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Master Thesis

From Research to Manufacturing

Entrepreneurial Implications for a Scientist in a Research-Based Young Venture Moving Towards Serial Production – A Case Study

GM1360: Master Degree Project in Knowledge-based Entrepreneurship

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Abstract

"This final goal for a researcher is to get an acknowledgement for his or her research in the academic community, whereas for a businessperson the primary driving force is profit and financial benefit"

(Siegel, Waldman, & Link, 2003)

Traditionally, university research and business have widely been considered separated in terms of actors involved in each field. Scientists and researchers on the one side, business people and manufacturing managers on the other. With the ongoing rise of academic entrepreneurship through which university knowledge is transferred into businesses, those boundaries have become blurry. Researchers do not only find value in understanding, but the commercialisation and creation of wider societal impact becomes a more and more attractive goal. Thus, some researchers become active entrepreneurs involved in commercialisation projects.

Arguably, having pursued a career in academia has strong influence on the individual and its behaviour. Throughout this case study, I find that the main challenges for the scientist/ entrepreneur in a specific venture context (strong dependence on researcher in technology and manufacturing, lack of market knowledge, limited time capacity of the scientist, simultaneous development of R&D and production/market). Consequently, it is shown how the scientist's past is related to the effectiveness of transforming research to production (more explorative mindset, strong scientific and weak industrial network, perception of the role of manufacturing for the future business). Finally, based on the research, I give guiding towards overcoming the challenges in the specific case and the scientific past of the scientist/ entrepreneur: creating structure, strengthening communication, understanding of customer demand, separation of leadership and management, focus on internal learning within the organisation to use existing human resources, and to integrate external knowledge through partnerships, new employees and so forth in order to fill knowledge gaps inside of the organisation.

As such, this in-depth case study of a Swedish venture founded on scientific knowledge contributes to the understanding of the role of the scientist/ entrepreneur in the context of transferring explorative R&D processes to exploitative manufacturing, a field to be investigated more broadly in future research over time.

Note of the author

The following thesis work contains the results of research performed at a young venture trying to commercialize scientific knowledge by introducing a new product based on a disruptive technological development.

The task of transforming a research-focused company to a research-driven manufacturer is a long path, and is strongly influenced by the people involved. This, obviously, includes the leading researcher, but also the management as well as the employees in the office.

The possibility to research this phase of organisational development and the case of Luxbright was offered to me during a 4-month internship, working with process mapping and early production planning in the company investigated. Having a background in engineering and some prior work experience at large a manufacturing company was vital in understanding both goals and challenges. The work was contractually divided into 60% work for the company, and 40% independent work on the research. As such, the research goals were clearly separated from the goals of the company, however, both sides did clearly influence each other.

Being involved in every day work allowed for better understanding of the challenges of the young company. Moreover, being able to work closely with the staff at Luxbright offered a way to build up understanding, confidence and mutual trust, which allowed for very personal and open discussions during the interviews performed for the study.

Moreover, the first three months of the internship were used to observe processes around the transfer from prototyping towards serial production – which is, at the current moment, not yet completed. The observations helped to put statements into context, to illustrate challenges and to find discrepancies between statements and the actual situation. Especially helpful was to understand the clear gap between management and employees, in terms of knowledge and communication, which to some degree was caused by the limited presence of the two founders in the office and the resulting lack of clear communication.

Being researcher and intern at the same time clearly has influence on the research outcomes, as explained further in the methodology section of this thesis. However, the insight gained throughout the internship was highly valuable.

I would like to thank Luxbright for the chance of experiencing the company's development directly and for supporting my research both with valuable information and resources. This research with its in-depth approach on the case company would not have been possible without the support of Luxbright.

Contents

Table of Figures

1. Introduction

1.1. Importance: Research-driven venture creation

The role of knowledge creation as a prerequisite for innovation, technological development and consequently new venture creation has been widely discussed and targeted by both academia and political institutions. It is generally acknowledged that new scientific knowledge is one key source for successful new product and/or service development, venture success and thus creation of externalities such as job creation, improvement of living conditions, solving of societal challenges and so forth (Etzkowitz, 2015). However, the role of universities as a driver of economic development remains underestimated (Shattock, 2005). Technological development does happen in the industry, through corporate R&D and industrial collaboration. However, more and more focus has been put on scientific research at universities as well as the transition between public research at universities and the wider economy, where the potential of scientific discoveries is put into effect in a variety of products, services or product-service-packages.

Thus, scholars, politicians and industry have long realized the importance of scientific research as a central factor of wealth creation, e.g. (European Commission, 2006). Globally, nations and regions thrive to become leaders in high-tech research fields promising to dominate economic development of the future, e.g. health and live science, materials and Nano science, IT and computing and others. University excellence may lead to excellent research, but one central question has remained crucial: how can knowledge created through public research be effectively translated into applications serving society directly through products and services, as well as indirectly through job creation and more general wealth creation?

One answer to this question is likely to be situated in the field of academic entrepreneurship, the application of scientific knowledge through venture creation by the university or the researcher, who thus becomes the entrepreneur. By taking out knowledge created through scientific research into a commercial venture, the researcher can exploit his scientific assets through marketing innovation in specific offerings to customers. Creating spin-off companies out of the university is a common way of exploiting scientific knowledge promoted by universities, politics and individual researchers alike, although for different reasons (Shane S. , 2004). However, leaving the academic world in order to exploit opportunities in the public

market does have severe implications, and researchers face many risks when taking such a step.

Having realized the potential of scientific knowledge created in universities as a key resource for successful innovating and venture creation, governments have invented a large variety of tools to promote and support academic entrepreneurship, ranging from funding university research, over consultancy and incubator services to direct funding of research-driven new ventures (Shane S. , 2004). As an example, the European Union has created multiple funds for promoting research-intensive SMEs (often originated from university spin-offs), among which are extensive funding programs like “Horizon2020”. Here again it becomes clear how certain actors focus on certain outcomes from knowledge creation and dissemination to commercialisation and exploitation of knowledge (Etzkowitz, 2015).

Such support is well-appreciated at most research-driven SMEs, as funding is usually one key constraint in the venture development process for firms working with high-technologies and related long-term and high risk product development processes. However, public funding initiatives have become more and more goal-oriented. Research is not seen as a goal per se in such environments. In order to achieve public funding, research-driven SMEs need to demonstrate both a commercialization strategy for the technology in question, as well as to demonstrate organizational and functional capabilities to successfully commercialize its technology (EUREKA, 2016). This does also include practical capabilities such as to manage production processes, quality control and cost efficiency in operations. These capabilities are central to any industrial venture, especially when concerned with some sort of physical production. However, university spin-offs are likely to be less experienced in those areas, having had the focus on research processes and small scale product development, rather than on large-scale production and customer interaction.

1.2. Focus: The scientist as entrepreneur

Entrepreneurship research is a field that is concerned with the processes involved when individuals act entrepreneurially, that is when they actively or passively look for opportunities, recognize them and take active decisions towards exploiting such opportunities (Shane & Venkataraman, 2000). Central to any entrepreneurial activity is per definition the entrepreneur himself, the person who is advertently taking risks when trying to exploit opportunities. Consequently, research in the field of entrepreneurship has focussed on the person of the entrepreneur. Who becomes an entrepreneur and why (Poschke, 2013)? Are there certain traits that distinguish the entrepreneur from the non-entrepreneur? Moreover, research has been made in order identify success factors of entrepreneurs, e.g. (McMullen & Sheperd, 2006). What differentiates an entrepreneur who grows his venture to sustainable success from the entrepreneur who fails in the process (Greiner, 1998) ? If such success factors can be defined, they can be applied in future ventures and increase the likelihood of entrepreneurial success.

However, entrepreneurs are complex individuals, and there are many possible explanations for success. According to (Burgers, Van Den Bosch, & Volberda, 2008), (Marvel & Lumpkin, 2007), prior knowledge of different kind has significant influence on the opportunity recognition process as well as the outcome of the entrepreneurial activity. For the researcher, his scientific knowledge and experience which can be translated into some sort of technological knowledge or application are often the main basis for the start of entrepreneurial endeavours. On the other hand, a scientific career has often made it almost impossible to gain operational and market knowledge to the same extent, as those types of knowledge are often only of marginal importance during a scientific career. Thus, when we investigate academic entrepreneurship with focus on the researcher as entrepreneur, we can identify some common assets, but we can also hypothesize that there are some general short comes, especially with regards to industrial knowledge, market knowledge, and operational knowledge (Visintin & Pittino, 2014), (Vohora, Wright, & Lockett, 2014).

1.3. Problem: Research and manufacturing, two worlds

A central problem when investigating in academic entrepreneurship is given by the term itself. While 'academic' refers to research usually conducted at universities or research institutes, entrepreneurship implies taking action on the open market for products and services. Those two worlds, however, are likely to function in very different ways. Moreover, together with the public interest represented by policy they form a complex "triple-helix" construct, three fields that are unquestionably entangled in the process of academic entrepreneurship, but which have very different expectations as well as working principles (Leydesdorff & Etzkowitz, 1996).

For a scientist involved in entrepreneurial activities, this is likely to have several consequences: firstly, his intellectual capital is likely to be focused on scientific areas, while he might lack experience and knowledge in both industry and policy (Visintin & Pittino, 2014) (Vohora, Wright, & Lockett, 2014). Secondly, it is likely that behavioural patterns that work in academia and are thus internalized by the scientist, are less effective or even counterproductive in the other fields of the triple-helix (Clarysse, Tartari, & Salter, 2011). Thirdly, it is likely that the adaption to industry or policy behaviour seems counterintuitive to the scientist/entrepreneur and thus difficult to be achieved quickly. And fourthly, as academic entrepreneurship needs balanced efforts in science, industry and policy, a short come in two of those field is likely to reduce the likelihood for entrepreneurial success (Perkmann & al, 2013).

1.4. Research gap and research questions

Until now, research about academic entrepreneurship has been focused on several areas:

1. The process of opportunity recognition in research environments, or why some researchers choose to pursue opportunities linked to their intellectual capital through separate ventures, while others follow their career path within the research community, in universities and similar (Lacetera, 2009) (Kolb & Wagner, 2015), (Lundqvist & Williams Middleton, 2013), (Perkmann & al, 2013), (Binkauskas, 2012).

