business models in a "public" domain. Both civil society and the economic system consider it the duty of the political system to take responsibility. However, the political system is facing decreasing resources, which makes it hard to develop a sustainable business model. For Project B, this challenge resulted in the establishment of a cooperative organization with limited liability. Different actors who were previously involved in the urban living lab became members of this organization. As such, some of the social capital that was generated within the urban living lab was leveraged to help sustain the innovation.

Nevertheless, socio-ecological transition must also be considered in a broader sense. Through (series of) experiments, project-based quintuple helix innovation can foster long-term change on a more latent level, by inspiring and stimulating debate on contemporary urban challenges and solutions. Applied to the socio-ecological systems way of thinking, urban living labs contribute to the *resistance* of an urban socio-ecological system. More specifically, this goal is achieved through the facilitation of flexible and agile experimentation with possible solutions for issues related to "system stress" caused by urbanization itself, and by doing so, adding to a long-term and latent social transition that is closely interrelated with ecological concerns and associated knowledge.

Conclusions and Discussion

This article bridges the theoretical propositions of the quintuple helix model and the practice-based concept of urban living labs. More specifically, we discussed the concepts of innovation diplomacy, mode 3 knowledge

production, the innovation ecosystem as a system of subsystems (related to the circulation of knowledge), and socio-ecological transition to analyze the urban living lab approach. Our findings largely support the theoretical assumptions of the quintuple helix model and elaborate on the urban living lab approach as a way to put this model into practice at the level of a single innovation development process. Urban living labs can be a way to work with ad hoc collectives, lowering the barriers for collaboration. The project-centric nature is a catalyst for knowledge exchange and collaborations within and outside the project and involved organizations.

A successful urban living lab can facilitate and balance top-down governance with bottom-up initiatives in the city. However, some challenges remain. Whereas experimental urban living lab activities activate and reinforce the quintuple helix ecosystem, it is still hard to harness the creation potential within the city in a sustainable way. Nevertheless, urban living labs facilitate urban transitions through an accumulation of experiments, which allow urban actors to experience change, leading to transitions in the long run. This logic suggests that urban living labs contribute to (long-term) sustainable socio-ecological transition, which is mainly facilitated by an interdisciplinary (and transdisciplinary) temporal experimental window that promotes collaborative learning and stakeholder engagement. However, although value is being created at the meso level (i.e., the project level), there is a need for a more formal value capture and retention processes at the macro level (i.e., the level of ecosystems and the overarching organization). In the urban context, it makes sense that local governments fulfil such a role. This is to some extent in line with the conceptualization of the government as a platform (O'Reilly, 2011).

The quintuple helix is a useful concept to understand and analyze how knowledge is created and exchanged in an urban environment, which can be studied as a collaborative innovation development ecosystem, while also taking the ecological context into account. Although such awareness is growing in most organizations, this dimension is not present in most distributed innovation theories and processes. An urban living lab thus can generate and evolve tacit and codified knowledge while focusing on the exchange of knowledge within a natural environment system. In this way, both the innovation outcomes and the urban socio-ecological transition can become more sustainable and recover ecological balance, thus ensuring the quality of life for future generations.

Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

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Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

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Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship

Bastiaan Baccarne, Sara Logghe, Dimitri Schuurman, and Lieven De Marez

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Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

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“A compromise is the art of dividing a cake in such a way that everyone believes that he has got the biggest piece.”

Ludwig Erhard (1897–1977)
3rd Chancellor of West Germany

As a steadily expanding source of venture capital, crowdfunding has become an alternative to traditional funding sources, such as banks and financial investors. The phenomenon of crowdfunding is represented by a growing number of Internet sites, here called crowdfunding platforms, devoted to the service. In this article, we investigate crowdfunding and their payout models, which are standard components on crowdfunding platforms. We consider the perspectives of both entrepreneurs and funders to determine the most attractive combination of models found on crowdfunding platforms. Our findings indicate that the most popular crowdfunding platforms, at the time of this study, reflect the preferences of entrepreneurs. The funders' favoured crowdfunding model, which we call the equity model, is not currently found, in combination with the often-grouped, non-financial crowdfunding models of pre-order, sponsoring, or reward, on any of the top platforms. Thus, the research identifies a new market for crowdfunding platforms.

Introduction

Firms in the start-up phase are often looking to attract external financing. However, traditional sources of funding such as banks and investors are of limited help when it comes to lending or investing in micro-businesses and small businesses (Belleflamme, Lambert & Schwienbacher, 2014). Small entrepreneurial firms have sought new ways to secure financing without having to deal with traditional sources (Mollick, 2013), given that, in many cases, the personal resources of would-be entrepreneurs plus any funding they acquire from friends and relatives is not enough to start a firm, and this is a reason that many ideas never become reality (Bradford, 2011). Thus, many entrepreneurs try new financing methods such as crowdfunding (Mollick, 2013). This financing problem sparked the now-booming crowdfunding movement (Belleflamme et al., 2014).

