

MECHANICAL ENGINEERING / PHYSICS /  
PRESERVATION OF THE ARCHITECTURAL  
HERITAGE / STRUCTURAL, SEISMIC AND  
GEOTECHNICAL ENGINEERING / URBAN  
PLANNING, DESIGN AND POLICY / AEROSPACE  
ENGINEERING / ARCHITECTURE, BUILT  
ENVIRONMENT AND CONSTRUCTION  
ENGINEERING / ARCHITECTURAL, URBAN AND  
INTERIOR DESIGN / BIOENGINEERING / DATA  
ANALYTICS AND DECISION SCIENCES / DESIGN /  
ELECTRICAL ENGINEERING / ENERGY AND  
NUCLEAR SCIENCE AND TECHNOLOGY /  
ENVIRONMENTAL AND INFRASTRUCTURE  
ENGINEERING / INDUSTRIAL CHEMISTRY AND  
CHEMICAL ENGINEERING / INFORMATION  
TECHNOLOGY / **MANAGEMENT ENGINEERING** /  
MATERIALS ENGINEERING / MATHEMATICAL  
MODELS AND METHODS IN ENGINEERING



Head:  
Prof. Paolo Trucco

## DOCTORAL PROGRAM IN MANAGEMENT ENGINEERING

### INTRODUCTION

The Doctoral Program in Management Engineering (DRIG) offers students advanced training and preparation to conduct research in the field of management, economics and industrial engineering. It aims at training professionals who are able to carry out high-quality research in the fields of management, economics and industrial engineering at universities or other research institutions. PH.D. graduates from DRIG are also well equipped with distinctive skills and advanced knowledge to pursue a professional career in manufacturing and service companies, regulatory authorities and other public bodies. The program allows the student to develop a sound methodological background and multidisciplinary knowledge by attending courses designed to provide a multiplicity of visions, theories and approaches, a broad cultural panorama. The program emphasizes the benefit of studying problems in an innovative manner, combining various analytical approaches and research methodologies.

The commitment of the Department of Management, Economics and Industrial Engineering (DIG) to research and scientific cooperation with other academic institutions, major industrial companies and other organisations results into an ideal environment in which for students to acquire leading-edge knowledge and cultivate their own research interests in a broad range of research subjects.

### PH.D. PROGRAM STRUCTURE AND CONTENTS

The Full Time doctoral program covers three years, whereas the Executive Program lasts four years. They are entirely taught in English.

The Faculty of DRIG includes, in addition to professors of the Department of Management, Economics and Industrial Engineering, several international scholars: Mike Wright, Imperial College London, UK; Irvine Lapsley, University of Edinburgh, UK; Hans De Bruijn, Delft University of Technology, The Netherlands; Christopher Worley, University of Southern California, USA; David Coghlan, Trinity College Dublin, Ireland; Donald Huisingsh, University of Tennessee, USA; Tobias Kretschmer, Ludwig-Maximilians-Universität München, Germany; Sarkis Joseph, Worcester Polytechnic Institute MA, USA; Gary Dushnitsky, London Business School; Roerich Jens, Università di Bath, David Peck, TU Delft.

The program covers three main types of training activities.

#### Main courses

- Mandatory courses in Epistemology of Research in Social Sciences and Academic Publishing.
- Methodological courses, addressing specific research methodologies and related skills relevant to research in management, economics and industrial engineering;
- Thematic courses, aiming at introducing students to the reference theoretical background and the cutting edge research in specific disciplines, such as Entrepreneurship and Entrepreneurial Finance, Innovation Economics and Management, Supply Chain Management, Organisational Theory and Design, Service Operations Management, Enterprise and Operations Risk Management, Sustainability and Social Challenges in Industrial Systems.

#### Elective courses and training on specific themes

Elective training activities are customised according to the specific needs and research interests of students. The aim is to strengthen the scientific knowledge of students in very specific topics and to introduce them to the international research community through their active participation to international scientific conferences and PhD schools.

#### Thesis

The aim of the PhD programs at Politecnico di Milano is to instil in candidates a research-oriented mind-set, along with expertise and skills relating to a specific research topic. To develop a research-oriented mentality, candidates must acquire the ability to solve complex problems, including a thorough analysis of the problem, identification of an original solution and the ability to evaluate the solution and its applicability in given contexts. PhDs who possess these abilities will have greater opportunities for advancement in research positions, both in the academic environment as well as in public and private organisations.

The main goal is the development of an original research contribution. The Ph.D. thesis should help increase knowledge in the applicant's research field. It also needs to be consistent with the research topics studied at the Department. The final thesis can be submitted in the form of either a monograph or an edited compilation of papers. The research projects presented in the following section are typical examples of the research work carried out by DRIG students.

### SCIENTIFIC AND INDUSTRIAL COLLABORATIONS

Students are required to spend at least one semester in a foreign research institution. In addition, students are encouraged to attend doctoral schools and workshops organized by other institutions and to participate in international scientific conferences. The presentation of an original research work in an international conference is mandatory for admission to the final exam. To his end, students are granted of a personal research budget, covering a three years research period, and have access to mobility support measures aimed at promoting international collaborations between the doctoral programs in Europe and overseas.

In addition, Double Degree agreements are in place at the PhD level:

- EDIM (European Doctorate in Industrial Management, [www.edim-phd.eu](http://www.edim-phd.eu)) is an Erasmus Mundus Joint Doctoral Programme run by KTH (Sweden, Co-ordinator), POLIMI (Italy) and UPM (Spain) and is funded by the European Commission (EACEA);
- Other Double Degree Programs (4 years): Pontificia Universidad Católica de Valparaíso (Chile), Copenhagen Business School (CBS, Denmark), Henley Business School (HBS) at the University of Reading (UK).

DRIG has also developed several research collaborations with private manufacturing and service firms, regulatory bodies, and other public research institutions to fund PhD oriented research. In recent years, the following organisations supported DRIG Scholarships: Value Partners, IBM, Siemens, Telecom Italia, Windesheim University of Applied Sciences, Fondazione Brescia Musei, Nextea, Ernst & Young, Thales Alenia Space, Costa Crociere.

### PROFESSIONAL OPPORTUNITIES AND THE JOB MARKET

Typical career opportunities opened up by the doctoral program include:

- Post Docs, research fellows and young lecturers at Italian and foreign universities;
- Researchers and scholars in Management Engineering at public and private organisations;
- Highly qualified personnel at research and training institutions, or at technology transfer centres in Italy and abroad;
- Professionals at leading management and strategic consulting firms who can provide deep and advanced insights into companies' business areas;
- High-level professional roles at national and

- international public institutions;
  - Managerial roles at multinational companies with a strong focus on innovation;
  - Entrepreneurs in contexts characterised by a high level of innovation.
- Support actions for placement are provided with the purpose of sharing experiences, services and information through a number of initiatives fitting the different types of career opportunities. Particular emphasis is given to career development in the Management Engineering area.