2. The wider impact of academic entrepreneurship for the society and the implications for policy makers, e.g. when deciding on methods and tools to foster and support knowledge transfer from the university to the economy (Grimaldi & al, 2011) (Czarnitzki & al, 2016).

3. Possible ways of capitalizing from scientific invention, e.g. through patenting, licensing or venture creation and why some methods are more profitable for different cases and actors (e.g. universities, companies, societies) (Siegel & Wright, 2015) (Haeusslera & Colyvas, 2011).

However, there is only limited research on the researcher/entrepreneur as founder and business leader. This is especially true for operational tasks around the value chain and the general value creation process of a company, founded by a researcher. General business research has ever since tried to find the keys to operational excellence in the operational process. Optimizing the value creation process, optimal resource deployment, dynamic capabilities as well as market-oriented strategizing remain key to sustainable firm success. For academic spin-offs, however, such factors have not been sufficiently discussed with regards to the scientist/entrepreneur himself. The operational side of an academic venture can in theory be developed by people other than the scientist himself (e.g. through separate operations managers or through outsourcing of manufacturing), however the case presented shows that the scientist is central when translating scientific knowledge into a production process, while she/he might lack corresponding experience. Defining clear research questions, therefore, is key to focusing the research sufficiently (Mintzberg, 1979).

Thus, the research questions sought to be answered through this thesis, are concerned with the function of the researcher within an academic manufacturing venture:

RQ1: What are the main challenges for a scientist when translating scientific knowledge to a value creation process within manufacturing?

RQ2: How is the prior experience and knowledge of the scientist linked to his effectiveness of translating scientific knowledge into a manufacturing process?

RQ3: What general strategies can be found to support the scientist in the process of building up operations with the goals profitably selling goods or services?

2. Theoretical perspective, Research Strategy, Methodology and Limitations

2.1. Theoretical perspective and research strategy

The study performed hereafter is designed according to common business research processes. As such, the study has a clear positioning as of how to position itself towards existing theory, as proposed by (Eisenhardt K. , 1989). Moreover, the prevailing paradigms with regards to knowledge and social entities are defined and will be explained further. Finally, based on the nature of the research, and the research paradigms, the research strategy is chosen, and then applied using a clearly defined research methodology.

The research questions stated above require an open-minded approach, and existing literature does not answer the questions sufficiently. Thus, an inductive approach is chosen for the study, allowing for generation of new hypotheses based on the observations made during the study. At the same time, profound literature review allows to contrast the generated insights with existing knowledge, thus leading to a more iterative process of theory development.

From an epistemological standpoint, the study follows the concept of interpretivism. As the study is mainly concerned with a human being (the scientist/entrepreneur) within a social entity (the new venture), the interpretivist approach allows to target the understanding of human behaviour, rather than trying to understand external forces that influence it (Bryman & Bell, 2015). As such, the study stands in line with the classic *Verstehen approach*, introduced by Max Weber (Weber, 1947).

The study is concerned with the action of individuals (the scientist/entrepreneur) within an organisation, that is affected by social interaction between many different parties. As such, both the setting of the research and the targeted outcomes predefine the ontological standpoint of the study. The social entities observed are considered to be build up from the perceptions and actions of the social actors involved. Thus, following the framework provided by (Bryman & Bell, 2015), the study follows the view of constructivism, and tries to examine processes by which the social world is constructed (Walsh, 1972).

In order to gather data to empirically answer the research questions described above, the study uses qualitative methods. Basic business research, according to (Bryman & Bell, 2015)

often uses qualitative methods, when generation of theory is the primary goal, rather than deductive testing of existing hypotheses. Moreover, the interpretivist/constructivist approach fits best with such methods. Thus, qualitative methods seem to fit best with the research performed hereafter.

At this point, it must be stated that the research performed hereafter is, as any research, affected by personal values of the researcher and other practical issues. In order to perform sound research, such issues have to be stated clearly (Bryman & Bell, 2015). Most notably, the research was conducted while being employed at the case company (see: Note of the author). This allowed for more detailed and complete insights, long-term observation and improved communication, however it is clear that the research as such cannot be seen as absolutely independent. However, the topic of the research, as well as the final outcomes, are not linked to any goal set by the case company and are also independent from the internship role. Nonetheless, the dual role as intern/researcher does have effects on how the research topic is investigated, evaluated and framed.

2.2. Methodology

2.2.1 Research design

The research is performed as an in-depth, single case study case study of Luxbright AB, a young knowledge-intensive start-up trying to leverage scientific knowledge and creating a new way of producing X-ray tubes.

The choice of conducting a single case study is motivated by certain aspects, both with relation to the expected outcomes of the research, as well as practical implications. Primarily, following the inductive approach and the qualitative methodology, the case study is considered an effective vehicle through which several qualitative methods can be combined (Knights & McCabe, 1997). Therefore, such a design is widely used in business research (Eisenhardt & Graebner, 2007), and focuses on the complexity and specific nature of the explicit case (Stake, 1995). The case approach study allows to focus on specific dynamics within a given setting (Eisenhardt K. , 1989). The approach therefore is suitable to study the behaviour of the scientist/researcher in a new venture context in detail, considering not only the people themselves, but the interrelations, social as well as physical aspects of the case

(Eisenhardt K. , 1989). Following Yin`s categorization of case studies, this research can be considered a *revelatory case,* focussing on a phenomenon that was previously not investigated scientifically (Yin, 2003). According to (Bryman & Bell, 2015), the revelatory case study focuses on the inductive approach, while the situation does not necessarily need to be uncovered by existing research.

From practical point of view, the single, in-depth case study is suitable for this research, as it is conducted while working at Luxbright AB. Thus, in-detail observation can be done daily, understanding the causal relationships much better than when only visiting a case company a few times. Moreover, the ability to build up confidence between researcher and case company allows for better quality of data, as answers given can be better understood in the company context. Finally, choosing only one single case for the study is somewhat limiting to the generalizability of the results (Bryman & Bell, 2015). However, due to the severe time constraints of the research project and the intention to go into detail, a single case seems more practical.

The case study was carried out by a combination of qualitative methods. In the centre of the research is a series of semi-structured interviews with employees of Luxbright, mainly focusing on the operational side of the young company. Thus, personal beliefs and observations build the main pillar of the research conducted.

The interviewees include Qiuhong, the scientist/ entrepreneur of the company; Greg, the current CEO; Avinoam, the part-time supply chain manager. All the ones mentioned are part of the leadership team of the young company. Thus, it is possible to perform an in-detail analysis of the scientist/entrepreneur, and then compare his opinions and views on the company with those of the other members of the leadership team. Additionally, 3 employees were interviewed, in order to get a better understanding between the leadership vision of the company transformation, and the actual work performed by the employees. Such a “team approach” supports the findings by giving various perspectives on the research topic (Eisenhardt K. , 1989). Moreover, the employee perspective helped to understand the consequences of the entrepreneurial action performed by the scientist/entrepreneur in terms of transformation towards manufacturing-focus better. How does a certain behaviour affect

the work performed on employee level, and how is this linked to the effectivity of transformation within the company? The interviews are illustrated in Figure 1.

	Leading team			Employees		
Name	Qiuhong	Greg	Avinoam	Employee 1	Employee 2	Employee 3
Position	CTO	CEO	Supply chain and manufacturing manager	Project Administrator	Finance administrator	research and production staff
Employment	Co-founder	Co-founder	part-time (5-10h per week)	full-time	full-time	part time (50% thesis work)
Role	Idea provider, head of R&D, customer contact (scientific), supplier contact (China), production control	business development, startegy, finance, investor relations	Supply chain and manufacturing manager (part time), supplier relations, production control and development	project administrator for R&D project, purchasing	financial controlling for research and production, purchasing	research and development (execution), managing internal production processes and exteranl resources in Sweden
Educational background	Undergrad in physics, master in physics (metals), PhD, post doc researcher (material science, semiconductors, nano materials, superconductivity)	Undergrad in Computer science engineering, entreprenurship studies, MBA in finance and strategy		undergrad in interantional relations, Master in business	undergard in mechanical engineering, master in finance	High school eductaion in natural sciences, undergrad in chemistry, currently master in materials chemistry and nano technology
work experience (prior to current position)	engineer in R&D facility, researcher in multiple R&D projects (university driven), research and development in university spin-offs,	founder (software IT companies), innovation and startegy consulting, investment banker (telecom, healthcare), investment manager at university incubator	change management, automotive spplliers, plant turnaround manager,	software support consultant, assisstant general manager, procurement manager in retail, head of procurement	internships in manufacturing (quality control, purchasing), internship in VC company (IT tech) as data manager and analyst,	internship in research and development
Length of interview	1h 35min	45min	47min	52min	42min	35min

Figure 1: Overview of interviews performed for the case study

The interview structure (see: Interview guide, Annex 1) was mainly derived from an in-depth literature review, focussing on academic entrepreneurship, new venture growth, and operational excellence within manufacturing. This literature review was not only basis of the interviews; however, it was also one main tool to interpret the results gathered from the interviews as proposed by (Eisenhardt K. , 1989). Thus, the literature review was extended constantly to cover as many aspects revealed through the interviews as possible.

In addition to these more structured approaches, it was possible to observe the case company in directly daily, making it much easier to interpret answers given in the interviews. This participant observation or ethnographic approach is underlined by the fact the author of this study was partially employed during the time of the study (see: Note of the author), enabling the observation of actual work relations, processes and communication between the scientist/ entrepreneur and the team on a day to day basis with the author of this study being directly involved. As such, the study follows the classic examples of (Roy, 1958) or (Lupton, 1963) who performed their research while being employed in a specific position at a company. As the study only focuses on a small part of the company - the research and development area and its transition towards serial manufacturing - the observations made fall under the so-called "micro-ethnography" proposed by (Wolcott, 1995). For the research, this micro-ethnography has some implications: By being involved, a more closely defined cultural understanding can be developed (Wolcott, 1995), allowing to perform interviews in a better-defined context. Additionally, outcomes of interviews can be contrasted with actual observations, giving a better understanding of conflicts between answers and how some statements are or are not paralleled by real-life action. In a stronger sense, being involved in the company allowed interviewees to relate to certain situations in the workplace without having to give the full explanation. Thus, communication during interviews is enhanced and actual statements can be openly and explicitly discussed (Bryman & Bell, 2015). Being a peer employee also means that the interviewees show better understanding and support for the research, without fearing negative consequences, due to the trust build up during the employment period.