Crowdfunding is defined as "financing projects or businesses with small contributions from large numbers" (Collins & Pierrakis, 2012). Crowdfunding represents a unique category of fundraising, building on inspiration from concepts such as micro-financing and crowd-

sourcing, and is now represented by a growing number of Internet sites devoted to the service. This concept has also opened the gates for people to fund larger-scale projects. All crowdfunding models are based on the principle that people invest funds in a project and expects a successful outcome. The funders' goals are heterogeneous and differ from services and products (Mollick, 2013). It is hard to tell when the idea of crowdfunding started, but we can find many examples of it in history. For example, the composers Mozart and Beethoven used a subscription system to finance compositions and concerts (Hemer, 2011). A more recent example is how US President Barack Obama used a web-based crowdfunding platform to receive numerous small donations during his 2008 presidential campaign (Hemer, 2011). Crowdfunding on the Internet can be designed in different ways, but an understanding of the entrepreneur's choices of crowdfunding models and what motivates the funder is a very important aspect (Belleflamme, Lambert & Schwienbacher, 2013).

In this article, we describe our work towards developing a universal categorization of the different crowdfunding models. Based on prior research, we suggest a frame-

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

work that covers all the existing crowdfunding models and relates them to the 10 most used crowdfunding platforms. We seek to fill a key gap in the literature by determining what entrepreneurs and funders consider as the optimal combination of crowdfunding models on a platform. An optimal combination would benefit both funders and entrepreneurs, and would help entrepreneurs more effectively fund their projects by tailoring their funding requests to the needs of potential funders.

We are aware that funders may be heterogenous from case to case (Mollick, 2013), but we want to propose a generic combination. The aim of the study is to find this optimal combination of crowdfunding models and payout models, regardless of product or service. That is a compromise between what both funders and entrepreneurs perceive as the most suitable combination of crowdfunding models. We also want to relate this optimal combination to an existing crowdfunding platform or suggest a new one that ought to exist based on identified needs. We deem this study relevant because existing universal definitions of the different crowdfunding models (Tomczak & Brem, 2013), have also failed to mention all existing crowdfunding models. Ultimately, we ask the following question: is there an optimal model for crowdfunding platforms?

Definitions and Literature Review

Universal definitions of crowdfunding and related terms would benefit any research in this field, although such universal definitions unfortunately do not yet exist (Tomczak & Brem, 2013). In this article, we define crowdfunding and related concepts as follows:

- *Crowdfunding*: A way for entrepreneurs to fund their "projects or businesses with small contributions from large numbers" (Collins & Pierrakis, 2012). This could be done either online or by physical interactions.
- *Crowdfunding model*: A way of crowdfunding a project that defines what will be invested, loaned, or donated by funders, and what the funders receive in return
- *Payout model*: Rules regulating how, when, and if a crowdfunding platform transfers funds to the entrepreneur
- *Funder*: An individual that funds a project via crowdfunding
- *Entrepreneur*: The individual looking for investors for their project

- *Crowdfunding platform*: A website dedicated to raising funds via crowdfunding. Such platforms typically make money by adding a fee to the amount funded.

Crowdfunding models

Tech (2014) summarized the approaches to categorizing crowdfunding models taken in four articles. The four articles did reveal several different crowdfunding models, but the problem posed by Tech (2014) is that different researchers tend to define the same crowdfunding model with different terms. The problem with the lacking of universal definitions for crowdfunding models are that researchers, entrepreneurs, and funders may talk about the same model in different terms without realizing it (Tech, 2014). Thus, through this article, we seek to combine existing research to define universal terms.

Based on research by Hemer (2011), Bradford (2012), Collins and Pierrakis (2012) and Belleflamme and colleagues (2014), we define seven different crowdfunding models:

1. *Donation* = Funding a project without any expectation of return. When comparing the costs of different sources of capital, donation is by far the cheapest, because the entrepreneur does not incur a cost (Belleflamme et al., 2014) other than the fee charged by the crowdfunding platform.
2. *Reward* = Funding a project and gaining a reward that is not the actual product or service (e.g., a branded key chain or t-shirt)
3. *Sponsorship* = Funding a project and in return for a publicly visible connection to the project
4. *Pre-order* = Funding a project by pre-ordering the actual product or service
5. *Lending with interest* = Funding a project by lending money to the entrepreneur in return for interest
6. *Lending without interest* = Funding a project by lending money to the entrepreneur without interest
7. *Equity* = Funding a project by buying equity in the firm (e.g., pure investment, profit sharing, or any other form of equity return) The progress of this crowdfunding model has been slower than expected, mainly due to regulations (Harrison, 2013).

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

Based on these seven models, we developed a framework with three categories: no reward, financial, and non-financial rewards (Figure 1).

Payout models

At the time of this study, crowdfunding platforms mostly use four different payout models for determining how and if a project is successfully funded and how and when the money will be transferred to the entrepreneur. The one thing the four models have in common is that the platform and the funder agree on a pre-determined amount of money that determines whether the project is successfully funded or not. Tomczak and Brem (2013) define the four models as:

1. *All or nothing*: If the pre-determined goal is not met, the funding project will be deemed unsuccessful and the money will be returned to the funders.
2. *All and more*: Even if the pre-determined goal is not met, the entrepreneur will receive the accumulated amount of money, at the cost of a higher platform fee for the entrepreneur.
3. *Holding*: The funder buys equity in a fund-seeking firm.
4. *Club membership*: The funder pays a fee to join a club, where experts invests or buys equity on behalf of others. This payout model exist to avoid legal issues, because equity crowdfunding are illegal in some countries.