### ADVISORY BOARD

Alavi	Maryam	Dean Scheller College of Business, Georgia Institute of Technology
Debruyne	Marion	Dean of Vlerick Leuven Gent Management School
Engwall	Mats	Head of Division of Industrial Management, KTH Royal Institute of Technology
Falco	Giuseppe	CEO, BCG Italy, Greece and Turkey
Feng	GengZhong	Dean School of Management, Xi'an Jiaotong University
Ferretti Peretti	Melissa	Country Manager Italy, American Express
FumagalliRomario	Aldo	President and CEO, SOL S.p.A.
Pignataro	Andrea	Founder & CEO, ION Trading
Purassanta	Carlo	Area Vice President of Microsoft France, Microsoft
Sahgal	Punam	Vice President (HR), National Institute for Smart Government
Schader	Martin	Associate Director of Quality Services, EFMD
Stephan	Paula	Professor of Economics, Georgia State University and a research associate, National Bureau of Economic Research
Suslow	Valerie	Associate Dean, Johns Hopkins Carey Business School
Symonds	Matt	Business School Media Consultant and Rankings Expert
Veugelers	Reinhilde	Professor of Managerial Economics, Strategy and Innovation, University of Leuven
Von Krogh	Georg	Chair of Strategic Management and Innovation, ETH
Zambon	Elena	Zambon President

# DIGITAL INNOVATION IN HOSPITALS: INDIVIDUAL AND INSTITUTIONAL DETERMINANTS OF ACCEPTANCE

Anna De Benedictis - Supervisor: Prof. Emanuele Lettieri

Healthcare is the most complex and fast moving industry that exists. New digital technologies are constantly being developed, all with the potential to support clinical practice by bringing many advantages into the healthcare sector (Barlow, 2017). Nevertheless, the healthcare industry has lagged behind in comparison with other sectors in the adoption of information technology in the workplace (Rudin et al., 2016). Some studies have analyzed both individual and institutional factors that affect the acceptance and implementation of information technology (Oliveira and Martins, 2011; Venkatesh and Davis, 2000) but they have generated mixed results (Holden and Karsh, 2010). Indeed, the mechanisms driving the adoption and implementation of information technology in hospitals remain unclear. Organizational Studies conceive organizations as strongly institutionalized settings in which individual behaviours are influenced by regulations, social norms and cultural systems (Scott and Davis, 2008; Gastaldi et al., 2019). In contrast, Information Science has mostly adopted user acceptance models, which emphasise individuals' rational and volitional assessment of the costs and benefits they would obtain from a new digital technology (Gastaldi et al., 2019). Only a few studies have tested both explanations (institutional and individual) in an integrative framework (Lewis et

al., 2003; Gastaldi et al., 2019) to explain the behaviour of hospital professionals (Mignerat and Rivard, 2009; Messerschmidt and Hinz, 2013) and comparing different types of digital technology. Following these considerations, this doctoral dissertation aimed to integrate these theories even more. Given the strength of the institutional forces in healthcare and the uniqueness of the hospital setting, the study viewed acceptance of technology as an effect of both individual and institutional forces, and it aimed to investigate the interplay between the institutional and the individual factors through experimentation with a new theoretical model, which combine different determinants coming from User Acceptance Models and from Institutional Theory. Another important aim was to evaluate whether and how to belonging to different professions (e.g. nurses and physicians) and the use of different types of digital technology - in particular management-led types and those introduced by hospital professionals - explain the behaviours of hospital professionals and their acceptance of technology. Two theoretical frameworks have been realized, one for each digital technology considered: Electronic Medical Record, as an example of technology management-led, and WhatsApp, considered as a

type of technology introduced by professionals. A quantitative study was designed and performed in a medium-size Italian University Hospital, including surveys and interviews. Hospital professionals (nurses and physicians), IT staff and hospital executives were selected as participants in the project. Furthermore, two systematic literature reviews have been carried out. The research project is detailed and described in the five appended papers. Paper I summarizes the results of a systematic literature review focused on the determinants of Electronic Medical Record acceptance in hospitals. Paper II explores the state-of-the-art, the key determinants and the strength of recommendations of WhatsApp usage in hospitals. Paper III studies the interplay between individual and institutional determinants of the intention to use Electronic Medical Record, which is an example of digital technology management-led, using an original theoretical framework that combines Technology Acceptance Model and Institutional Theory. Paper IV studies the interplay between individual and institutional determinants using a similar theoretical framework, but applied to the use of WhatsApp to support clinical processes, considering WhatsApp an example of digital technology introduced by professionals. Paper V is the psychometric evaluation of an original

questionnaire about the determinants of WhatsApp acceptance and usage by hospital professionals. From an academic viewpoint, the study offers an original perspective with a new theoretical framework, and it provides academics with at least three main contributions. First, the results confirm the importance of individual determinants, not only as directly related to the acceptance of digital technology, but also as important mediators between institutional determinants and acceptance of technology. Second, even if the data are preliminary, the study is one of the first to compare the professionals' behaviours towards two different types of technologies, those who are management-led - and that require at least a careful process of adoption, design and implementation -, and those who are introduced by hospital professionals without any planning or prevision of impact on processes, quality and safety of care. Third, the findings show significant correlations, which are worthy to be better explored, between being nurse or physician and the perceived ease of use and intention to use different types of digital technology in hospitals. From a managerial perspective, the research offers a novel insight for hospital executives, middle managers and hospital professionals since it provides several important insights into which levers can be used to improve the

acceptance of digital technology, both in the case of technology management-led or introduced by professionals. For hospital executives, the results shed a new light on the role of normative factors (e.g. peer influence) in promoting the acceptance of new technology. More specifically, mimetic forces influence the perceived usefulness of the two different types of digital technology. One of the main limitations of the study relates to the generalizability of results, as the research design is based on a single case study. Further research should consider a multi-centre design, to increase the generalizability of results.

## Keywords

*Digital Innovation, Hospital, Technology Acceptance Model, Institutional Theory, Electronic Medical Record, WhatsApp.*

# MANAGING THE HYBRIDITY TRADE-OFF. AN EMPIRICAL ANALYSIS OF IMPACT VENTURING IN ITALY

Veronica Chiodo- Supervisor: Prof. Mario Calderini

## Research Background

The research analyses how the firm's managerial challenges translate when the organization embraces a hybrid paradigm, which blends the generation of social and commercial value.

An organization is defined as a hybrid when it shows the combination of multiple organizational identities, organizational forms or different types of institutional logic. Within the hybridity realm, we find the Social Venture (SV), an entrepreneurial entity whose primary aim is to provide solutions to the wicked problems – such as ageing, climate change, refugees' crisis – leveraging on forms of entrepreneurship and trading. The disruptive characteristic of this new paradigm is “the ability to integrate a business model to the provision of a social need” (Hynes, 2009: 114); as a result, in the same business model, values traditionally pertaining to not for profit sector blends with the creation of economic value traditionally pursued by for-profit companies. The current trends suggest that it is very likely that in the near future every company worldwide will need to understand how to implement operations that integrates social impact and financial returns. Indeed, CSR activities are becoming part of the core business of corporations and the market of sustainable and social investments is growing at an impressive pace.

Therefore, the research wants to shed light on the managerial challenges emerging from hybridity, by understanding whether the hybrid nature causes situations of trade-off not experience by profit-maximizing ventures and how they can be overcome. Scale is a major challenge for hybrid organizations that aim to generate systemic change in society. Moreover, the concept of growth in hybrid organizations should be framed with a broader scope than the mere change-size perspective prevalent in the entrepreneurship literature. When the goal is increasing the level of fulfillment of a social need, growth might also occur outside the organization, without modifying its configuration, but just increasing the outcomes it produces. The second domain where the research tests the assumption of the hybridity trade-off is access to finance, which is usually pinpointed as one of the most pressing challenges for ventures. The combination of weaker financial institutions following the financial crisis, disruptive disintermediation-enabling technology and a socio-economic as well as cultural shifts is challenging the paradigm of how finance is provisioned. A novel hybrid approach to finance has emerged, labeled Social Impact Investments (SII). SII is a strategy of asset allocation, which combines financial

profitability with a measurable social and environmental impact. Both the streams of literature on SVs and hybrid organizations are still young and growing.

The influence of social value generation on economic sustainability has attracted the attention of many organizational scholars. However, so far, they have conceived the question of hybridity in terms of tensions and paradoxes. Just recently the literature has shifted the focus on the actual trade-offs underlying those tensions and affecting the SV's strategies and processes.

## Research Objective and Design

The objective of the research is to understand how growth and access to finance are affected by the co-existence of the commercial logic and the driver of increasing the positive benefits the activity of the venture creates for society. The research problem is investigated in the empirical setting of the Italian Impact Venturing, namely organizations that implement a blended value approach, generating positive value for the entire society alongside being economically sustainable. Therefore, the study is based on primary data on social ventures and social impact investors in Italy. A mixed methodology based on statistical techniques and thematic analysis has been employed to analyze the data due to the

exploratory nature of the topic.

## Key Findings and Related Implications

The research identifies a quantitative relationship between the organic measures of social and commercial growth which supports the chance of a hybrid concept of growth.