2.2.2. Execution of the case study

The case study was performed through a combination of qualitative interviews with central members of the company, as well as on-site observation over a timeframe of 3 months. In the following, the research concept is set in context with the case of Luxbright. Both interviews and observation take place in the present stage of the company development. Thus, they are likely to mainly reflect the current state of Luxbright, current challenges and current processes. However, in order to achieve a better view point, the time perspective of the company is of central importance, that means that starting from the presence, both past and future of the company have to be reflected, using the available information. The time perspective is visualized in Figure 2.

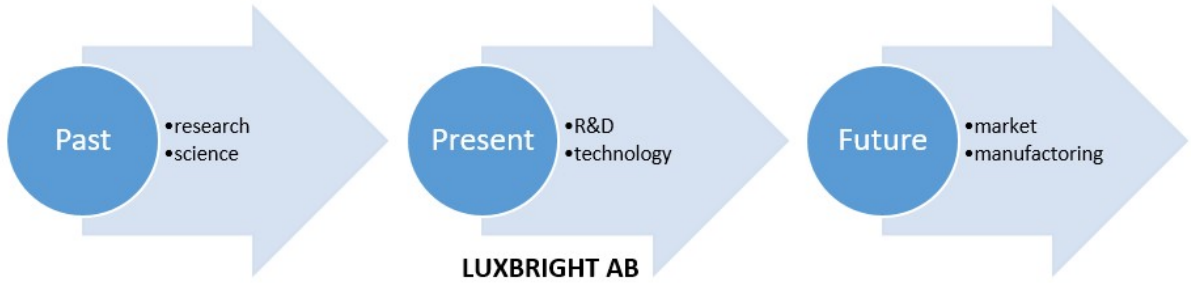


Figure 2: Luxbright AB timeline

As for most companies, Luxbright has been heavily influenced by its founders. When focussing on the path from being a research-driven start-up towards a manufacturing company, it can be said that Qiuhong has the idea provider, research and production responsible and know-how carrier, has and has had strong influence on the company. Arguably, this influence is likely to have effect on the company's future, especially considering the fact that Qiuhong is likely to keep playing a central role. In order to understand the case of Luxbright and the influence of the researcher/entrepreneur better, the case study starts from analysing the present situation of the company, in the transition from research towards manufacturing. This current state can be captured through the interviews with currently employed people, as well as by observing the way the company is working today towards development of manufacturing processes.

Moreover, the past of the company can be evaluated as well. Interviewees were asked to describe their past with Luxbright, and especially the interviews with the two founders gave insight in how the company came along, and why certain decisions were made in the past, having effect on the company as a whole and the R&D and manufacturing processes specifically. Due to this relation between historical decisions and current structure, it is also possible to use observation of current processes and events in the company trace back the reasons for why things are done as they are done today.

If we are looking at the other side of the continuum, we see the future of the company. This part is especially of interest, as the main purposes of the young start-up lies still ahead. Having impact with its products is a challenge that is yet to be achieved, and thus are many activities required in order to reach future goals. Especially the transition of the company from research and development, towards a manufacturing company delivering quality product to customers, as well as inherent growth of the organisation are of interest to this research. The future state, however, cannot be easily described based on the empirical data available. The inherent uncertainty of the future state does prohibit this. However, both through analysing the interviews and the observation of current events, it is possible to draw a picture of future challenges, goals, and ideal states. Interviews give indications about the ideas central people in the companies have, both in terms of goals or visions formulated, as well as in terms of challenges identified. On the other hand, observation of current activities can lead to interpretation of the future state by identifying what activities have already been started and with what priority as well as what issues have not been addressed yet.

Thus, the case study describes, starting from the current state of the company, the timeline from past over present to future. Main inputs are achieved through multiple analysis of the qualitative interviews, on-site observation as well as the contrasting of results from both data sets. Finally, the interpretation of the results with focus on the research questions and the existing literature of the field helps to create a complete picture of the challenges for Luxbright, and especially the scientist, with regards to transferring the focus from research to production. The overall concept of the case study is visualized in Figure 3.

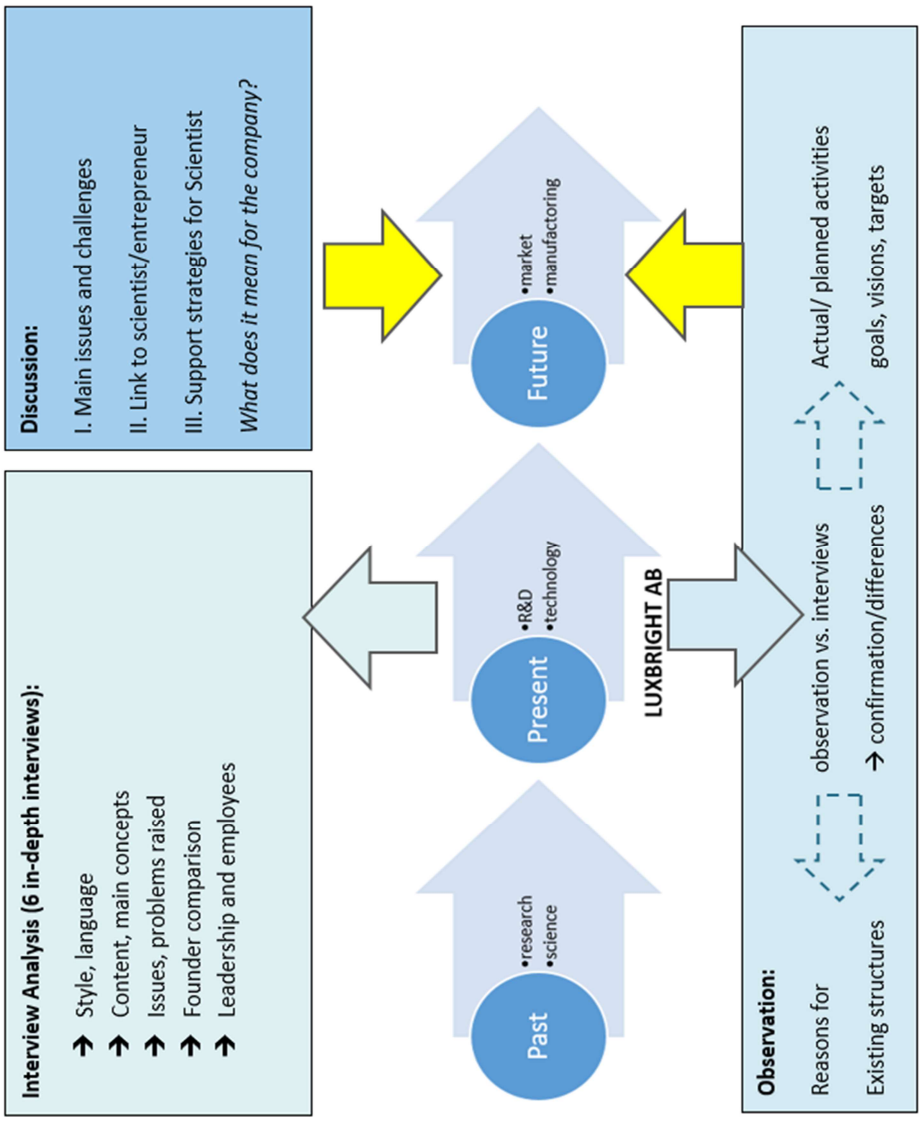


Figure 3: Conceptualisation: Execution of the case study

2.3. Limitations of research design choice

There is discussion in literature regarding the question if measurement validity, internal validity, external validity ecological validity, reliability and replicability are central to a case study. Writers who consider those factors as more significant for case studies often come from a more quantitative approach (e.g. (Yin, 2003), while writers who focus primarily on the qualitative nature of a case study tend to play down the role of those factors (e.g. (Stake, 1995)).

In the following, the approach described in (Bryman & Bell, 2015) is followed, concentrating on one central aspects of the case study as a research design: external validity and thus

generalizability. The limitations of a single case study in terms of external validity are obvious: the findings generated while investigating in Luxbright AB, and the role of the scientist/entrepreneur in terms of manufacturing activities is highly specific to the case. As such, the single case study cannot be seen as a basis of a more general truth, applicable in other similar environments. All the insights generated are simply unique to the case company. However, the outcomes generated in this research can serve as a starting point for future research. Hypotheses generated can be tested in many different situations to find generalizable results. Similar case studies might be performed in other companies, highlighting the similarities and differences to this case study. Alternatively, this case study can simply be an inspiration for future research about the role of the scientist/entrepreneur within a manufacturing start-up.

Another limitation is the small size of the case company and its young age. Therefore, only a limited number of employees could be interviewed. Additionally, the companies track record is not long enough as to show clear results of the aspects discussed further on. A possible way of overcoming this issue would be to extent the observation over a longer time frame, which is however not possible in the limits of this study itself and must therefore be left for future research.

3. Literature Review

3.1. Academic Entrepreneurship

In the introduction, the terms entrepreneurship was defined with (Shane & Venkataraman, 2000) as action taking based on the recognition of an opportunity. Moreover, the connection between academia and entrepreneurship was introduced. In this passage, a more detailed review if the relevant literature with regards to the case is executed.