Motivators

Research suggests that psychological motivations in an economical setting can be broadly divided in two sets of motivation drivers called intrinsic motivation and extrinsic motivation (Ryan & Deci, 2000). Intrinsic motivation can be described as gaining satisfaction from the activity itself, whereas extrinsic motivation can be described as gaining satisfaction from the outcome of the activity. At the same time, many cases are more complex and a mix between intrinsic motivations and extrinsic motivations can be distinguished. A known issue when offering a choice between intrinsic and extrinsic motivations is the tendency of funders to choose extrinsic motivations before intrinsic motivation (Ryan & Deci, 2000). Cholakova and Clarysse (2014) suggest that a combination of non-financial rewards, for example what we in this article call *reward* and *pre-order*, can be combined with financial rewards, as *lending with interest* and *equity*, without reducing the willingness of the funder to fund the non-financial objectives.

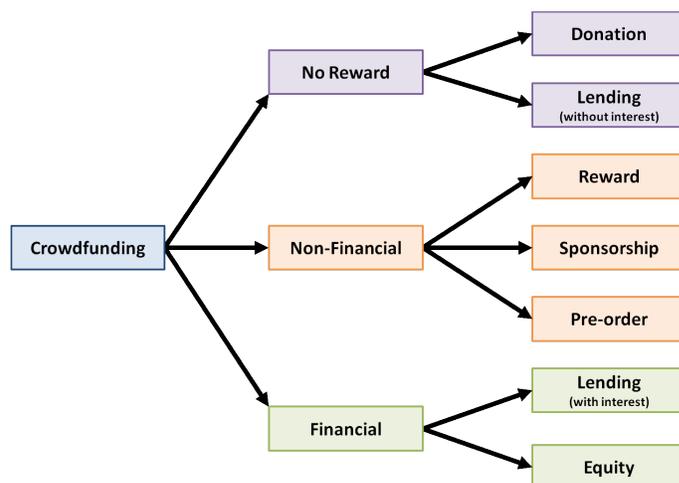


Figure 1. A three-category framework of the seven crowdfunding models

Gerber and Hui (2013) find that funders are motivated because of empathy for the project. Some funders wish to connect with others to satisfy a need for a feeling of belonging in a social context. Other funders feel a need to help the entrepreneur realize their goals (Gerber, Hui & Kuo, 2013). These motivators may be present in any model, but are particularly relevant with *donations*.

Another strong motivation for funders is desire to own the product itself or receive a tangible reward, what we here call *pre-order* and *reward* (Gerber & Hui, 2013). In these cases, the funders are acting as consumers when backing a project (Belleflamme et al., 2014) and expect some form of return or reward (Belleflamme et al., 2013). In any case, the entrepreneur is driven to satisfy the felt need from the funders, because the goal for the entrepreneur is to fund his or her project (Gerber & Hui, 2013).

Gerber and Hui (2013) suggest that one of the main deterrents for the funder is the distrust of the way the entrepreneur is going to use the funds, meaning that they worry that the entrepreneur is not going to fulfill the goals of the project and will just take the money for themselves. With the all-or-nothing model, the funder will only be forced to pay when and if the entrepreneur's project is successfully funded. The model prevents fraud within crowdfunding, both by not giving the entrepreneur any funds until the project is fully funded and the crowdfunding also binds the entrepreneur by a contract to deliver what they have promised. According to Tomczak and Brem (2013) the all-or-nothing model also works well for the entrepreneurs because

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

they do not have to deliver on a promise they cannot keep without sufficient funding. This phenomena was earlier described by Kraut, Resnick, and Kiesler (2012) as "contingent commitment, wherein the willingness threshold for contributing is lowered because the investment will be completed only if the project is fully funded.

Research Design and Methodology

This study aims to find the best mix of crowdfunding and payout models for both funders and entrepreneurs. To achieve this aim, we evaluated previous research to find the models which were described earlier in the article. Tomczak and Brem's (2013) conceptual model is similar, but too comprehensive for the purpose of this study, which embraces the respondents' eventual lack of knowledge about the underlying components of crowdfunding. To our simplified version of Tomczak and Brem's (2013) model, we added *lending*.

Crowdfunding platforms

To relate our seven crowdfunding and four payout models to existing crowdfunding platforms, we used Alexa (alexa.com), a service that measures Internet traffic and rank websites. to identify the most visited crowdfunding platforms. Given that the focus of our research is on crowdfunded entrepreneurship, we excluded plat-

forms that solely focused on charity. After the ranking of the 10 most visited sites used by entrepreneurs to crowdfund projects, we categorized them according to our seven crowdfunding and four payout models (Table 1).

Development of the hypotheses

Crowdfunding platforms are designed in different ways with different crowdfunding models and payout models. We want to determine if there is one or several platforms on the market that correspond with the wishes of the entrepreneurs, the funder, or preferably a combination of these. To examine this question, we have defined the following hypotheses:

H1: The entrepreneurs' preferred combination of crowdfunding models and payout models are reflected in one of the most visited crowdfunding platforms.

H2: The funders' preferred combination of crowdfunding models and payout models are reflected in one of the most visited crowdfunding platforms.

H3: The entrepreneurs' and funders' preferred combination of crowdfunding models and payout model combined, is reflected in one of the most visited crowdfunding platforms.