However, the findings raise concerns about the opportunity for long-term sustainability for SVs. Therefore, the study theoretically deepens the problem of accessing to finance of socially oriented hybrid organizations along the stages of their life cycle. The results verify that the institutional solutions in terms of financing which are commonly exploited by high-tech start-ups for growth are not enough to support social tech start-ups to scale. It identifies the concept of Social Impact Investments (SII) as a possible solution and discusses its potential contribution. Specifically, three main areas appear crucial for explaining its evolution: demand-supply matching, the development of a proper accountability infrastructure, and the development of the regulatory framework.

Building on that, the study goes in-depth into this under-investigated phenomenon, addressing in particular the issue of demand-supply matching. First, it draws a picture of SII state of the art worldwide, laying the foundations for the development of the framework to interpret the evolution of this emerging industry. Secondly, the project jointly analyses the obstacles experienced by SVs in accessing funding and the characteristics of SII to verify whether it represents an actual opportunity for them. It discusses the reasons why there is still a misalignment between the funding

needs of socially oriented hybrid organizations and the expectations of capital providers. Five themes emerged from the analysis – *lack of strategic alignment, intangible infrastructure, need of a keystone, collaborative approach* – which represent the supplier perspectives on the SII Italian ecosystem. They have been, then, discussed in light of the structure of the demand side and the comparison leads to the identification of potential solutions to foster strategic alignment.

The current research places itself first and foremost within the growing literature on social ventures. One overarching contribution is, thus, the application of different established and emerging theoretical lenses - such as firm's growth theory, resource-based theory, ecosystem perspective - to a new field. This work feeds the empirical heterogeneity of the literature on SVs and hybrid organizations that is mostly dominated by a case study approach. Indeed, it built a consistent and unique dataset composed of 456 responses of SVs and 30 interviews of social impact investors and it feeds two streams of literature, SVs and SII, which are still lagging in terms of availability of data.

Moreover, by investigating hybrid growth modes, it answers the call by prominent scholars in the firm's growth literature to shift the focus from growth rates and determinants to how companies grow. It clarifies the concept of scaling by providing a more precise way to conceptualize it and going beyond the prevalent descriptive approach using so far. In doing so, it opens the opportunity to undertake further quantitative analyses on this underexplored issue.

It expands the growing literature on SVs by addressing a challenge, the access to financial resources, that scholars pinpoint as one of the most pressing. It contributes to the literature on SII and, specifically, trying to support the legitimation of this market by demonstrating a real demand for social impact investments. Moreover, leveraging on the research agenda proposed by the scholars in the ecosystem literature, it identifies the challenges hampering the strategic alignment in the SII Italian industry. The results of applying the hybrid paradigm contribute to the literature on ecosystems by bringing the attention to the intangible infrastructure needed by the members of the ecosystem (represented by capacity building and instruments to assess the social performance).

# LABOUR FLEXIBILITY CONTRIBUTION TO WORKLOAD CONTROL IN TO-ORDER FLOW SHOP COMPANIES

Federica Costa – Supervisor: Prof. Alberto Portioli-Staudacher

Production Planning and Control mechanisms support companies in facing the continuous challenge coming from turbulent market changes and unpredictable customer's behaviours. They open new possibilities for companies to achieve competitiveness and flexibility, two vital characteristics for being in the market in the long run. Literature has proven that companies that have a to-order production process take most of the advantage from Production Planning and Control mechanisms, and, specifically, from Workload Control, if production processes are characterized by a high mix and low volume. Workload Control models are based on input and output control. The former uses information about jobs in order to decide when incoming orders can be released into the production process, while the latter uses information about system capacity in order to regulate the workload in the system. Output Control has been quite overlooked in the literature even if its impact on performances has been recognized as important as input control's one. The aim of this research is to consider and investigate, through simulation, a specific output control in Workload Control: labour flexibility: workers are shifted from underloaded station to overloaded station, no extra capacity is introduced. Labour flexibility or multi-skilled workers has been recognized as a way to adjust and

manage the system's capacity. It is a managerial tool to achieve volume flexibility in production and volume flexibility is recognised as a strategic mean to face uncertainty in markets and growing global competition. This research presents firstly a deep dive in the understanding of the context, given from previous literature and an industry perspective, that revealed labour flexibility to be one of the managerial lever that enables improvements lasting in the long period. Labour flexibility is, then, investigated, through simulation, in a workload controlled flow shop and results show the impact of labour flexibility in the contexts of make-to-order flow shop, explain how labour flexibility realizes performance improvements and identify solutions to take advantage of labour flexibility in practice. Exploiting underload and overload period, this time at Workload control order review and release of customers' job is then addressed. Mathematical models for the two most important order review and release approaches are presented in order to integrate, for the first time, at this control level of workload control worker's capacity and availability information. Moreover, worker's allocation decision, Who will be shifted and Where is decided at order review and release of customer's jobs based on workload imbalances amongst stations. Results show that throughput time

and delivery related performances improve and how, suggesting that resource capacity information should be considered at order's review and release. Moreover, this brings relevant insights for practice, simplifying worker's allocation since it is taken prior order's release. Along with multi-skilled workers, their flexibility and efficiency has been modelled in Dual Resource Constrained literature by means of flexibility and efficiency matrices, that express whether a worker can perform a task and according to which efficiency level. Workers can be assigned to an overlapping range of stations, something called baton-zone bumping in Protzman *et al.* (2016). While it is obvious that techniques as baton-zone bumping are most effective if all workers are equally efficient at all stations, it is often not desirable to rely on such a highly skilled work force. However, these matrices have been always considered has a given environmental factor in the experiments plan, that, for example, was aimed at testing different allocation's rules. Rather matrices have been designed with the aim of improving performances, by shaping, for example, the outperforming bowl pattern, where faster stations are placed in the middle of a line. Different matrices have been designed, considering the latest research on capacity adjustments in Unbalanced Lines, and tested in a

Dual Resource Constrained flow shop, in combination with different rules concerning worker's transfer, When, Where and Who rules. Results show whether heterogeneous workers are better than homogeneous, to what extent fully flexible and efficient workers outperforms heterogeneous cross-train configuration, that could place faster workers in different positions along a line i.e. beginning, centre or end stations of the line. Relevant insights for practice emerge regarding the positioning of workers on a line when heterogeneity exists and cross-training investment decision.

## Keywords

*Workload Control, Output Control, Labour Flexibility, Multi-Skilled workers, Heterogeneous Flexibility, Heterogeneous Efficiency, Flow Shop, DRC shops*

# OPENING THE BLACK BOX OF LOCAL COMMUNITIES; EXPLORING THEIR PERCEPTION AND JUDGMENT

Roya Derakhshan – Supervisor: Prof. Mauro Mancini

## Background

Project organizations are globally facing challenges for satisfying local communities through allocation of higher financial resources on hard infrastructure and development programs. Ascending trend of communities' protest and resistance against the projects, on the other hand, deems the efficiency and effectiveness of these schemes. Furthermore, reviewing the stakeholder management literature elucidates that vast majority of stakeholder research is underpinned by the implicit assumption that the focal organization is the one and only decision maker and thus over emphasizes on reflecting the organization's viewpoint. Consequently, the perception and viewpoint of the local communities are neglected and the literature fails to bring a comprehensive image of the debate.

Against this background, this research is designed to depart from the organization centric approach of stakeholder management literature and analyze the local communities' stakeholders to explore how they perceive the project organizations. To achieve that, this research establishes its foundation over the normative core of stakeholder theory and adopts theoretical lenses from psychological research, organizational studies and ethics of care to investigate how individuals within local community

perceive organization's activities and how contextual and organizational factors influence this perception.

This research entails addressing this main research question:

**RQ.** What are the processes and influencing factors underpinning the local communities' perception from project organization behavior?

This generic research question is then divided into four sub-questions as follows:

This research question will be answered through the investigation of the following sub-questions:

**RQ1.** What are the roles and rights considered for local communities in project management literature and how these stakeholders are encountered by project organizations?