Following the argumentation of (Binkauskas, 2012), the emergence and rising importance of the universities' role in entrepreneurship links to 3 main factors: for universities, public funding is more and more difficult to obtain and there is increasing competition for funding. The industry cannot be considered independent from academic research as it influences academic research increasingly, while universities become a part of the industry environment when cooperating in the knowledge creation process. Thirdly, the universities role in enabling application of knowledge through industry collaboration, spinoffs or licensing are heavily affecting local labour markets and thus becomes increasingly important for the wealth and development of regions (Leydesdorff & Etzkowitz, 1996) (Shattock, 2005). There are multiple ways of how the academic community can transfer innovative and more advanced products and services over to business. (Louis, Blumenthal, Gluck, & Stoto, 1989) present five of those: Consultancy, funded research, research companies, patents and licensing, and via spinoffs

The rise of academic entrepreneurship as a field of strong interest, and consequently the formation of a triple helix between industry, policy and university (Etzkowitz, 2015), does also link back to the incredible success of many university spinoffs. For example, (Shane & Stuart, 2002) report that from 1980 to 1986 about 18% of all university spinoffs from the Massachusetts Institute of Technology went public, a rate about 250 times higher than the average firm.

For the study performed in this thesis, academic entrepreneurship is defined according to (Shane S. , 2004), who puts the academic spinoff in the centre of the definition: The academic spinoff is a new venture created by students or researchers in order to exploit intellectual property created at the university.

Focus on academic entrepreneurship can differ throughout existing literature. Usually, some sort of commercialisation of university knowledge seen as the starting point for research. However, the literature has been focusing on many different aspects of academic entrepreneurship in the past. Some studies have been focussing on licensing activities and the relationships between the different actors involved, such as (Jensen & Thursby, 2001), (Mazzoleni, 2005). Others have focused on contractual agreements between universities and spin-offs (Macho-Stadler, Perez-Castrillo, & Veugelers, 2006). This study, however, is focused on the scientist as an active entrepreneur evaluating and acting upon opportunities in order to be able to exploit knowledge created earlier, similar to the approach taken by (Lacetera, 2009).

Consequently, the term academic entrepreneurship covers a wide range of possible commercialisation of scientific knowledge. Having the person of the scientist / entrepreneur in the centre of investigation, this study follows the concept of (Würmseher, 2017), wherein academic entrepreneurship can be categorized in terms of involvement of the researcher in the commercialisation project (see Figure 4). The continuum is framed by two extremes: (a) the researcher decides to go on his own, thus becomes the entrepreneur (*"the inventor entrepreneur model"*) and (b) the researcher decides to let go his technology to other people interested in its commercialisation (*"the surrogate entrepreneur model"*).

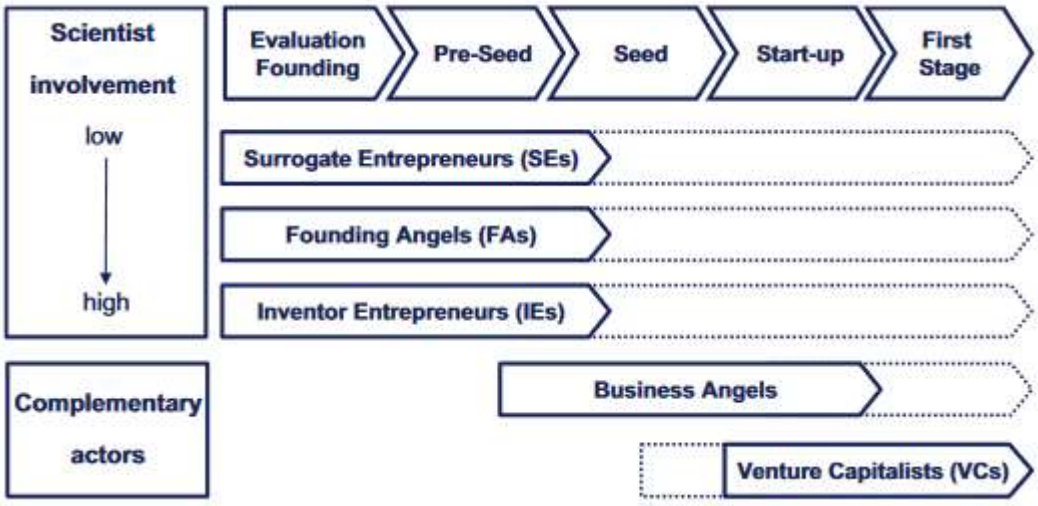


Figure 4: Overview of idiosyncratic starting points of different actors associated with university spin-offs. Figure adapted from (Festel, 2011)

Thus, the role of the scientist within the venture becomes more central in the literature. Consequently, (Clarysse, Tartari, & Salter, 2011) find that scientists' individual attributes and

experience are key predictors of entrepreneurial engagement. Other researchers, such as (Perkmann & al, 2013) identify the influence of individual factors as age, gender, seniority and prior experience as key determinants of entrepreneurial involvement of the scientist, while (Goethner & al, 2012) and (Prodan & Drnovsek, 2010) investigate individual-level economic and psychological attributes as central for entrepreneurial intentions of scientists.

(Würmseher, 2017) classifies scientists involved in commercialisation in three categories (see Figure 5): type 1 scientists seek to gear academic research towards market needs and commercialisation and would pursue an opportunity actively as (co-) founder. Type 2 scientists have a very strong focus on academic targets, while not actively pursuing commercialisation efforts. Type 3 scientists seek market orientation and feedback for research projects while being open to venturing skills with an appropriately skilled business partner.

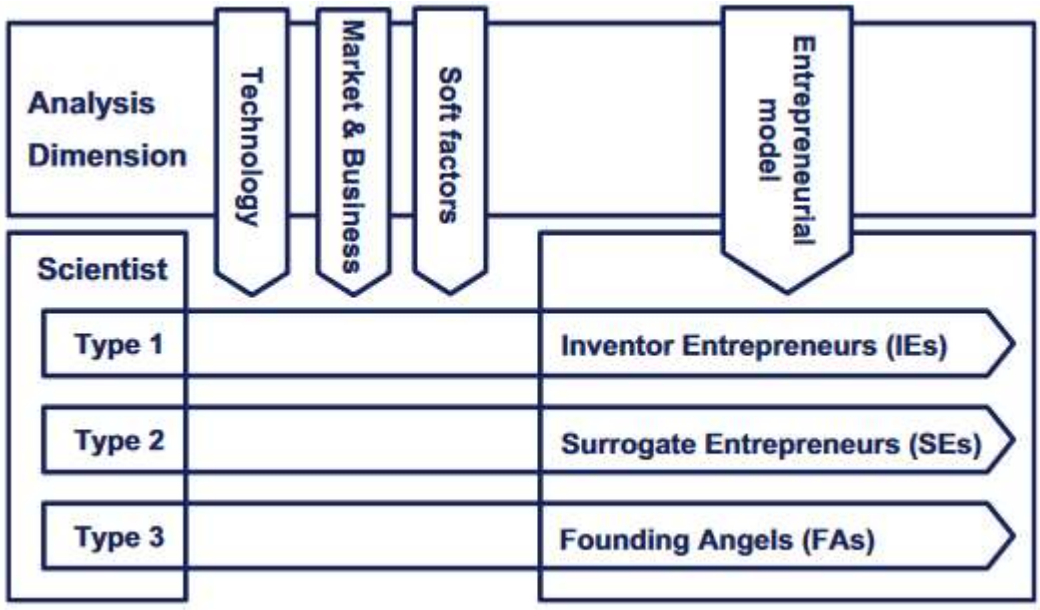


Figure 5: Types of scientists within academic entrepreneurship (Würmseher, 2017)

The case investigated hereafter is situated around the commercialisation of a scientist that is close to type 1, with regards to the classification made by (Würmseher, 2017). Qiuhong actively decided to pursue the commercialisation efforts for the technology he worked with throughout his scientific career. Some qualities of the scientist can be also associated with type 3, as Qiuhong is co-founding the venture together with Greg, a partner with vast business knowledge. As Qiuhong was pursuing commercialisation in other projects before, however, the classification of Qiuhong as “inventor entrepreneur” can be motivated.

3.2. Knowledge types in academic entrepreneurship

The entrepreneurial process, as states before, is highly influenced by the individual's ability to perceive and recognize opportunities. Moreover, knowledge, experience and skills of the entrepreneur do significantly increase the likelihood of new venture success (Bruderl & Preisendorfer, 1998), (Duchesneau & Gartner, 1990). Luxbright, as a somewhat typical start-up with direct links to academia, does mainly derive its competitive position from knowledge. This includes both explicit knowledge in the form of patents and patent applications, but also tacit knowledge of the scientist related to the details of the production process and interconnection of different parameters therein.

As such, the technological knowledge base of Luxbright is of relevance, as it allows to create a unique value proposition to customers, as well as it is protected against exploitation by the competition through patents. However, technological knowledge alone is not enough. Without a good sense of market mechanisms and operative excellence, the success of the venture is less likely. Researchers have shown, however, that possessing one type of knowledge may lead to a blind spot of the entrepreneur or venture on another type of knowledge. Such trade-offs have been demonstrated for interrelations between technological knowledge and market knowledge e.g. by (Hamel & Prahalad, 1991) (Leonard-Barton, 1995) (Christensen, 1997).

In the case of Luxbright, technological knowledge is obviously focused in the person of Qiuhong, while Greg adds business knowledge, analytical skills and entrepreneurial experience. However, neither of both bring significant market experience or experience in manufacturing. While knowledge in manufacturing has not been addressed by literature in detail, it has been shown that people with prior experience in a specific industry often know better how to meet demand conditions in that industry, as they have gathered industry specific knowledge that outsiders cannot gather (Johnson, 1986). While most founders tend to start businesses in fields where they were employed before (Aldrich, 1999), the success of ventures focusing on offerings close to those of the entrepreneurs' prior employer are more likely to survive (Cooper, Woo, & Dunkelberg, 1989).

3.3. Exploration and exploitation

The role of the entrepreneur is thus connected to his or her prior experience and the way new tasks are perceived. However, this perception is also linked to a more general understanding of purpose. As (Siegel, Waldman, & Link, 2003) illustrate, a scientist in academia has a different perspective on achievement compared to a business man. Scientific knowledge generation and acknowledgement within the academic community also trigger different strategies towards opportunities compared to profit and financial benefits on the market. This leads back to a central concern within studies of adaptive processes: the relation between exploitation of old certainties and the exploration of new possibilities ((Schumpeter, 1934), (Kuran, 1988)).