Table 1. Crowdfunding and payout models of the 10 most visited crowdfunding platforms for entrepreneurs

Platform	Global Alexa Rank	Donation	Reward	Sponsoring	Pre-order	Lending without Interest	Lending with Interest	Equity	Payout Model
Kickstarter.com	512	X	X	X	X				All or nothing
Indiegogo.com	1396	X	X	X	X				All and more
Gofundme.com	1446	X	X	X	X				All or nothing
Teespring.com	2077				X				All or nothing
Angel.co	2373							X	Club membership
Patreon.com	5310	X	X	X	X				All or nothing
Lendingclub.com	9582						X		All and more
Kiva.org	12575					X			All and more
Pledgemusic.com	27118			X	X				All or nothing
Crowdfunder.com	28178							X	Holding

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

To find support for H3, it is important that there is support found for both H1 and H2, otherwise the optimal combination of both crowdfunding and payout models, for both entrepreneurs and funders does not exist, at the time when the study was conducted. By optimal, this study refers to one crowdfunding platform were the preferred combination of both crowdfunding and payout models of both entrepreneurs and funders are represented.

Surveys of entrepreneurs and funders

Two separate quantitative surveys of 18 entrepreneurs and 97 potential funders were conducted. Some items in the surveys were common, but others were tailored to funders or entrepreneurs. We based the surveys on our newly developed categorization of existing crowdfunding models and also included some items that can suggest further research. The respondents were asked to rank the payout and the crowdfunding models according to what they deem most attractive. The payout models are ranked from 1 to 4 and the crowdfunding models are ranked from 1 to 7.

The survey was written in Swedish given that all respondents are native Swedish speakers. The funders were reached through personal networks. Schwienbacher & Larralde (2010) describe the average funder as a white, married, middle-aged male in the middle to upper class with a university degree and high-speed Internet. Accordingly, we included questions about sex, age, income, education, civil status, and Internet connection. Race is not a commonly used distinction in Sweden, so we excluded questions relating to it. One other bias could be that funders that are not used to participate in crowdfunding initiatives may have a more extrinsic view, given that most people that are not used to using crowdfunding platforms, or even when using them for the first time tend to choose tangible rewards (Ryan & Deci, 2000), and most of our respondents probably have not participated in crowdfunding schemes before. We asked inexperienced participants for three reasons: i) crowdfunding was a new phenomena for Swedish people at the time of this study; ii) we wanted to receive views from funders that had not yet determined their preferred crowdfunding platform with a existing combination of crowdfunding and payout models; iii) an essential aspect of crowdfunding is that, regardless of background or experience, anyone can be a backer.

The entrepreneurs were reached through entrepreneurial hubs such as Science Park in Halmstad, Sweden, a centre gathering a large number of companies, and

through the authors' personal networks. A web-survey reduced interference linked to having to answer the survey at a specific time and place, and also the presence of any of the authors in the room. The main problem of the survey was that crowdfunding is a rather unknown phenomenon, but by providing definitions of each crowdfunding and payout model, which made it clear to the respondents what the different definitions stood for, we reduced biases linked to lack of knowledge.

We selected entrepreneurs in the start-up phase, because that is the time the entrepreneurs are looking for low-level financing and turn to alternative investment mechanisms, such as crowdfunding platforms (Bradford, 2012). By contacting entrepreneurial hubs, we reached the target entrepreneurs easily. We did not select the sample for the funders in the same way as the sample for the entrepreneurs. By distributing the survey for the funders through the authors' social network contacts a wide target could be reached with variation in age, gender, ethnicity and occupation, although a majority of the respondents of this survey were students.

Empirical Analysis and Discussion

In this section, we summarize the data collected through the two different surveys as well as some brief observations made when conducting our categorization of the 10 most used crowdfunding platforms, as compiled using SurveyMonkey (surveymonkey.com). The ranking system is based on a 10-point scale where the highest average score is ranked as the favourite pick. The total score is presented in Tables 2 to 5 and in parenthesis after each of the mentioned models.

Crowdfunding platforms

Two clear, and quite important, observations were made when categorizing the crowdfunding platforms and their corresponding crowdfunding and payout models. First, if a platform offered any of the three crowdfunding models in the non-financial category, the other two also were represented. In the case of Tee-spring, the whole purpose of the site is to buy t-shirts; therefore, no reward or sponsorship opportunities were offered. PledgeMusic enables users to pre-purchase music that has not yet been created and, although they offer sponsorship, they do not offer a reward option. This observation led to the conclusion that the three non-financial crowdfunding models co-existed because funders tended to opt for extrinsic motivations, as suggested by Ryan and Deci (2000). But, because funders, as suggested by Mollick (2013), are heterogenous from

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

case to case, and the sponsoring, reward, and pre-order crowdfunding models require different input of capital, where sponsoring requires the least amount of money, followed by reward and pre-order, all three models are needed when crowdfunding products. The second observation was that crowdfunding platforms only operate with one payout model; so, when suggesting the optimal crowdfunding platform for both funders and entrepreneurs, only one payout model will be possible.