**RQ2.** How do local communities' individuals perceive project organization's practices?

**RQ3.** How do contextual factors influence local communities' perception?

**RQ4.** How does organization's behavior influence local communities' perception?

## Methodology

This research covers an umbrella of different methods, approaches and reasoning to address the abovementioned questions. The first phase of the research involves systematic literature review (to address RQ1) and conceptual inductive reasoning (to address RQ2), while the second phase has a focus

on investigating the actualities of the phenomena, seeking for evidences to support the theoretical constructs and extend them (to address RQ3 and RQ4). The first stage of data collection includes investigations on the local and organizational level of four projects in oil and gas sector in three developing countries, interviewing informants from local communities and project organization. The second stage of empirical research entails of deduction from the results of the previous phases through analyzing a single rich case of community protests against an organization.

## Findings

The results of this research suggest that project organizations essentially assign roles and rights to the stakeholders according to their group belonging. In the governance structure of the organizations, the local communities' stakeholders are routinely positioned quite distal from the organizational level where the decision making processes are undertaken. The local communities' individuals, consequently, are excluded from the decisions that influence them the most. Conceptualization through attribution theory elucidates that this exclusion results in development of negative bonds between the organizations and local communities. The communities' perception can also be influenced by the level of power and perceived legitimacy of local government

and media. Informed by feminist formulation of stakeholder theory, this research suggests that construction of the organization's knowledge from the demanded care of the local communities and carrying out the caring activities at the local level considerably alters the perception of the communities. To recognize the communities' demanded care, the organizations ought to decentralize the decision making to their border where individuals from inside and outside of the organization are in contact with each other. Through principled dialogues, these multidimensional selves at the local level develop a unified army to conduct the caring activities. The responsibilities of organizations, therefore, are not essentially identified by the organization's limited knowledge and are not broad brushed by excessive concentration on the financial developments. They rather have an adoptive and democratic nature and are designed according to the recognized demands of the local communities. This approach empowers the local communities and protects them on their vulnerable points from the harm of the projects.

## Implications

For the practical implications, this research suggests that management for stakeholders in large organizations ought to be done through the embodiment of virtue of caring in individuals. It is believed that these

are the virtuous individuals that allow the organization to perform ethically. The code of ethics and formal contracts developed at the organizational level do not independently result in satisfaction of local communities. Furthermore, these contracts cannot support the local communities' individuals to make correct perceptions from the motives behind the organization's behavior. These are the individuals at the local level who, getting connected to these stable components of the organization, make caring activities practical and by conducting principled dialogues with them create an environment within which the perceptions at the two sides of the organization border are mutually constructed.

# PLURAL LEADERSHIP AND EMPLOYEE-DRIVEN INNOVATION: COLLECTIVE PRACTICES IN THE EVOLVING WORLD OF ORGANIZATIONS

Nicole Flocco - Supervisor: Prof. Raffaella Cagliano

## Research background

Nowadays organizations operate in a complex and evolving environment. Globalized competition, shortened product lifecycles, sustained technological progress and economic uncertainty have all contributed to the rise of new management challenges and have led organizations to search for effective responses to the changing environment. Leadership and innovation are presented, both in academic and practitioner discourses, as essential elements to face the aforementioned challenges. If we look at the prominent studies in both these research areas, we can clearly see a diffused convergence toward plurality. Indeed, today, it seems unrealistic for a single individual, acting alone, to possess all the knowledge and skills required to innovate and to lead a company into the future. This dissertation relies on the investigation of the common trend toward plurality visible both in leadership and innovation fields. Specifically, this work focuses on the concepts of plural leadership and employee-driven innovation (EDI). Plural leadership is described as a collective phenomenon that is distributed or shared among different people, potentially fluid, and constructed in interaction. While EDI refers to innovative practices contributed by any employee

(outside the boundaries of his/her primary job responsibilities), at all levels of the organization. Both these research areas present interesting insights, however some relevant issues are still unexplored. First, several companies are currently using a variety of initiatives to involve employees in innovation (i.e. hackathons, contests, innovation time-off policy etc.), however the literature on this topic is at its infancy, and little is known about which design choices are more suitable in which situation and their implications. Also, there has been a paradigm shift toward shared, collective and distributed forms of leadership, however researchers have not yet agreed on *how* multiple leaders, both formal and informal, practically emerge and collaborate. In order to address these issues, this dissertation explores four research questions:

- *RQ1: What kind of practices managers put in place to involve employees in innovation and how these practices differ for intended outcome and design?*
- *RQ2a: To what extent is plural leadership involved in EDI?*
- *RQ2b: How does plural leadership practically work in the context of EDI?*
- *RQ2c: How do formal leaders and informal leaders collectively construct a shared direction?*

## Methodology

Due to the explorative nature of the research questions and to the focus on innovation and leadership processes, a qualitative approach was selected to achieve the aim of each paper in this collection. As already explained, the literature on EDI is recent and multiple exploratory case studies were considered the right choice to reduce the gap between theory and practice. Moreover, since plurality is involved in EDI, qualitative research allows to capture this phenomenon from different perspectives and to understand the dynamics unfolding in these processes. On the other side, qualitative research is necessary also to capture the collective and dynamic dimensions of plural leadership. Scholars have been wrestling with different ways of conceptualizing and researching leadership in plural or multiple terms. Traditionally, leadership has been studied with a variance approach, focused on individuals more than collectives and processes, however plural leadership theory is interested in the construction of leadership, and requires new approaches, like 'leadership as practice', discursive approaches, dialectical views, to take into consideration relationship and time or the 'fluidity' of leadership. In this dissertation I have collected qualitative data for Paper 1 and Paper 2 through multiple cases, while I have used a single case and

a short ethnography for Paper 3. In Paper 3 indeed, the goal was to unpack the internal dynamics of plural leadership, therefore a process perspective was adopted, and beside traditional interviews, I have collected data by shadowing people, observing face-to-face meetings and analysing some email exchanges, in order to catch plural leadership 'in the making'.

## Key findings

The first paper in this dissertation enriches our understanding about employee-driven innovation, building a model to classify these practices (as *Community-nurturing practices*, *Solution-based practices* or *Integrative practices*) and helping practitioners to choose between different strategies to implement EDI (single, sequential, simultaneous), depending on the intended outcome they want to pursue.

The second paper in this dissertation creates a connection between plural leadership and EDI literature, exemplifying through cases how leadership roles are distributed between formal and informal leaders and *why* and *when* leadership rotates between them. This paper points out several interesting insights: (i) plural leadership is involved in EDI, (ii) power should not be ignored in the study of plural leadership, as it might affect the distribution of leadership roles and the moment in which informal leaders emerge, (iii) *leading process* and *leading content* are two necessary roles for innovation and are usually divided between formal and informal leaders to answer the competing demand of exploration and exploitation.

The third paper in this dissertation contributes to plural leadership theory, empirically investigating a

particular configuration that includes hierarchical, functional and informal leaders. It shows both formal and informal leaders can influence the direction of a project by leading content and leading process, and followers have an important role in determine the persistence or fall of a direction. Finally, this paper shows the plural leadership "dance": formal leaders can swing between empowering ordinary employees, and controlling the project, they can interfere in several moments to (re) direct the team, and even when they are not physically present, they can nevertheless exert leadership through the material scripts they impose and the traces they leave.

## Implications for theory and practice

From a scientific point of view, this dissertation contributes to plural leadership theory by stressing the role of formal leaders as a central element of plural leadership, and empirically, by supporting the leadership-as-practice movement, providing one of the first studies to explore 'pocessually' how formal and informal leaders interact when the goal is innovation, and one of the first studies to investigate leadership in EDI.

If we look at the managerial implications, several considerations can be made. With reference to employee-driven innovation, this work provides a model to navigate the variety of EDI practices that are proliferating in organizations. This model gives managers a valid tool to plan and design EDI initiatives according to the intended outcome they want to pursue, and highlights for each strategy some points of attention.

The main takeover from the leadership side is that organizational

tools for leadership assessment should be integrated with a pluralistic perspective. Leadership can be seen as a collective and dynamic process, that involves a variety of actors in different possible configurations, and values also dialectics and dissent. If companies will be able to rediscover leadership as the production of direction, alignment and commitment that arises with the dynamic contribution of formal leaders, informal leaders and followers, more than a set of approaches that might be applied by a 'hero' leader in specific situations, this will bridge the current gap between theory and practice. The scientific world is moving towards plural leadership, this dissertation invites also practitioners to consider this shift.