(March, 1991) illustrates these two concepts further: exploration can be captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery and innovation, exploitation is more focusing on refinement, choice, production, efficiency, selection, implementation and execution. (March, 1991) also draws an interesting conclusion by saying that both concepts do not lead to success on their own. Exploration alone is likely to *"suffer the cost of experimentation without gaining many of its benefits".* On the other side, if focusing primarily on exploitation, organisations are likely to *"find themselves trapped in suboptimal stable equilibria."*

Such research is especially of importance in the case of academic entrepreneurship. While a scientist does not necessarily thrive for financial benefit, as pointed out by (Siegel, Waldman, & Link, 2003) before, but is more focused on knowledge generation, such a person naturally is more concerned about explorative strategies. With it becomes more obvious that the core of academic entrepreneurship might be situated in exploration at the early phase. However, it must be mentioned that the later goal of any business must be exploitation of the underlying opportunity to at least some degree. Thus, the academic venture needs to undergo a certain transformation, for research and technology focus towards more market focus. This leads to the question of commercialisation of academic knowledge addressed by (Perkmann & al, 2013). The role of the researcher, as discussed in Perkman's paper, does change significantly when involved in commercialisation projects, but also is effected by the prior role. Thus, the scientist/entrepreneur is both different from pure scientists and pure business men in terms of goals but also strategies and behaviour (Perkmann & al, 2013).

3.4. Learning from customers through production

Understanding the market needs is essential when trying to commercialise a project. However, young ventures often do not possess large amounts of experience in the market, nor do they commonly have an extensive network. Thus, it is important for such companies to leverage their existing resources in such way as to maximize communication with the market. This communication should consist of two sides: the envisioning of future markets and the communication of that vision to the customer (Hamel & Prahalad, 1991) as well as the active communication of customer feedback (O'Connor, 1998). Figure 1 shows how market learning is focusing more on the "technology voice" for breakthrough products, and more on the "customer voice" for incremental innovations (Rangan & Bartus, 1995). It is important to understand that learning for all innovations should combine both sides of market learning, however to a different degree, as shown in the illustration.

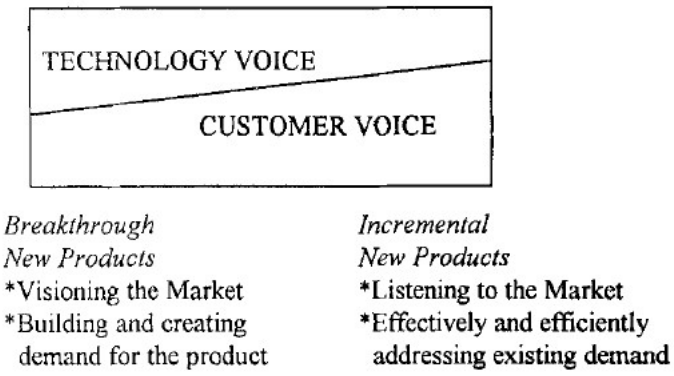


Figure 6: Two Models of Market Learning (from (Rangan & Bartus, 1995))

Especially companies with innovative new products often have a difficult time to communicate their innovation. The market has often not seen a similar product, and cannot refer to the firm's earlier products. Thus, getting into conversation with the market with prototypes might be beneficial, as it allows to really understand the expectations and wishes of the customers (Cooper, Gimeno-Gascon, & Woo, 1994)(Bandini & Sartori, 2010). At the same time, getting involved in an early manufacturing process can strengthen the tights towards suppliers and industry actors and thus create an important source for learning (Chorev & Anderson, 2015).

Again, the topic of market knowledge and customer involvement is critical to the scientist/ entrepreneur, as those areas are likely to be underdeveloped (Scholten, Hartmann, & Trott, 2015). Moreover, research agendas may significantly differ from commercialisation targets in the goals pursued and the methods applied, thus the mentality of the prior researcher is likely to influence the capability of getting in touch with the market (Goethner & al, Scientists' transition to academic entrepreneurship: economic and psychological determinants, 2012) (Perkmann & al, 2013).

3.5. Manufacturing in Academic entrepreneurship

Literature mainly focuses on technological and market knowledge as the main categories (Christensen, 1997) (Leonard-Barton, 1995). Thus, research could demonstrate how those the amount of those types of knowledge enable or limit entrepreneurial success. However, research has not yet sufficiently covered specific areas within market and technological knowledge, as well as the intersections between the two categories. In general management literature, operational excellence is one key to success. Keeping cost, time and quality of production optimal is key to competitiveness in the global markets of today. However, for entrepreneurial start-ups within manufacturing, the experience within operations has not been discussed much. This might be the case since many new ventures do outsource a significant part of the production process due to high investment costs when building up production and the lack of resources in general. However, in the case of Luxbright two facts become apparent: Firstly, some processes can be done in-house with low investment, and might be also critical to outsource due to IP involved. Secondly, even if outsourced, manufacturing processes need to be understood and managed from within the company.

Subsequently, (Scholten, Hartmann, & Trott, 2015) show that involvement in manufacturing processes and consultancy help academic start-ups to learn quickly and affect the growth patterns for such ventures. According to them, academic start-ups can use such activities to increase market knowledge. Competition, suppliers, customers were discovered more thoroughly and operational learning helped increasing the profitability of the ventures. While (Scholten, Hartmann, & Trott, 2015) focus on activities done outside the own venture to achieve learning, their outcomes lead directly to two ideas: firstly, entrepreneurs with experience in operations and market related activities grow their ventures more sustainably. Secondly, the learning of operations and market mechanisms provides enormous potential for academic start-ups.

For an academic entrepreneur, scientific and technological knowledge are usually well available. Often, this is the one central asset the venture is founded upon. However, research indicates, that scientists are likely to lack market knowledge, and thus are somewhat imbalanced when trying to commercialise their knowledge ((Visintin & Pittino, 2014), (Vohora, Wright, & Lockett, 2014)).

4. Case Study: Luxbright AB

4.1. The case company

Luxbright AB is a young R&D performing[1] venture developing a new type of X-Ray tube. Several new technologies are implemented into the X-Ray tube, making it suitable for all classical radiography applications such as medical (X-Ray examination of humans, animals), non-destructive testing in production and maintenance, as well as security (X-Ray scanners, e.g. at airports). The technology promises to improve radiography in current scenarios, e.g. through lower energy consumption, shorter examination time and reduced exposure of the examined subject to radiation. Moreover, due to specific properties of the new tubes, e.g. small size and pulsing capabilities, completely new applications of radiology can be achieved.

For this case study, Luxbright AB is especially interesting due to the nature of its knowledge-base and how it was and still is transferred into the venture: The main principles of the new technology used in Luxbright`s tubes links back to research performed by one of the founders, Dr. Qiuhong Hu from Chalmers University in Gothenburg. With more than 20 years of experience in research and development of physics and material science, Dr. Hu hold several patents with relation to field-emission and related areas. Those patents, together with the knowledge gathered over the long research career, are core to the product developed by Luxbright.

However, Luxbright is not a university spin-off in a classic sense. The technology that is the ground for the newly developed product has been commercialized before by the researcher and other partners, in different ways. Through various commercialization efforts, and by combining parallel research at the university, Qiuhong extended his university knowledge with some market and industry knowledge. So, in that sense Luxbright is a second-level spin-off, or a re-pivoted university spin-off.

Luxbright was founded through a university incubator programme at GU Ventures in Gothenburg. Greg Carson, then working at GU ventures, developed the business idea together

[1] The term *"R&D performing"* is used in accordance to the EUREKA EUROSTARS application process, a programme co-funded by the European Union. For a SME with fewer than 100 employees as Luxbright, this means that either 5 full-time employees, 10% of the employees or 10% of the overall revenue are dedicated to R&D (EUREKA, 2016). In case of Luxbright, more than 10% of the workforce is dedicated to R&D at this point.

with Qiuhong Hu, and together they started Luxbright. While Greg, with his extensive experience in entrepreneurship, strategy and management took the role as CEO, developing the business side, Qiuhong remained responsible for R&D, product development as well as initial production planning. As such, the start-up process is typical for academic entrepreneurship, e.g. as described by (Shane S. , 2004).

Currently, Luxbright is in the transition phase from R&D to production. Several prototypes of the new X-Ray tube have been build and tested, however, the actual production process has yet to begin. This is a crucial phase for the company, especially considering that neither Greg nor Qiuhong have extensive experience with manufacturing. More specifically, it is of interest for this study, how easy the researcher Qiuhong will be able to adapt the current research-focused procedures targeted on generating knowledge towards a more standardized production process focused on lead time, quality and cost effectiveness.

This need is not only driven by the requirement to produce at adequate quality and price, in order to be competitive on the market, but is also imposed by external requirements, such as product certifications (e.g. CE marking), process certifications (e.g. ISO9001) and requirements put forth by investors (e.g. guidelines and reporting requirements of EU funding).

4.2. Interview analysis and findings

4.2.1. The interviews

As described above, the main empirical sources for this case study consist of in-depth interviews and on-site observations. In the first part of the analysis, the focus will be put on the interviews. Analysing style and content will help to understand the role of the scientist/entrepreneur inside of the company and his historical influence on the R&D and manufacturing side of the company. Moreover, comparing language style and content of the different interviews will allow the evaluate the topic from different perspectives.

In order to get multiple views, interviews were done with different people inside the company: the main focus lies on Qiuhong, the researcher/scientist, idea provider and co-founder of the company. Secondly, Greg as the second co-founder gives a contrast in the way that he, as CEO and business development responsible, is more focused on the economic side of Luxbright.