Entrepreneur preferences

As presented in Table 2, *sponsoring* (5.06) was the favourite crowdfunding model selected by the entrepreneurs. Although *donation* (4.67) and *pre-order* (4.44) were picked by more entrepreneurs as their highest ranked choice, *sponsoring* gained a higher total score. The attraction to the sponsoring and donation crowdfunding models can be explained by the desire of entrepreneurs to seek the lowest cost of capital available (Belleflamme et al., 2014), given that donation gives funders nothing more than the intrinsic reward of feeling good about themselves (Ryan & Deci, 2000) and sponsoring could take the form of a written thank you on the website of the funded project. The attraction to the pre-order crowdfunding model is that all projects on crowdfunding platforms have an actual product as their goal. This finding relates well to the need of funders to gain a tangible reward or the actual product itself and the entrepreneur's need to fill the funders' needs (Gerber & Hui, 2013).

By applying the top picks from Table 2: *sponsoring*, *donation*, and *pre-order*, to the findings from Table 1 (crowdfunding models offered on the platforms), we see that the three most visited crowdfunding platforms offers the entrepreneurs' three most favoured crowdfunding models.

Entrepreneurs prefer the *all-and-more* payout model (3.17); almost half of the respondents picked it as their top choice, followed by the *all-or-nothing* model (2.72) (Table 3). This finding can be explained by the goal of entrepreneurs, which is mainly to raise money (Belleflamme et al., 2014), and the all-and-more model, as opposed to other payout models, lets the entrepreneur

Table 3. Entrepreneurs' ranked preferences for each payout model (n=18)

Payout Model	Rank				Average
	1	2	3	4	
All and more	8	7	1	2	3.17
All or nothing	6	5	3	4	2.72
Holding	2	5	4	7	2.11
Club membership	2	1	10	5	2.00

Table 2. Entrepreneurs' ranked preferences for each crowdfunding model (n=18)

Crowdfunding Model	Rank							Average
	1	2	3	4	5	6	7	
Sponsorship	2	6	2	7	1	0	0	5.06
Donation	6	1	3	2	3	1	2	4.67
Pre-order	4	1	5	1	4	2	1	4.44
Reward	2	3	3	3	1	4	2	4.00
Equity	2	2	4	3	3	1	3	4.00
Lending without interest	1	4	1	2	4	6	0	3.78
Lending with interest	1	1	0	0	2	4	10	2.06

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

keep all the money they raise, minus the crowdfunding platform fees. (Tomczak & Brem, 2013). IndieGOGO was the second most visited crowdfunding platform, according to Alexa's Global Ranking system, and it offers the *all-and-more* model. According to Tomczak and Brem (2013), the *all-or-nothing* model also works well for entrepreneurs because they do not have to promise the funders something that they cannot deliver, which could explain the second-place finish of the *all-or-nothing* model. The low level of interest in the *holding* and *club membership* models may reflect the reluctance of entrepreneurs to give away the equity of their firms (4.00). By looking at the individual surveys, it was clear that entrepreneurs who chose *investment* as a top choice also selected *holding* or *club membership* as their preferred payout model. With the above discussion in mind, the suggested mix for entrepreneurs would be to use a platform that uses a mix of crowdfunding models and the payout model *all and more*, similar to the Indiegogo service, as described in Table 1.

Because the entrepreneurs' top picks of both crowdfunding and payout models were represented among the most popular crowdfunding platforms, our first hypothesis (H1) is supported by our findings: the entrepreneurs' favourite choices exist among the most popular platforms.

Funder preferences

According to the literature, one of the main goals of a funder is to support a project or help an entrepreneur

to realize their project (Gerber et al., 2013). These intrinsic motivations (Ryan & Deci, 2000), are not reflected in the findings of this study. The most picked choice, and the choice with the highest total score, was the *equity* option (4.86). To our knowledge, there is no theory supporting *equity* as a top choice of funders, which makes this an interesting discovery. Because equity crowdfunding is highly regulated by law, and for example, has not been available to American citizens until recently, this is a form of crowdfunding that rapidly is gaining in interest (Harrison, 2013). When compared to existing literature, the next four picks – pre-order (4.54), sponsoring (4.13), reward (4.12), and donation (3.79) – were expected as the top choices with support from Gerber, Hui, and Kuo (2013).

For funders, a key consideration is the legitimacy of the entrepreneur (Gerber & Hui, 2013). This perspective is represented by the top choice, *all or nothing* (2.8), among our funder respondents. The *all-or-nothing* model gives the funder the comfort of knowing that if the project is not successfully funded, the funder does not need to contribute any money to the project (Tomczak & Brem, 2013). This concern may also explain why the *all-and-more* model (1.99) was the least favoured choice among our respondents. The second and third most favoured payout models, *holding* (2.69) and *club membership* (2.52), corresponds to the high interest of funders to buy equity in projects. When comparing the top pick from Table 5 with the top platforms' payout models from Table 1 it is clear that the *all-or-nothing* model is included among the most popular platforms.