## IMPROVING HOSPITAL PATIENT-FLOW: AN EXPERIENCE-BASED CO-DESIGN STUDY

Raffaella Gualandi - Supervisor: Prof. Cristina Masella

It is recognized that the success of service providers depends on their ability to provide customer-centric services. In the healthcare sector, this topic is addressed under two main aspects. On the one hand, the evaluation of healthcare services from the patient's perspective, by including his/her experience as well as satisfaction and clinical outcomes; on the other, the involvement of the patient in quality improvement initiatives.

In an effort both to improve value for patients and to use resources efficiently, healthcare organizations are addressing how to involve patients and professionals in the redesign of healthcare services. However, analysis of the literature shows that some gaps exist. First, there is a need to compare different empirical settings in order to provide more effective results on co-creation (Galvagno et al. 2014). In particular, the issues and the opportunities of the involvement of patients to co-create their own experience of service delivery is only partially addressed by the literature. Secondly, it is not clear how professionals and patients may contribute to the redesign of a key business process so as to achieve results both for the patient and the provider (Winasti et al. 2018). Finally, few studies analyse how patient-experience data translate into improvements in the quality of care (Donetto et al. 2019). Therefore, there

is a need to understand whether and how the patient can contribute to the improvement of service delivery. The purpose of this thesis is to explore the contribution and challenges of patients and healthcare professionals in hospital patient flow improvement by using an Experience-Based Co-Design (EBCD) approach. In particular, this research aims to identify whether the patient perspective can capture the core of hospital process-related problems and generate different solutions centered on patients' needs. Therefore, this thesis aims to address these gaps by answering to the following research question and related sub-questions:  
RQ1 – How can patients and healthcare professionals be involved in improving a hospital cross-functional process?  
RQ1.1 – How can patient perspectives and experiences contribute to the improvement of hospital patient flow?  
RQ1.2 – How can healthcare professionals and patients contribute to the improvement of a cross-functional process?  
RQ1.3 – What are the challenges of using an EBCD approach for the improvement of hospital patient flow?  
A systematic literature review was conducted at the beginning of the project to provide a complete, exhaustive summary of current evidence relevant to the research sub-question 1. The results show

how a wide range of actions are reported to improve hospital patient flow, but the patient perspective is scarcely considered. Moreover, patient involvement in the process improvement is rarely mentioned and occurs only with the patient's consultation on the satisfaction or otherwise of an intervention adopted. The patient-journey process was then mapped from the moment of the first outpatient visit to the first follow-up visit after discharge from the hospital, to understand how different methodologies of qualitative research are able to capture patient experience of the hospital journey. In particular, qualitative study of orthopaedic patients admitted for hip and knee replacement surgery was performed. Eight patients were shadowed from the time they entered the hospital to the time of transfer to rehabilitation. Four patients and sixteen professionals, including orthopaedists, head nurses, nurses and administrative staff, were interviewed. The three different standpoints (patient shadowing, health professionals' interviews and patients' interviews) allowed different issues to be captured in the various phases of the journey. Results show how hospitals can significantly improve the quality of the service provided by exploring and understanding the individual patient journey. In particular, when dealing with a hospital-wide process,

the involvement of all professionals, including non-health professionals, can reveal priority areas for improvement and for services integration. After this phase, a survey was conducted to explore whether real-time patient feedback could capture relevant issues to improve the quality of hospital patient journeys. Both qualitative and quantitative data were collected from patients admitted for surgery in the Orthopedics department. A total of 254 patients completed a questionnaire evaluating their hospital journey with both closed and open questions at two different points in time: when entering the ward and at discharge. Results show how the patient experience changes along the journey and can be captured in real time by considering their needs, the environment and the emotional states they traverse. Finally, the co-design groups were carried out. Three workgroups were set up to involve at least 2 patients, 1 nurse or head nurse, 1 orthopedic doctor. From the first observations, some interesting issues emerged. First, the patient only if stimulated by the physician intervention declares his "submerged" needs. Second, the patient identifies some behaviours of professionals (haste, lack of availability, the need to wait for a bed) as a result of organizational problems rather than lack of attention to the patient himself. Finally, when

interviewed individually at the end of the co-design team, the health professionals declare that they cannot tell the patient about the gaps that take place behind the scenes. These first data will be the basis for testing a framework that defines under which conditions of engagement co-creation produces value. By following an Executive Ph.D. Programme within a rapidly growing organization – the Campus Bio-Medico University Hospital of Rome – and through an insider perspective, a series of practical contributions have been achieved. First, the study of patient flow from a patient perspective enables hospital managers to understand how to improve this process both for better use of resources and services integration, and in order to give the attention to the patient that underpins the hospital's mission. Second, this research focus on patient experience has stimulated an early cultural change at the level of hospital top-management in the way that the patient's perspective on service delivery is assessed. Third, the participation of front-line professionals as well as middle and top managers and researchers in a cross-hospital improvement project has increased the level of awareness about the possibility of improving the patient experience by revising and integrating the work-flow processes. From an academic viewpoint, the

contribution of this research is threefold. Firstly, the results of this study contribute to broadening knowledge of healthcare service design by understanding the role the patient may have in the redesign process. Secondly, this study provides an in-depth understanding of how valuable patient experience is for the design of the patient journey, revealing the dynamic and complex interconnections among multiple actors that determine it. Finally, its results also contribute to advances in methodological quality improvement research by taking into account the contextual variables of hospitals and patients' perspectives. Effective design of patient-centered healthcare services relies on collaboration between patients, front-line staff, decision-makers, and managers. More research is needed to understand whether expanding co-design solutions in the redesign process will enable health managers to get more patient-centered services. The achievement of this goal will represent a competitive value for the organizations.

# BUSINESS MODEL INNOVATION AND ORGANIZATIONAL CHANGES IN THE ERA OF DIGITAL TRANSFORMATION: AN EMPIRICAL STUDY IN THE ENERGY UTILITY INDUSTRY

Vito Maria Manfredi Latilla - Supervisor: Prof. Vittorio Chiesa

This doctoral thesis aims at examining the organizational change process that enables energy utilities to innovate their business model (BM) while exploiting digital technologies. Digital technologies (such as Big Data, Internet of Things, and Cloud Computing), are changing the way people live, as well as the way businesses bring value to customers. As noted by Bonaccorsi et al. (2006) and Amit and Zott (2001), digital technologies have opened new opportunities for organizing business activities, completely reshaping previous BMs for established firms. To say it with Autio et al. (2018) the integration and embedding of digital technologies challenge the core business of many organizations to alter products, services, operations, and employees' behavior. Digital technologies, indeed, have enabled new organizational architectures and have ignited important changes at organizational level (Sosna et al., 2010). Even firms in traditional industries, as energy is, are increasingly realizing the disruptive potential of the digital transformation era we are living (Dellermann et al., 2017). Hess et al. (2016) report indeed that incumbent firms face significant challenges even if senior leadership teams are internally motivated to support the digital transformation of business models, structures, and processes. Fitzgerald et al. (2014, p. 2) define

digital transformation as, “the use of new digital technologies (social media, mobile, analytics or embedded devices) to enable major business improvements [...] or creating new business models.” Liu et al. (2011, p.1730) argue that digital transformation is “as an organizational transformation that integrates digital technologies and business processes in a digital economy.” Rogers (2016, p. 308) argues that “digital transformation is fundamentally not about technology, but about strategy,” meaning that senior leadership teams must find ways to capitalize on new and unexpected business model innovations that optimize customer needs and experiences. Extensive academic literature has analysed what a BM is and what is its role in the value creation process of a firm (i.e., Zott et al., 2011; Spieth et al., 2014; Tucci et al., 2017). A comprehensive literature review on business model innovation (BMI) has been performed by Foss and Saebi (2017) analysing more than 150 peer-reviewed articles on BMI published between 2000 and 2015. Specifically, it has emerged that BMI literature is mainly focused on either examining BMI as an organizational process or identifying new and innovative types of venture. Building on these premises, the present thesis focuses on BMI intended as an organizational change process related to the “architecture of value creation, delivery and