Thirdly, Avinoam recently joined the company, signing responsible for supply chain development and manufacturing. Those three people have very different backgrounds and knowledge bases, however share the responsibility of the leadership of the company. As a contrast to the leadership view, additional 3 interviews were performed with employees of Luxbright, a research project administrator, a finance person and a junior researcher and manufacturing worker. Therefore, it is possible to contrast the interviewees in multiple ways:

a. ***The co-founders: scientific, technological vs. strategic, finance and investment oriented (Qiuhong and Greg)***
b. ***The leadership team: R&D vs. business development vs. supply chain and manufacturing (Qiuhong, Greg, Avinoam)***
c. ***Management level vs employee level***

The interviews were performed using a semi-structured approach (see interview guide in annex 1). Each interview had a duration between 35 minutes and one hour and 35 minutes, were the main focus was put on the scientist/entrepreneur. The interviews were transcribed and subsequently reviewed by the participants enhance the quality of the empirical data. Due to the small size of the company and the fact that some employees just started during the period of the case and/or were working unrelatedly to research and manufacturing, additional interviews were not added to the data analysed hereafter.

Figure 1: Overview of interviews performed for the case study shows an overview of the 6 interviewees, their positions and roles. Moreover, some basic facts are displayed in Figure 7 in order to provide some guiding for the further analysis performed hereafter.

	Leading team		
Name	Qiuhong	Greg	Avinoam
Position	CTO	CEO	Supply chain and manufacturing manager
Employment	**Co-founder**	**Co-founder**	part-time (5-10h per week)
interview style	narrative; widely chronological structure; many side aspects and unrelated stories; many details, figures, names, dates	Overall very structured; with end in mind; many causal relations; clear and short statements; overall vision in focus;	very structured; often listing arguments and points; aware of lacking experience in the company; clear to-do-list style
use of words	scientific, academic, facts, dates, details	finance/business related, investment, visionary, strategic	product oriented, manufacturing vocabulary,

	Employees		
Name	Employee 1	Employee 2	Employee 3
Position	Project Administrator	Finance administrator	research and production staff
Employment	full-time	full-time	part time (50% thesis work)
interview style	emotional; large scale comparisons to other business; enthusiastic about product and potential; aware of own knowledge gaps	organized and reasoned; aware of many issues; aware of own knowledge gaps; trying to make sense of overall picture	cautious about giving information; aware of knowledge gaps, cautious statements; soft formulations; focused on on learning

Figure 7: Interview style analysis of the 6 participants

4.2.2. Language analysis

Language is an important indicator of how people perceive a topic, and additionally gives indices on behavioural attributes linked to the individual person. The words used, the way the interviewee structures answers, and recurrent patterns can give insight not only to the surface of things said, but also to underlying believes and personal traits. Figure 8 shows how the leader of Luxbright use words more frequently in certain areas. Out of the 100 most frequently used words, Qiuhong clearly uses the most in the field of science/academia and technology, while Greg uses most words related to business and finance, and Avinoam uses many business related and manufacturing related terms.

	Scientific/ academic	Technical terms	Business/ Finance	Manufacturing / Value chain
Qiuhong	**17**	**12**	7	4
Greg	3	10	**12**	4
Avinoam	1	7	10	**6**

Figure 8: Out of the 100 most frequently used words in the interview, how many fall into a specific category?

For this research, the interviews were analysed and contrasted in different levels. The initial focus, obviously, his put on Qiuhong as the scientist/researcher, who has been in the central role of research, technology development and manufacturing up to the present day. Therefore, the language used by him has been analysed individually first. In a second step, Qiuhong's interview was contrasted with his more business oriented co-founder Greg, especially focused on Luxbright's development and the way manufacturing fits into the overall picture. Thirdly, the language of Avinoam, an experienced manager within supply chain and manufacturing is contrasted to the researcher, bringing additional insight into the perception of challenges with the transformation of the company. And finally, the employees' language is analysed, revealing some interesting gaps between the perception of the leadership team and the staff.

Qiuhong has a career that has been dominated by studies in physics and a sub-sequent research career. Although he has been involved in some university-driven development projects and university spin-offs in the fields of his research, in his answers there are many words that can be associated with the scientific field. In a way, this represents his past experience, but can also be seen as an indication of how he looks at topics and challenges around him today. By doing a word frequency analysis (with elimination of commonplace words), it can be shown that out of the top 100 words by Qiuhong, 17 can be associated with the field of science and academia (see Figure 8).

Another very striking aspect of his language is the abundance of detail used. Not only is almost every answer supported by related background information, Qiuhong also adds an incredible amount of facts and detail to the conversation. This might be exact dates, times, names of people, description of places, minor details like the old Western name for the Chinese city he studied in and so forth. It can be clearly seen, that details matter to him, and that details and

facts are part of the way he investigates into things. As a researcher, this addiction to details and to investigate into them has been a main driving force in his career.

The structure of his interview style is a great example for an explorative mind. His answers are usually presented in the form of chronological narratives with many loosely linked side stories. His mind often seems to find new interesting aspects about the stories told and follows such leads in order to explore and explain them. This is the case of him trying to explain the origins of his research projects by connecting them to historical discoveries within science, or telling related background stories about people that played an important role in his career. One key word here is 'coincidence'. This term is of large importance and will be investigated in more detail later, but it can be stated that there is some sort of coincidence in the way he structures his answers. Small details, names or places coincidentally said lead to a new aspect of the answer. When we say 'structure', we could here also say that it is the lack of clear structure, start and end point, that is evident in his answering. The lack of structure, the at times unsystematic way of answering can be seen as the basis for his explorativism, and is paralleled by some of his career decisions, which were not strictly planned, but triggered by coincident, and him being mentally and professionally flexible.

The narrative structure of his answers is even more supported by the recurrent use of direct speech in more than 30 instances during the interview. Thus, the answer gives a feeling of being in the moment, reliving the situation in detail. Rather than generalizing facts or events, Qiuhong is taking the interviewer with him in order to explore the events described in a lively manner.

The specific language used by Qiuhong during the interview is illustrated with some examples in Figure 9: Language used by Qiuhong during the interview.

language analysis	examples
words used frequently	science (21x), lab (14x), professor (14x), university (12x), Chalmers (11x), physics (11x), atom (10x), studying (9x), research (7x), scientist (7x), student (7x), electrons (6x), medicine (6x), Phd (6x)
usage of abundant details	Western name of Chinese hometown Names of researchers (Erwin Neuer, Dr. Solow, Pauls, Sir Peter Hirsh), naming ionic species (types of yttrium oxides), exact dates: of his initial interest in light (1993), conferences announcement in Grenoble (1994), meeting with Dr. Solow at Chalmers library (1996)... exact size of grants received for various projects
Chronological structure	Usage of years, times, seasons... in order to put events into relations Chronological links ("then", "after that", "before"...)
side stories	story of erwin Neuer Story of his "fundamental paper" Story of the atom bomb
usage of direct speech	overall all used in more than 30 instances during the interview Then he realized: "oh, I am actually looking at a single atom". I said:" Hej, Professor Solow, how are you?" and he said: "Oh, I was looking for you, I asked people where you were, but nobody new." So I went to him and said: "Oh it looks they really got something!". He said:" Oh well, if you want to have a look, go there

Figure 9: Language used by Qiuhong during the interview

Investigating into the languages used by the two co-founders, it can be stated that there is a clear difference in how they describe the history of Luxbright. While Qiuhong, as described above, pictures the birth of Luxbright and the milestones of the business based on coincident events, such as his scientific discoveries, the proximity to certain people from the university world, timing of meetings, timing of research grants, the discovery of their first customer, Greg describes the history of Luxbright more as a series of strategic decisions. For Greg, Luxbright started from the bankruptcy of Qiuhong's prior commercialisation project, and was consequently put forth by business and market analysis, search for investment, and analysis of customer needs.

Although both interviews share both aspects of coincidence as well as strategic approach, it is obvious that Greg focuses much more on exploiting strategies, while Qiuhong has a much more explorative way of thinking about Luxbright. This contrast can be illustrated by two examples:

For Greg, the first time mentioning coincidence or unplanned event, is when he talks about the explorative invention process for the microfocus technology developed by Qiuhong: *"The original plan was to make a ring and do an electromagnetic solution, but Qiuhong just came in one day and said he figured it out. We were working in the lab a little bit, but it was more on his mind than in the lab. Because the inventive step happens more in the shower apparently.*

We have a bunch of ideas like this. But then it took us a while to evolve the Eleena technology." (Greg, CEO and co-founder of Luxbright).

In contrast, when talking about the re-evaluation of the technology and the IP created in the previous company with Greg, Qiuhong mentions using a business analytic approach rather than a technology focused view the first time in all the interview. However, directly responding to it he starts an explorative process of prototyping and developing: *"At the time we have two guys doing market analysis and business analysis. We did some market study for x-ray and it turned out that this is a good idea. So, we started and made some prototypes and did some measurements."* (Qiuhong, scientist and co-founder of Luxbright)

These two examples of both Greg and Qiuhong talking about the opposite approach emphasizes the two sides of the company thus far: explorative and technology-driven in research under Qiuhong, exploitative and market-oriented in business development under Greg.

When Qiuhong's language is compared to Avinoam, some more interesting things can be found. Compared to the narrative way of talking seen with Qiuhong, with all the twists and side plots, Avinoam answers very controlled and structured. Often, he puts thoughts in order, for example when he says: *"I would say two things. First of all, the bad news is that you can't do one thing first, and the second thing second."* (Avinoam, Supply Chain and Production Manager), we have a good example for how he structures his speech. From the beginning, he defines two arguments that are presented one after the other. At the same time, he gives also insight in his way of working through the process: controlled, organized, defining tasks and working through it. This is an important aspect, because it shows the state of manufacturing at Luxbright, and where it is supposed to be heading. Currently, Qiuhong still oversees and performs virtually all technical tasks from R&D to manufacturing and testing. Decisions are made ad-hoc, based on his knowledge and network. Bringing on Avinoam to the team is an important step to start separating explorative R&D efforts and a more exploitative manufacturing process. Avinoam's way of structuring tasks seems suitable for bringing structure to the manufacturing processes, which as of now is slightly chaotic and underorganized with Qiuhong.