Table 4. Funders' ranked preferences for each crowdfunding model (n=97)

Crowdsourcing Model	Rank							Average
	1	2	3	4	5	6	7	
Equity	31	15	10	16	9	7	9	4.86
Pre-order	20	12	18	18	12	13	4	4.54
Sponsorship	9	17	13	26	13	9	10	4.13
Reward	7	20	21	9	22	6	12	4.12
Donation	13	9	16	13	14	17	15	3.79
Lending with interest	8	16	10	7	12	21	23	3.41
Lending without interest	9	8	9	8	15	24	24	3.14

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

Table 5. Funders' ranked preferences for each payout model (n=97)

Payout Model	Rank				Average
	1	2	3	4	
All or nothing	33	26	24	14	2.80
Holding	31	26	19	21	2.69
Club membership	15	35	32	15	2.52
All and more	18	10	22	47	1.99

Because *equity* is not combined with the non-financial crowdfunding models among the 10 most popular platforms from Table 1, we do not have support for our second hypothesis (H2). In other words, the funders' optimal mix of crowdfunding and payout models are not represented among the crowdfunding platforms in Table 1. This is a valuable discovery because it directs attention to an unexplored market opportunity.

Combining the models

To support our third hypothesis (H3), we would have needed support for both our first (H1) and second (H2) hypotheses. Given that support was not found for H2, we do not have support for H3 either. Because H1 was accepted, we conclude that crowdfunding platforms focus on sellers who, in the crowdfunding context are the entrepreneurs. Kickstarter is the most popular site

Table 6. Combined scores of entrepreneur and funder preferences for crowdfunding models

Crowdfunding Model	Combined Score
Sponsorship	9.19
Pre-order	8.98
Equity	8.86
Donation	8.46
Reward	8.12
Lending without interest	6.92
Lending with interest	5.47

(Table 1), but many entrepreneurs must use a platform with a payout model they might not prefer, because they want to raise as much money from as many funders as possible (Gerber et al., 2013). Thus, in search of an optimal mix of crowdfunding and payout models, we added the average scores of entrepreneur (Table 2) and funder (Table 4) preferences for crowdfunding models and for payout models (Tables 3 and 5). The resulting combined scores are listed in Table 6 and Table 7.

The optimal payout model for a crowdfunding platform, according to our data, would consist of a platform using the *all-or-nothing* payout model (5.52), which is found in most of the platforms in Table 1. Given that our investigated platforms only worked with one payout model per platform, and with the mindset that it is the funders that makes the entrepreneurs' projects possible, this choice seems logical. A new discovery from this study is that funders would like a combination between both non-financial and financial, in particular *equity* (4.86), crowdfunding models. None of the existing platforms in Table 1 offer this combination of crowdfunding models to its users. As mentioned in the observations made when categorizing the crowdfunding platforms, there is an underlying need for all three of the non-financial crowdfunding models to be present, because they require different amounts of capital; removing one might cause a potential funder not to back the project at all. Thus, we combine equity with all three of the non-financial crowdfunding models, and not only the top combined crowdfunding models. Even though it is stated in previous research that there may exist some dissonance when combining the intrinsic

Table 7. Combined scores of entrepreneur and funder preferences for crowdfunding models

Payout Model	Combined Score
All or nothing	5.52
All and more	5.16
Holding	4.80
Club membership	4.52

Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

and extrinsic, where the extrinsic motivation can undermine the intrinsic (Ryan & Deci, 2000), Cholakova and Clarysse (2014) suggest that funders are open to a crowdfunding platform that offers both financial and non-financial crowdfunding models, especially where the financial models influence the non-financial models in a positive way.

Conclusion

This article examined the favourite crowdfunding models and payout models of entrepreneurs and funders with the aim of finding if the optimal platform, in terms of these models, exists among the top 10 most visited crowdfunding platforms. To our knowledge this is the first article investigating both the entrepreneurs' and funders' points of view and proposing to combine them in search of an optimal model. The combination of the all-or-nothing payout model with both non-financial and equity crowdfunding models is what our findings points out as the optimal combination for both parts. The top 10 crowdfunding platforms are lacking in the funders' top choice, the equity model, in combination with the subsequent choices of pre-order, sponsoring, or reward. Our research also shows that the entrepreneurs' favourite models are represented in most visited crowdfunding platforms, at the time of the study. The results presented here can be of value for crowdfunding platforms, which can be designed according to an optimal combination of models. The results can help entrepreneurs choose which platform to use by providing information about which payout and crowdfunding models are preferred by funders, and therefore which platforms may improve their chances of successfully funding their projects.

Finally, we recommend the following future directions of study:

1. Carry out a study with a bigger sample, given that the survey made for this article had a limited number of respondents. A bigger survey is needed to strengthen the reliability of the results, particularly across different cultures.
2. Further investigate why the most popular crowdfunding platforms have not yet combined the equity model with other non-financial crowdfunding models, which suggests an asymmetry between funders and entrepreneurs. Crowdfunding platforms that are combining both financial and non-financial crowdfunding models were available on the market at the

time of the study, but are not represented in the list of the most popular platforms. Future research should attempt to better understand these findings.

3. Study and introduce a third party in this ecosystem, namely the crowdfunding platforms themselves, which may reveal an optimal combination that reflects these three different interests.
4. Introduce a longitudinal aspect to the study, which will help grasp the evolution of the platforms and crowdfunding models over time.

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Crowdfunding: Finding the Optimal Platform for Funders and Entrepreneurs

David Gedda, Billy Nilsson, Zebastian Sâthén, and Klaus Solberg Søylen

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Keywords: crowdfunding, crowdfunding models, payout models, crowdfunding platforms, financing

TIM Lecture Series

Huge Memory and Collection-Oriented Programming: Less Code, More Speed?