capture mechanism” of a firm (Teece, 2010, p. 191). BMI can indeed be interpreted as a dynamic process that requires the design of proper organizational structures to facilitate the change in the BM, involving all the levels of the organization (Chung and Choi, 2016). Hence, BMI is interpreted as the outcome of the organizational change process; it is, as noted by George and Bock (2011, p.24) “the design of organizational structures to enact a commercial opportunity”. Notwithstanding the aforesaid, Foss and Saebi (2017), argued that the role of organizational design has been almost completely neglected in the research on BMI, even though organizational design is strongly intertwined with BMI and a successful implementation of it requires correspondent changes in the organization (i.e., the structuring of the organizational processes, the coordination of activities and the role of functions, units and departments within an organization). The role of organizational design within the research on BMI is even more important today in the wake of the proliferation of digital technologies (Gambardella and McGahan, 2010). This pervasiveness has a radical impact on firms' BMs, as firms are called to recombine existing non-ITbased resources and activities with the digital ones (Svahn et al., 2017). This demands for shifting, with different degrees of radicalism, from

an existing BM to a new one (Tucci et al., 2017). Indeed, when a new technology becomes available on the market, a firm that is interested in adopting it should investigate whether the current BM is suited to support the nascent technology or there is a need for innovating its BM.

BM may evolve, change and be source or vehicle of innovation (Mitchell and Coles, 2003; Massa and Tucci, 2013), to the point that there is debate whether we should generally talk about BM change, adaptation, renewal, development and so on rather than using (or abusing) the term “innovation” (Spieth et al., 2014; Saebi et al., 2017). Foss and Saebi (2017) adopted the conceptualization of “business model reconfiguration” for incumbent firms, which have to modify their architecture to adapt to changes in the external environment. Adaptation through BM reconfiguration, hence, can be the key to survive in an era of major technological change, where traditional BMs are not anymore guarantee of success and profitability for established firms. Recognizing a gap in the academic literature in the lack of understanding of the relationship between BMI and organizational changes, the purpose of the present doctoral thesis is to understand whether a change in the organizational design is an antecedent or a consequence of a change/innovation in the BM. Since in its early stage of development, this specific stream of research on BMI as organizational change process “inherently requires more of a qualitative approach” (Foss and Saebi, 2017, p. 209). Consequently, an empirical analysis has been conducted on a sample of established energy utilities that need to

innovate their BM to respond to external societal and technological trends. Eventually, we would like to contribute to the resolution of research questions that “are not currently being systematically posed, addressed and answered reflecting the emerging nature of BMI research” (Foss and Saebi, 2017 p. 201). The domain of research at the intertwin between organizational design and BMI represents, indeed, a hot topic of research nowadays, both in the business and academic community, since environmental dynamism (market and technology turbulence), intra-industry threats (competitive forces) as well as extra-industry threats (factor conditions, complementarities) and regulatory changes (taxation, product-related regulation etc.) are common triggers (Ansoff, 1975; Christensen, 1997; Zott, 2003; Demil and Lecocq, 2010; Sosna et al., 2010; Cavalcante et al., 2011; Saritas and Smith, 2011) that demand a continuous adaptation and innovation of BMs. Furthermore, current major technological trends pose great threats to the profitability and, ultimately, to the survival of established firms, since they are less able than new comers to innovate and embody digital technologies in the design and commercialization of new products and services (Greenstein, 2017; Bresnahan et al., 2012; Dyer et al. 2009; West and Gallagher, 2006; Chesbrough, 2003; Frambach and Schillewaert, 2002; Teece et al., 1997). The present thesis hence addresses the following research question: *What organizational changes BMI requires and why? Is organizational change an enabler of BMI and how?* with the aim of developing a proper understanding of the new organizational structures that energy utilities shall adopt

to innovate their BMs in a time of technological transformation. To do so, the thesis builds on an inductive, longitudinal series of case studies of energy utilities. To support answering the above main research question, three additional research sub-questions (RSQ1, RSQ2 and RSQ3) were proposed and answered through the appended papers, i.e.:

- Paper A: *What organizational changes does BMI require and why? How does organizational change influence BMI?*
- Paper B: *How do established companies embrace organizational re-design to innovate their business model while exploiting digital technologies?*
- Paper C: *What are the micro-foundations of business model co-innovation in digital transformation?*

Papers A and B look at the organizational design and change within organizations and how such process is intertwined with BMI. They aim indeed to understand whether a change in organizational design is an antecedent or a consequence of a change in the business model. Paper C looks at how established organizations and external partners, such as startups, work together in co-innovating the traditional business models of established organizations in a digital ecosystem.

## Keywords

*Business Model; Business Model Innovation; Business Model Co-Innovation; Organizational Design; Organizational Change; Dynamic Capabilities; Digital Technologies; Energy Industry*

# TOWARDS A NEW APPROACH FOR GLOBAL DISTRIBUTION NETWORK DESIGN: THE INTEGRATION OF LOGISTICS AND FISCAL ISSUES

Lorenzo Bruno Prativiera - Supervisors: Prof. Marco Melacini, Prof. Elena Tappia

All modern supply chains have nowadays some type of global presence. Trade barriers reduction, widespread application of ICT and improvement of technological solutions led in the last decades to a progressive growth in worldwide trading, whereas logistics increasingly represents the backbone of the internationalisation process. Global distribution network design (GDND) is thus a relevant problem for companies, which refers to designing the downstream part of global supply chains and determining the best way to transfer goods from points of supply to points of demand (i.e. the number of network facilities and their location, operations to be performed in each node, and links between them) in a way that minimises total network costs. When the perspective is not global, distribution network design refers to managing the trade-off between logistics costs and service level to customers. Nevertheless, when designing global distribution networks a mere logistics perspective may be reductive, since GDND involves multiple aspects referring to different areas. This research is one of the first attempts to go beyond traditional logistics boundaries by taking a multidisciplinary attitude in order to develop a new approach for GDND. Specifically, it looks towards exploring a research area that is still under-

represented in the current academic

landscape, i.e. the integration of fiscal issues within GDND. To explore tax implications (e.g. the differences in corporate income taxes, or duties to be paid at import) related to different distribution network configurations is an increasingly relevant problem for practitioners. However, most of the current literature about GDND ignore the role of taxation, despite that significant tax implications related to the geographical distribution of value-added activities. Concretely, the present research project aims firstly at enlarging the performance measures for GDND, by specifically including legal and fiscal elements alongside logistics issues. Then, given that multidisciplinary research is particularly relevant for complex and interdependent systems as global distribution networks, the research project looks at enlarging the perspectives of analysis with two main sub-directions. On the one hand, it aims at including production issues in logistics network configuration (to define what is known as the postponement boundary problem). On the other hand, it aims at deepening the relationship between logistics channel and trade channel design. To pursue these research objectives, a pragmatist paradigmatic preference was adopted and a multimethod approach was considered. A combination of qualitative and quantitative methods was thus

applied: a structured literature review was performed, single and multiple case studies were carried out and analytical models were developed to address specific sub-problems related to the integration of fiscal issues within GDND. The formalisation of the results was then achieved through a collection of four papers, submitted to international scientific journals. These papers summarised the contributions of the research, whose primary value lies in the enrichment and development of the existing literature, pushing the current body of knowledge through:

- the formalisation of a new approach to address GDND, broader than the usual one which included exclusively logistics elements;
- the exploration of new and underestimated problems (such as warehouses' location in lowtax jurisdictions for tax purposes; the relevance of a geographical perspective for global postponement and its inclusion alongside the conventional temporal perspective in a conceptual framework; the strict connection between logistics and trade channels design);
- the development of a set of tools supporting strategic decision-making, which can be easily handled by practitioners and also easily extended by academic scholars;

- the establishment of a structured theoretical foundation about the interface between logistics and fiscal domains, in order to foster and guide future research in the field.