Finally, in the current stage of company development, it is interesting to see the differences between the leading team and the employees. Qiuhong and Greg have been working with Luxbright for 4 years. Many important decisions were made by those two together, but with each person clearly responsible for one side of the business. Over the past two years, and more pronounced in the last months, the company has grown in number of employees, from 2 to about 10 (of which some are working part time). With growing complexity of the business and the simultaneous development of both business and technology within the company, this is a common development. However, when the language used during the interviews is analysed and compared between the leadership team and the employees, interesting insights can be found. While the founders naturally have a clear picture about what is happening in the company, and what the next steps should look like, it can be found that there is uncertainty for the employees. All three of them use expressions like *"as far as I know", "probably", "I am not sure", "I don't know yet".* This can be a sign that communication inside the company about central challenges is not perfect, and apparently reduces the confidence of the employees to take own decisions. In some way, this must be expected as the employees only recently joined, and the leadership team still controls many of the central activities themselves. However, from a company development point of view, this is certainly an area where improvement should be achieved in the near future.

4.2.3. Content analysis

After having analysed the interviews from the language standpoint, it is now time to go over to analyse the actual content. What do the interviews actually say about the company's situation, upcoming challenges, their own roles and the transition from pure R&D towards manufacturing?

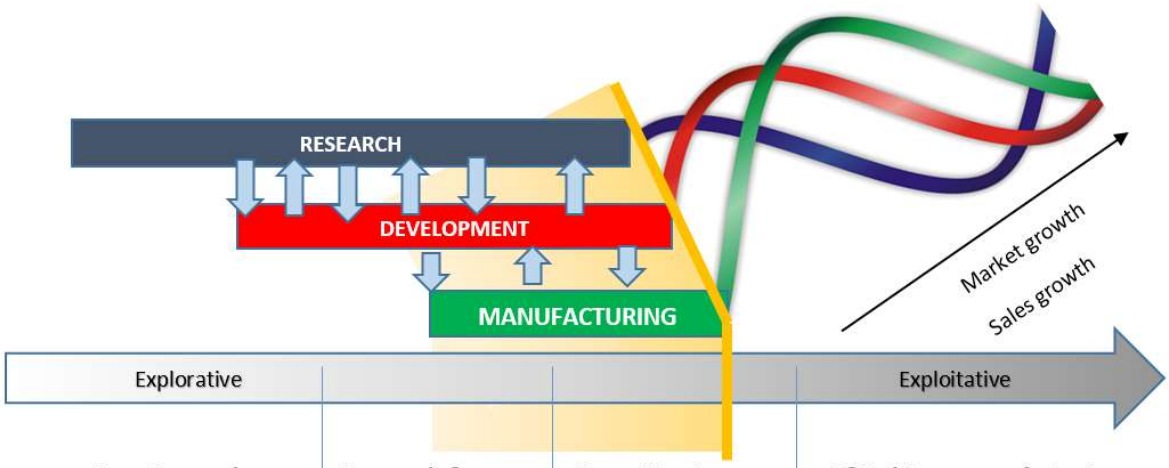
The "helix of venture growth"

A recurrent image used by Greg, but also mirrored in the other interviews is the interconnectivity between the different parts of the company. *"We are moving from a linear progression from idea to invention to market, and now you have to look at it more like a helix on that same market growth." (*Greg, CEO)

Luxbright originated from the research done by Qiuhong in the past. Over the last years, over a development cycle, this research knowledge has been transferred into a product idea and finally a prototype. Now, the company is planning to build up structures to support larger scale production of quality products. In first place, this seems like a rather linear process. Idea – Product – Market. But already at the second view it becomes obvious that there are strong interrelations between research, development and production and the people within, as mentioned by (March, 1991). The iterative nature of product development is described multiple times by Avinoam, for instance: *"I think that I can take some of the information that we have, go to our supply base, discuss it with them and both make demand with them and bring feedback from them. I think this is another flow of information that could feed the project."* (Avinoam, supply chain and manufacturing)

The tricky part is in the timing for Luxbright. While in the beginning it seemed natural to start working with the research side, to then start initial product development, now those two efforts have to be handled at the same time with building up manufacturing and quality systems, as well as to enter the market. This is, according to Greg, one main difference to a disruptive start-up as Luxbright and an established manufacturing company: *"So, the problem is when you have a disruptive element you have to move much quicker, and you have to move for market share as well as innovation."* (Greg, CEO)

Figure 10 below is an attempt to graphically show the process of moving from research, over development, to a becoming a research-driven manufacturing company. Interestingly, both the early part, as well as the late part seem quite well defined, while the transition phase in between does seem to be a big challenge for Luxbright at the moment. It means moving from single flexible, explorative processes towards interrelated exploitative operations. While the latter require some sort of structure and processes, the former can be better handled without too much structure. During the transition, however, moving towards manufacturing logic without established structures might be difficult, while introducing complex structures too early might slow down the explorative processes needed in the earlier phases.



Pure Research	Research & Development	Transition to manufacturing	R&D driven manufacturing
Research focus	exploration	Creating processes	Stable, established processes
Generating knowledge	Idea evaluation	Prototyping	Producing quality product
Feedback from science community	Market evaluation	Industry and first customer feedback	Market feedback into R&D

Figure 10: Linear processes to helix: From research to R&D driven manufacturer or the helix of venture growth (illustration by the author)

Existing structures and links to Qiuhong (dependence)

When starting off an academic venture, founders prior experience and networks are often highly valuable assets (Goethner, Obschonka, Silbereisen, & Cantner, 2012). In case of Luxbright, Qiuhong's technical knowledge and IP was the main asset. However, his network stemming from research and product development also had immense influence on how the manufacturing processes are set up today. This can be seen in various steps of the process:

External test equipment is still accessed through Chalmers university (e.g. SEM imaging devices), as one employee points out: *"We need resources. For example, there are a lot of different methods we can try, but we don't have them here. I think, like resources and, not instruments, but you know, methods and techniques, like Chalmers has. And then you can try out different things."* (Employee 3). Thus, the university links are still essential to many processes performed within the company. The company is therefore dependent on those links.

Another example is that manufacturing partners are found through prior connections of Qiuhong. The Chinese manufacturing partner, for example, was found through a prior contact of Qiuhong developed through earlier commercialization activities *"We were trying to make lamps, and we need sent one lamp to Taiwan and needed a power source. The guy who could help me was a KaiLong guy, because I knew him back from 2007. This was already 2013. I met him in Vienna for a radiology conference. So, I went there to bring him this lamp so he could take it to China, and then the Taiwanese guy can get it from there. So, I went there, and went to the radiology conference and talked about the cold cathode. "Oh yeah, that's interesting.". So, when I came back, Greg and I discussed how we should pursue this."* (Qiuhong, scientist and co-founder).

But also, initial customers are found through the academic network of Qiuhong. This became incredibly valuable at the early stage of the venture and helped to increase credibility among partners and investors: *"Because that paper, there was that one guy from Phillips, he wrote a similar paper in the same area with a professor in Glasgow. So, we had some email communication. "You have to come to Eindhoven, just give me a call…" And it turned out that this guy was a guest professor in New Zealand, Christchurch. That was the reason…[…] And check his webpage, he was doing X-Ray CT things. So, we I asked him and he told me what they did. And I said:" Well, actually we could probably do some cold cathode source…" So, then we*

started talking on a different level. So, when we needed a customer we called him. So, he wrote back and said: "If this thing is like that, we would like to have it". Totally random." (Qiuhong, scientist and co-founder)

However, not only actors in the current supply chain can be traced back to Qiuhong's scientific and research career, but also the way different processes are handled still resemble more the research process of scientists than the production processes found at manufacturing companies. This includes ad-hoc decision making, small order quantities and high flexibility of how to execute specific tasks.

Manufacturing as decisive capability vs. the manufacturing butler

How the role of the manufacturing process in the future company is influenced by the various people at Luxbright right now is hard to say. By adding experienced people to the team, the view on manufacturing and supply chain for the company might change drastically over the next years.

However, as of right now the technical side of the company is still largely reliant on Qiuhong and his experience. How his logic of manufacturing might differ from the one brought in by new people can be seen in some examples given throughout the interviews. For the researcher Qiuhong, the manufacturing process needs to be handled by people dedicated to the process, a "good butler" as he calls it. Then, in his opinion, manufacturing can create the output needed to fulfil demand. He does not go into the idea that much, that the manufacturing process might have to be restructured more thoroughly from the current development process: *"To me, there is not much difference. Because I have run a lab in Taiwan with 10 people from scratch to the final lamp and test and all that. So, all this small details in technology, everything I know, is not that kind of a challenge to me. It is more like when you scale up you need to keep the reliability and you need a person who is really dedicated to the process. In a way, you need a really good butler, so you know everything, where is the pepper, where is the salt. And you have people who can cook…"* (Qiuhong, scientist and co-founder)

On the other hand, Avinoam approaches the manufacturing in a different way. Although not seen as the primary challenge of the company at the moment (which is creating and capturing demand), he argues that manufacturing will decide on the success or failure of the company.

Having said this, he stresses the integral function of a dedicated manufacturing process in being the basis for discussion with customers, as well as an important source of learning through industry collaborations, a view also shared by (O'Connor, 1998): *"There are very strong suppliers who have huge amount of knowledge. And to answer your question specifically, we don't have the knowledge in house. So, the years and years of working with GE or with Phillips or with Toshiba, about what is good and what is bad about a tube, what a customer likes, and what they don't like, where are the pitfalls in the manufacturing? Who makes decisions? There is a mountain of information that our competitors have and we don't. And that's really what is going to determine the success of this company. Number two is: how good are we in acquiring this? And number one is: how valuable is the innovation that we are bringing?"* (Avinoam, supply chain and manufacturing)

Learn from customer vs. study the technology

How much the mentality of a person can define the approach in tackling a challenge, and how this decision can influence the outcome, is again illustrated by the contrasting of Qiuhong's narration to the picture drawn by other people of the company. Focusing on the leadership, both Greg ("helix") and Avinoam ("iterative process") stress the links between manufacturing and development and the dialogue to the market (especially customers and partners) (Hamel & Prahalad, 1991). Manufacturing needs to be able to address customer demands and wishes quickly in order to keep a dialogue alive. Avinoam bring this to the point when he says: *"Let's say, that you have walked into a very important X-Ray machine user and you told him: "I brought this innovation, and you can have more power and a smaller focus". And the guy would say:" Wow, this is really something interesting for me and I would like to do that!". That is great news. Now, the immediate next question would be:" Ok bring me the tube and I try it!". Right? Because otherwise, it was very interesting theoretical information. What do you do with this, if you want to keep the momentum? That is why these cycles are very iterative. You have to develop the product to know what is reasonable to propose to the client and then you have to have already some idea of how you can manufacture, so you don't come back two years later and the guy already went to play golf or something like that."* (Avinoam, supply chain and manufacturing)

Literature has discussed the way that market knowledge influences technological development. It has been discussed that the focus depends on whether the innovation is more incremental or disruptive, e.g. by (O'Connor, 1998) (Rangan & Bartus, 1995).