Dave Thomas

“I'm always trying to build more software faster by writing less code using fewer people.”

Dave Thomas
Chief Scientist/CSO, First Derivatives FD Labs

Overview

The TIM Lecture Series is offered by the Technology Innovation Management (TIM; timprogram.ca) program at Carleton University in Ottawa, Canada. The lectures provide a forum to promote the transfer of knowledge between university research to technology company executives and entrepreneurs as well as research and development personnel. Readers are encouraged to share related insights or provide feedback on the presentation or the TIM Lecture Series, including recommendations of future speakers.

The second TIM lecture of 2016 was held at Carleton University on March 8th and was presented by Dave Thomas, Chief Scientist/CSO, First Derivatives FD Labs (firstderivatives.com). The lecture focused on the disruptive aspects of "huge persistent memory", in terms of the technology shift it represents, the impact it has on how developers write software programs, and the corresponding business opportunities it brings about.

Summary

In this lecture, Thomas emphasized that the enormity of datasets used with "Big Data" demand lighter, query-based programs that allocate as much available memory as possible to the data, rather than the overhead of overly complicated programs.

He began by describing how developers over the years must face or least push back, the "memory wall", which is the limit of overall computer speed imposed by the limits the speed of memory. And, opportunities may arise in the quest to overcome this memory wall, particularly when considering the overall cost of an applica-

tion, which consists of the costs of hardware and software plus the costs of management. Current downward trends in the cost of hardware mean that investing in hardware is an efficient way to bring down costs.

Recent leaps in the amount of memory that can be put on, for example, an DIMM card or gum stick (e.g., 3.5 TB), have reinforced the notion that storage and memory hierarchy must continue to scale. But, NAND/SSS does have its problems, including the required complexity of the software that runs on it, the slow writing speed relative to the fast reading speed, the loss of data on large writes if there is a power failure, the failure of the NAND memory after many writes, and the security vulnerability associated with need for large persistent storage without encryption.

Announced in August 2015, Intel's Micro 3D XPoint memory is 1000 times faster than NAND, has 1000 times more endurance than NAND, and is 10 times denser than conventional memory (Intel, 2015). However, with the greater memory performance in memory technology, there is a need for built-in data protection features to enable enhanced data security. Thomas explained that Intel non-volatile memory has enhanced data security with:

- *power loss data protection*: made so you can turn off power and writes will still complete; prevents data loss during unexpected system power loss while writing data (completes all writes in progress, even during power failure)
- *a surplus array of NAND*: surplus array of NAND Flash on SSDs furthers drive reliability; provides system protection against individual NAND die failure

Huge Memory and Collection-Oriented Programming: Less Code, More Speed?

Dave Thomas

- *encryption*: 328-Bit AES encryption when used with an ATA drive password; provides an additional layer of security

In step with the advances in memory technology, the Storage Networking Industry Association (SNIA; snia.org) have highlighted a new programming model for non-volatile memory, the NVM Programming Model (tinyurl.com/jpyya3z). This new model takes advantage of memory mapped files to communicate directly with persistent memory instead of using the traditional model, which relies on file systems and disks as intermediary technology. This new, and much simpler, programming model and its associated standard represent a breakthrough in terms of performance and the potential for more interesting applications than were previously possible.

Thomas' own research with the new Intel SSD DC P3700 memory technology found impressive and encouraging performance results against the STAC benchmark, which is used in the financial industry.

The impact on software

The advances in hardware and new programming models have impacts on software, and in particular on the feasibility of using object-oriented techniques. For example, automatic memory management (or "garbage collection") cannot cope in contexts with truly large amounts of data. Unfortunately, current languages, and most current developers, are not yet able to adjust to this new context.

Thomas outlined the differences (Table 1) between the conventional approaches to online transaction processing (OLTP) and a new OLTP approach using Hstore and Estore high-performance SQL database technologies, which offer substantial performance advantages by specifying complete workloads (i.e., collections of

transaction classes) in advance (Stonebraker et al., 2007). This new approach addresses the common mismatch between databases and hardware, meaning that many conventional OLTP techniques are not appropriate for use with modern hardware.

Collection-oriented programming

Next, Thomas traced the evolution of our concept of "programs" up today and into the future, when collection-oriented programming will become prominent:

- *1960s and 70s*: Programs = Data Structures + Procedures
- *1970s and 80s*: Programs = Database + SQL
- *1980s*: Programs = Logic + Control
- *1990s*: Programs = Objects + Methods
- *2012*: Programs = Functional Programming - Data Structures + Functions
- *2017*: Programs = Collections + Queries

The drive toward collection-oriented programming is driven by the increasing complexity of software and the need for a simpler approach, particularly when working with Big Data. Applications become small function scripts of collections and queries, making the approach easy to use and accessible to most programmers, who can then write smaller, simpler, and faster programs that are easier to maintain and run. The approach includes:

- Tables, Dictionaries, and Lists
- Operations and Functions for all collections
- Simple value semantics (no pointers)

Table 1. The conventional versus new approach to online transaction processing (OLTP) (Stonebraker et al., 2007)

Disadvantages of Conventional OLTP	Advantages of New OLTP
<ul style="list-style-type: none"> • Disk-oriented storage >> memory • And indexing structure (B trees) • Buffer pools to reduce latency • Multithreading to hide latency • Locking-based concurrency control mechanisms • Log-based recovery • Hardware cache unaware 	<ul style="list-style-type: none"> • Column store • Memory based • One-shot single-threaded transactions • No knobs • Replication instead of logs • Anti-caching for massive data

Huge Memory and Collection-Oriented Programming: Less Code, More Speed?