With recent trade tensions running high new challenges open up for GDND, and managers have to manage complex, multifaceted and nuanced issues. This turbulent and uncertain landscape calls for further exploration, and this research project is meant to offer a first theoretical step to inform and motivate not only peer academics, but also those charged with leading and managing today's and tomorrow's global supply chains.

# A PERFORMANCE EVALUATION OF DIGITAL LEARNING IN HIGHER EDUCATION

**Mara Soncin - Supervisor: Tommaso Agasisti**

The dissertation consists of three papers that provide evidence about digital learning in higher education. Digital learning is stimulating the debate about the future of higher education, given the possibilities offered to increase accessibility, foster sustainability and personalise the learning path. An increasing number of HEIs are exploiting the use of digital technologies for education, particularly in the form of blended, online and massive open online courses (MOOCs). The declared underpinning motivations for their adoption vary from increasing visibility and recruitment to fostering the educational quality. The effects generated have been mainly analysed in terms of magnitude of the impact on student achievement, by highlighting mixed evidence. Blended learning has emerged as related to small positive effects on achievement compared to traditional education, while fully online delivery tends to have negative or null effects. Other impact measures, particularly costs, have been often neglected and, whenever assessed, rarely jointly considered with measures of effectiveness.

The dissertation addresses these different issues in digital education, by specifically investigating how it is possible to assess the performances of digital learning in HEIs and which is the magnitude of the generated effect. Given that performance

management directly includes strategic planning, while the link between the strategic orientation and results have been hardly explored in the literature, the dissertation firstly analyses the issue of the strategic formulation and deployment of digital learning in HEIs, as important for performance assessment. Then, I move to the measurement issue by contributing on the estimation of the effectiveness and the cost-effectiveness of digital education. In Paper 1, I analyse, by means of a multiple case study, three European technical HEIs offering MOOCs. The aim is to investigate how corporate entrepreneurship, defined as a strategic change in resource allocation following the entrepreneurial orientation, can be driven by digital learning, making specific reference to the stages of corporate entrepreneurship, namely the strategic formulation, the deployment and the monitoring and learning. Results highlight the heterogeneity in the organisational level at which the centre of power for digital learning is placed, with implications for strategic deployment. Strategic formulation and deployment emerge as “relational”, meaning that they enable links and trade-off between the organisational levels. These links involve financial resources, technical infrastructure, empowerment and procedures for implementation. The use

of performance measurement for monitoring and learning is characterised by more or less structured control systems depending on the case investigated, while overall no systematic performance measurement systems were observed.

In Paper 2, the MOOCs' issue has been explored to bring further evidence on the effect of digital tools on student achievement. In line with the organisational strategy, I analyse the effect of using MOOCs as foundation courses to cover pre-requisite skills of physics and mathematics for prospective engineers. By using a propensity score matching approach, I compare students as similar as possible in their personal characteristics and academic careers, but different in the MOOC completion, and I assess their ability to pass the on-campus related exam depending on this. Results highlight the potential usefulness of MOOCs to cover pre-requisite competencies, in line with the literature. The specific contribution is related to how MOOCs' completion should be fostered. Indeed, in mathematics, a subject longer experienced by students, a “bite-sized” approach works better than course completion, in the measure of a 9% greater probability to pass the related on-campus exam. In physics, a subject studied only since the high school, students need to complete the course to observe

an effect on their ability to succeed on-campus, in the measure of a 7-16% greater probability depending on model specification.

In Paper 3, I further explore the measures of effectiveness to be used in performance evaluation and I jointly consider measures of costs. In this case, I tackle the topic of professional education by analysing the relative cost-effectiveness of a blended MBA program in comparison to two other programs taught by same teachers and with a similar design, despite a different use of digital technologies. By following the literature on cost-effectiveness analysis, data about the cost of delivery are purposefully collected for each program, by providing an empirical framework to be replicated in different contexts. Moreover, measures of effectiveness have been traced back to the three dimensions of the Community of Inquiry framework, which considers the student experience as made of three components, namely the social presence, the teaching presence and the cognitive presence. Results highlight how net savings may emerge on the total costs, but the cost per student increases because of the limited number of students admitted to the blended format. Scalability has been limited to strategically focus on quality. In terms of effectiveness, student achievement is the dimension in which the blended format mostly outperforms the

counterparts, while it struggles on the teaching presence. When combining measures of costs and effectiveness, the increase in costs is larger than the gain in student achievement, so the blended format turns out to be the least cost-effective option. Findings challenge the assumption on the cost savings expected by digital learning, by highlighting the trade-off between scalability, costs and quality. Moreover, results stress the relevance of considering multiple measures of effectiveness as well as of analysing jointly costs and effects.

The dissertation contributes to the academic debate related to the performances of digital learning in higher education. Theoretically, I propose a framework to analyse in a holistic way how organisations are strategically changing to adopt digital learning, as well as how to assess their performances from a quantitative perspective. Empirically, I provide analytical evidence on the in-depth comparison of different cases and on the magnitude of the effect generated by different digital tools. Moreover, the contribution is practitioner-oriented for its managerial and policy implications. Research evidence may be used by university managers to adopt digital learning strategies, by stressing aspects related to the implementation process and to the design of initiatives that could foster effectiveness and cost savings. Finally, evidence could inform policy-makers

to design evidence-based procedures and guiding principles in digital learning.

Despite the aim to implement methodologically grounded research, I highlight some limitations that may open the way for future investigation. Firstly, I do not use clickstream data about the student-platform interaction because of data constraints, so the potential of learning analytics is still to be explored. Secondly, the time horizon adopted does not focus on the long-term impact of digital learning, while this may become an interesting cue for future research. Although limited in this respect, I hope that the contribution made along the dissertation can be helpful to foster the discussion about the transformation of higher education by means of digital learning.

# CHANGEABILITY IN COMPLEX ENGINEERING SYSTEMS: QUANTIFICATION OF SYSTEM SUITABILITY & CHANGEABILITY DEVELOPMENT FRAMEWORK

Brendan Patrick Sullivan - Supervisor: Prof. Monica Rossi, Prof. Sergio Terzi

Change is inevitable and can arise during any phase of a systems lifecycle with the potential to create insurmountable obstacles that increase cost and time for the design and development of systems. As the complexity of systems increase, it has become increasingly important for them to operate and deliver value throughout their extended life. Today's industry is challenged with managing large and evolving complex systems in a world characterized by dynamic changes in global economies, technology and politics. Competitive advantage and ability to correspond to technological innovations, dictates designing the "right" system the first time. However, decision challenges impacting system-level development and design are unavoidable, due to decisions undertaken with partial and/or incomplete systems knowledge, and changes in customer requirements.

## Research Overview

Consideration for change has become an important part of engineering efforts, with failure to anticipate and design appropriately causing perturbations that can affect the value and reliability of systems. The goal of this research is to support the development of extended value systems through the fulfillment of requirements, ensuring successful interfaces and performance of system objects on time and on cost. To meet this objective, changeability was employed to provide value irrespective of context or time to enable

changes to be imposed on a system with minimal negative effects, in the most efficient and effective manner. To consider the value implications that changes can have on the system it was critical to understand how changes were enacted, where they initiated from and the implications that they have on the systems before making/recommending a decision. When properly managed this approach to extended system value can reduce risk, enhance reliability, reduce design effort and reduce costs. These characteristics are directly related to the latent costs of implementation and can help determine if such an approach is appropriate for the system.

Based on the elements of changeability illustrated in Fig. 1, this research facilitated the development of a methodology to quantify the suitability

of complex engineering systems for the implementation of changeability to increase value and reduce costs. This allows for the identification of systems / components and designs, that are most well suited for changeability, and the respective level of changeability the maximizes value. This distinction when considering changeability and extended value is important for two reasons: (1) to allow for design alternatives with different levels of changeability to be compared, in order to identify which change options provide the most extended value, in order to decide how much changeability should be implemented into a system, and (2) for providing a means of quantification that allows for cost and value in relation to changeability to be communicated to decision makers.

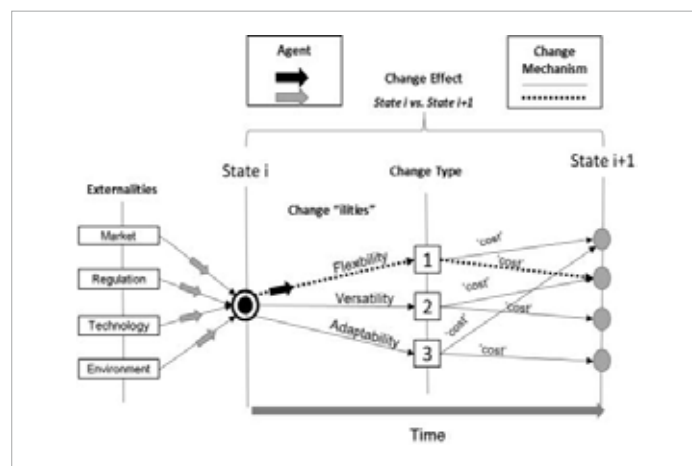


Fig. 1 - Elements of Changeability

## Methodology

To develop the principles and methods developed in this dissertation both normative and descriptive means of characterizing changeability were incorporated. Focusing on a descriptive approach to characterize the nature of the problem, using historical cases and empirical investigations to identify key components of changeability and design principles metrics were developed to support the quantification. The normative approach focused on extracting relevant attributes to isolate trends, that formed the basis for the theoretical model used to describe and evaluate changeability. These aspects include definitions of changeability, suggestions for when to design for changeability, changeability metrics, system characteristics, and principles for changeable system design. This research is grounded in both theory-based and practice-based methods. While prescriptive methods were employed to advance the state of the practice using normative principles, it was determined that for this to be relevant to industry a series of practical limitations and constraints were needed. The work contained in this dissertation informs the descriptive research through three distinct thrusts: 1) a basis for defining and quantifying system changeability; 2) case study research; and (3) mathematical modeling.

## Outcomes

This dissertation developed a method

for determining a systems suitability for implementing changeability and complementary development methodology that reduces the risk and uncertainty of changeability for systems during concept development. The research and cases evaluated, were used to determine if/how changeability and which systems were most well suited for implementing changeability to maximize value. Historically and according to the literature many customers and stakeholder identify and requestilities to resolve uncertainties that the system may encounter. Looking at the trend in this research field it is critical that system designers understand the effect of changes beyond conceptualization and begin looking at the real and direct effect that changeability has on development. The outcomes derived from this work allowed for the analysis of systems suited for implementing changeability in order to reduce cost, time and increase value throughout the systems life cycle. Through consideration of the findings, a series of cases were used for verification and testing to support the development three maritime vessels, where it was found that:

- Changeability at any level when incorporated into a system through lower level ilities represents a real cost.
- Systems most suited for changeability have inherent complexity, operate in changing

context and have long life cycles.

- Lower levels of changeability are more well suited when development limitations exist (process maturity, experience, data availability, resource availability, etc.).
- Changeability when not adequately planned increases risk and uncertainty (increases time and cost).

Through each of these points generalized from the findings in this work it was determined that while all systems can implement changeability, not all systems are ideally suited to benefit from it or capable of being optimized for change. In conclusion, this dissertation and associated research advances the existing academic and practical gaps in three main areas; (1) provides a consolidated explanation of the elements and principles of changeability according to design decisions that support implementation, (2) develops a quantification method to measure a systems suitability for changeability which allows for the system and development process to be evaluated in order for a more complete and well-planned design to be created, and (3) development of a methodology for developing changeable systems through a risk mitigating approach that intersects with the systems engineering development process.

# UNFOLDING INDUSTRIAL ECOSYSTEMS: CONCEPTUALISATION AND ANALYSIS FROM A STRATEGIC NICHE MANAGEMENT PERSPECTIVE

Ebru Susur - Supervisors: Prof. Davide Chiaroni, Prof. Antonio Hidalgo (UPM)

This thesis confronts the challenge of sustainability problems in traditional industrial production systems which work under linear production routines. It focuses on the industrial ecology approach as one prominent way of addressing those problems. Industrial ecology theory argues for the need of realising circular production routines to overcome the unsustainable linear practices. The overarching principle of industrial ecology thinking is based on achieving the symbiotic resource exchanges among the actors of industrial production systems which can evolve into industrial ecosystems with an analogy to mimic the natural ecosystems. To achieve this, the established routines are subject to some substantial changes, and such changes are related to both technical and social aspects of industrial ecosystems. That also enforces the need to recognise and consider the systemic innovation nature of industrial ecology and calls for a socio-technical approach when studying industrial ecosystems.

Industrial ecology literature provides comprehensive industrial ecosystem case studies distributed over different spaces. These cases mostly remain sustainable fringe experiences and cannot penetrate the mainstream industrial production system development. The existing knowledge in the industrial ecology literature does not explain how transitions into industrial ecosystems following industrial ecology

principles can take place; neither establishes the cognitive grounds for understanding unfolding fringe industrial ecosystems. Industrial ecology as a systemic innovation model to drive for transitions of industrial production systems has not found enough attention in the literature, neither the co-evolution of the social and technical aspects of industrial ecosystems. The industrial ecology literature requires to be expanded in both conceptual and empirical accounts, considering those underexplored aspects.

Thereby, this thesis aims to advance the understanding of industrial ecology-inspired transitions by conceptually framing and empirically analysing the unfolding industrial ecosystems. Thus, the overarching research question is: *How can unfolding industrial ecosystems be conceptualised and empirically analysed?*

The focus is on two most-studied scales of industrial ecosystems: local and regional. This differentiation also enables a scale rendered approach which provides the grounds for conceptual pluralisation and a deeper understanding of the dynamics of potentially unfolding industrial ecosystems through different scale applications of industrial ecology. Particularly for conceptualisation ambitions, the thesis initially indicates a missing link between the industrial ecology domain and sustainability transitions field from innovation

studies. It argues that middle-range theories of the sustainability transitions field which adopt a systemic view on socio-technical transitions can be insightful for conceptualising unfolding industrial ecosystems. The thesis chooses and engages with the strategic niche management framework from sustainability transitions research. In that sense, industrial ecology is approached as a systemic innovation model and industrial ecosystems as a socio-technical construct, more specifically, as prominent strategic niches for transitions of industrial production systems.

The thesis embodies three research studies with inquiries on unfolding industrial ecosystems. Refined conceptualisations of unfolding industrial ecosystems are proposed taking the niche, experiment, and experimentation concepts as central to the analytical design on niche emergence. The niche-building processes, which are the articulation of expectations and visions, social network-building, and learning processes, are among the core contours of overall conceptualisation. Then, each research study proposes a different conceptual framework for the operationalisation and empirical assessment of unfolding industrial ecosystems.

The thesis relies on methodological pluralisation constructed by employing

different methods in the research studies. The first research study follows a case survey through a systematic literature review for analysis of already studied local industrial ecosystem cases (n=104) in the industrial ecology literature through reinterpretation building on the proposed conceptual framework. The second research study employs a multiple case study methodology for analysis of three unfolding local industrial ecosystem cases in the Italian context. Finally, the third research study adopts a single embedded case study methodology for the analysis of an unfolding regional industrial ecosystem in Spain.

Conducted research studies show that the strategic niche management framework provides appropriate and fruitful insights and grounds for conceptualisation and analysis of unfolding industrial ecosystems. The findings suggest that three niche-building processes steer the industrial ecosystem experimentation journey. Moreover, the spatial context has a mediating influence on the interaction and functioning of those processes. Continuous experimentation with industrial ecology projects is vital to maintain the momentum going for unfolding industrial ecosystem niches. If a broad and deep industrial ecosystem niche network emerges, and if it designs and implements appropriate learning tools, then that niche can destabilise the regulatory, normative, and cognitive

rules of the existing industrial production systems. Finally, the established linear production routines may experience a shift into circular production routines, and industrial ecology-inspired transitions may occur..

## Keywords

*Industrial ecology; industrial ecosystems; sustainability transitions; strategic niche management; industrial production systems.*