Dave Thomas

- Tables attributes are columns in a column store and can have trillions of rows
- Select, Update, Upsert, Delete for tables with functions in any position; implicit join, group by make it easier than SQL
- Each f(Map), f/ (Reduce), f\scan

As a result, most of the memory is devoted to the data rather than the programs, resulting in high performance with large datasets; however, the remaining challenge is to improve our ability to think in terms of formulating effective queries. Additional tools can be added to make queries even easier, for example: i) faster ETL (extract, transform, and load) without programming, ii) Visual Query simplifies Big Data querying but enables full power, and iii) a Big Data spreadsheet for non-linear analysis. Also, visual data exploration allows iterative, real-time visualization and pattern detection within massive datasets.

Thomas concluded the lecture with four key takeaways that summarize the near-future technologies and programming approaches:

1. Think more, and write less code.
2. Programs now consist of collections and queries.
3. Leverage the hardware: it is fast and inexpensive.
4. Simplicity reduces the time and cost of development and often improves performance.

About the Speaker

Dave Thomas is Chief Scientist/CSO, First Derivatives FD Labs. He is also Founder and Chairman of the YOW! Australia and Lambda Jam conferences, he is a GOTO Conference Fellow, and he is an ACM Distinguished Engineer. With a unique ability to see the future and translate research into competitive products, he is known for his contributions to object technology including IBM VisualAge and Eclipse IDEs, Smalltalk, and Java virtual machines, and more recently, he has been a proponent for the use of applied functional programming. He holds close links to the R&D community as an Adjunct Research Professor at Carleton University in Canada, and he has held past positions at UQ, QUT, and NICTA in Australia. While a professor at Carleton, he formed the Object-Oriented Research Group and established Ottawa's leadership in object-oriented technology. Dave has been a business and technical advisor to many technology local and international technology companies. And, among his past roles, he was Co-Founder and Chairman of Bedarra Research Labs (BRL), Founder and CEO of Object Technology International (OTI), becoming CEO of IBM OTI Labs after its sale to IBM.

This report was written by Chris McPhee.

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Keywords: programming, databases, memory, speed, object-oriented programming, collection-oriented programming, queries, huge persistent memory, very large databases, Big Data

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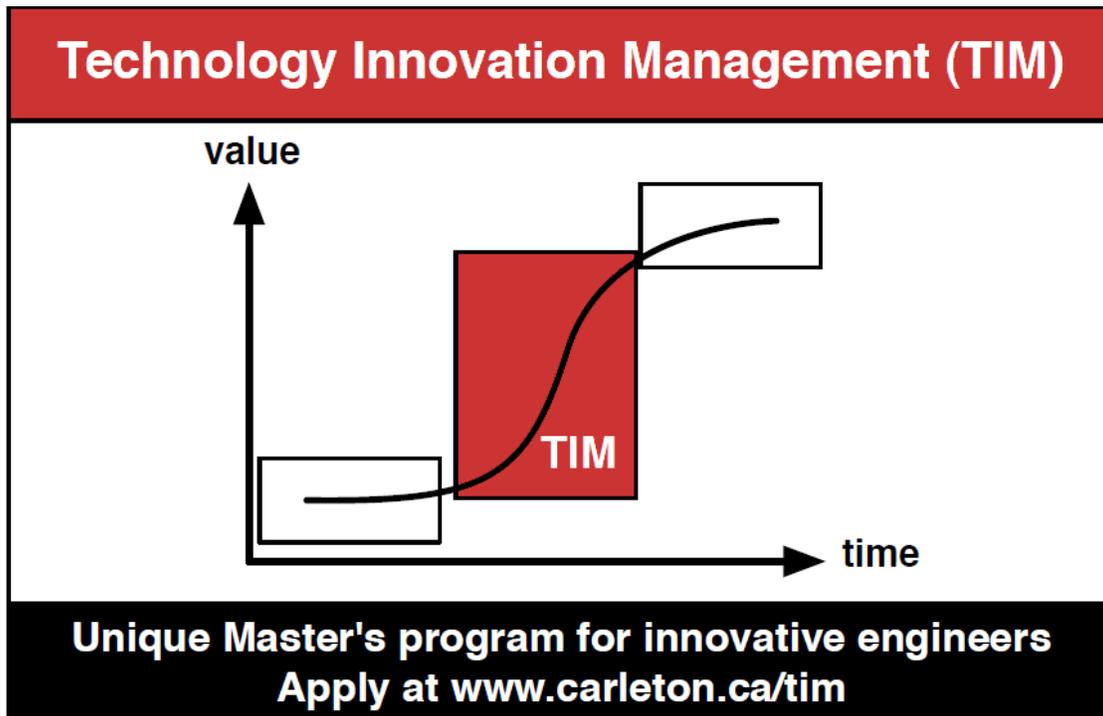
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