And following up on the same topic, Avinoam characterizes the lone researcher as a not ideal model for product development and manufacturing strategy. Studying facts and figures does not seem sufficient for such complex processes: *"So, you need to come to someone with some idea. But nobody is going to sit for 6 months and do mind experiments with you in order to really thin what's critical, and what not. And even if they did, a lot of the times they won't know. So, I think that you can go to the customer and make a step forward."* (Avinoam, supply chain and manufacturing)

A very interesting parallel is found here, when comparing Avinoam's statement to Qiuhong's history, moving on from being researcher to product developer. Following up on his initial product idea, Qiuhong did use the "research-way" of developing a technology, rather than following the market based approach proclaimed by Avinoam above: *"So, I was rocking my chair thinking the physics should be the same, there is not much difference in the physics, what can be different. And all of a sudden I realized when I can replace mercury, that is a big thing. I went to the library. That was 93, pre-internet, you had to pull old papers to know how lamps actually work, all types of lamps… […] The first thing I did was trying to understand how a lamp actually works, all types of lamps. But on physics level! I collected everything… There was nothing like this, so I started thinking, if I produced an ideal lamp, what would it be, what materials would you need."* (Qiuhong, scientist and co-founder)

Such statements highlight the "researcher" within Qiuhong's personality and how this might influence the approach towards solving challenges. As such, it underlines the existing literature, indicating that there is a significant difference in the business logic between scientists/ entrepreneurs and industrial managers (Siegel, Waldman, & Link, 2003) (Perkmann & al, 2013). It also seems evident, that such a behaviour is not supporting the learning of market knowledge, rather than focusing on technological aspects.

Imposing technical facts to customers vs. customer dialogue

Planning the transition to manufacturing also means to clearly understand what to produce for which customer. Therefore, the company needs to simultaneously understand customer needs and requirements, but also needs to find ways to communicate disruptive changes. Introducing a new technology with disruptive elements to the market is not easy, which has been realized by Luxbright early on: *"How does the market perceive the advantages or the innovation that we are bringing? I think that the popular media convinces us that in fact people are very eager to change. But in fact, that's quite the opposite. And the more you move away from the individual consumer to professional consumers, this becomes stronger and stronger. There is a huge barrier to make changes."* (Avinoam, supply chain and manufacturing)

Consequently, there is a need to convince potential customers of the benefit delivered through the new technology. Firstly, Qiuhong has an important point when he asks the question of who the company has to convince and how this must affect the way of discussing the technology: *"It all depends on what sort of people you try to convince. Look, if you tell a physicist:' I dropped something in Los Alamos, and all sand became glass.' He knows what that means, because if you want to melt sand to glass you need about 2000 degrees, and you have such a large area where the sand has converted to glass, you need a huge one. But if you tell the emperor of Japan: 'I have converted sand to glass!' – 'So what?!! so what?!!'."* (Qiuhong, scientist and co-founder)

However, during the interview Qiuhong, nonetheless, uses technical argumentation in order to put forth his innovation. In a way that resembles a scientist doing research and publishing results, he is making use of facts that he addresses towards potential customers: *"If you want to convince experts, you use knowledge, if you want to convince a normal man, you have to use real hard facts, you have to show the consequences. It is very interesting. You can tell people, some understand by listening, but some have to see."* (Qiuhong, scientist and co-founder)

Bringing in more manufacturing experience, Avinoam contrasts this view by highlighting the benefits of conversation with customers. Not only does this conversation help to develop a better product, but it also increases market knowledge gained directly from the market addressed: *"So, you need to come and tell them what you are offering. But, while you are doing this… you need to be selling, you need to promote the idea, but at the same time you need to*

be open to feedback that they are giving you back. Because, if you are only selling, you are not listening and you don't understand. If you are only listening, then people often don't know what to say. We need to project to the clients that we know the solution, that we know what the solution is, but at the same time to be very open to their feedback to see if what we are offering is the right thing to do. So, this is a hugely important iterative loop that we have to run." (Avinoam, supply chain and manufacturing)

The problem of communicating new products with customers based on disruptiveness was already illustrated in chapter 3.4 by and Figure 6. Thus, balancing the creation of demand and listening to the market is key to success (Rangan & Bartus, 1995). Nevertheless, this keeps on being challenging for Luxbright.

Internal communication and support structure

It is unquestionable that Qiuhong's capabilities, his knowledge and experience are essential to Luxbright, now and in future. This was highlighted by existing literature such as (Bruderl & Preisendorfer, 1998) (Duchesneau & Gartner, 1990) already. During the discussion of the interviews, several areas of potential opportunities to leverage his work could be identified. Throughout all interviews, however, two aspects have been highlighted frequently: structure and communication. In order to both leverage the researcher's impact and the impact created by every single employee, communication and structure a required to improve. This starts from relieving Qiuhong from many tasks, so he can focus his resources better, where they are actually needed: *"And by management, you need to keep things happen in the same way and synchronize them in a smooth way. For management, first of all, we cannot have you or I or Greg doing everything. That is not possible, we need someone you can run this and that."* *(*Qiuhong, scientist and co-founder)

That such communication and structure is directly linked to manufacturing and market contact, is obvious. However, a recurrent image of the company shown during the interviews was that of a company lacking exactly those connections. In consequence, both internal and external tasks were not fulfilled in a satisfying manner. Every improvement here, can directly increase the effectivity of production as well as market acceptance. *"As far as I can say, this has been done in an unsystematic way. They sit in the meeting "okay you want one tube with*

these specifications, then Greg to Qiuhong when do you think we can build this? And then Qiuhong: maybe we can have it next month, I need to get to china and the them manufactured". So, there is no clear process that the sales team has a meeting with a customer, there is even an order with requirements start planning the manufacturing." (Employee 2)

As often, such main challenges are not to be handled by one person alone. It is not Qiuhong who has to change somethings in his work. It is Luxbright as a whole that has to evolve with direction and vision in mind (see (Hamel & Prahalad, 1991). Therefore, it is important and positive, that the company's leadership does not only have a vision of how the product changes the market, but simultaneously realizes organisational challenges. This is the most important step in developing actions guiding the team to the future: *"But definitely it is a challenge. You always have the head scientist is going to evolve over time, but mainly that is our job as a team: to give him the structure he needs. I think he adds a lot of value to us both in access to the Chinese market and in his patents and his ideas are incredibly valuable. So, the more he can build the ramp-up and build that energy the better. And the more people he has to leverage his work, the better. Systematize."* (Greg, CEO and co-founder)

4.3. Current situation: observation and opinion

During the time frame of 3 month, the case company was observed 5 days a week (see: Note of the author). Thus, internal processes with regards to transformation of the research based company towards manufacturing and the role of Qiuhong as scientist/entrepreneur in that transition could be observed. It is possible to extract some main topics that show the importance of Qiuhong in this process, but also shows how his strong role offers both opportunities and risks to Luxbright.

a. Dependence on Qiuhong' knowledge and experience with both the technology and the manufacturing

Qiuhong's knowledge is of extreme value of the company. His ability to understand the underlying principles of the technology and to find solutions to technical challenges are essential to Luxbright. Greg puts this to a point, when he says: *"I think he adds a lot of value to us both in access to the Chinese market and in his patents and his ideas are incredibly valuable."*

People at Luxbright are aware of his role, as can be seen in every day work. Qiuhong's opinion on technical questions are almost always accepted, employees have huge respect of him, to a point where Qiuhong's work is not being checked critically. Two facts play a large role here: on the one hand side, employees are by far not experienced as he is and have not been in the company for long. Secondly, most employees simply lack knowledge in the field of the technology or the manufacturing and thus cannot evaluate certain arguments brought up by him.

The company can react in two ways: One is to add people with specific knowledge and experience to the team, that can help but also challenge Qiuhong in many disciplines. Avinoam being hired for production and supply chain is one example, an expert currently being hired for the field of quality control and certification another. *"So, if we have someone who is experienced and it would be a very smooth transfer of the knowledge and everything from the management to that person I think it would be more beneficial for the company. So, someone who can extract the information from the management and take charge over that section."* (Employee 2)

*"Right now, we don't really know what the others are doing, so I think we should organize it in such way that he doesn't have all the responsibility for himself, because if he doesn't work, then the production will just stop. If he is sick or anything…" (*Employee 3)

The second way of reducing the dependence on Qiuhong is internal learning. With many young and motivated people working at Luxbright, there is opportunity to take responsibility from Qiuhong's shoulders. Examples for this can be found especially in the employee interviews: *"Yes. Because right now I am also in that face that I am trying to understand what we want, and what's the goal. But after I know more, I could also come up with ideas: "Aha, maybe we want to do this, and I can go there…"."* (Employee 3).

b. Reliance on Qiuhong's presence / contact

Strongly linked to the point above, due to the dependence on Qiuhong in many production related processes, the employees are highly reliant on getting in contact with Qiuhong. During the time of observation, in total 13 weeks, Qiuhong was only present in the office for about 2.5 weeks. Lengthy travels to the manufacturing sides in China to overview production, customer, supplier and investor meetings, as well as other obligations prevented him from being present. As, at the same time, communication over phone, messaging system and email were difficult, employees could often not continue with work to be done. This becomes obvious as a general problem, when looking at some of the employee responses: *"It is mainly the other way around that does not work that effectively. Like we don't get information… I don't. It is very hard to contact him sometimes, he is very busy. I think we respond quite quickly if he needs something."* (Employee 3)

On the other side, it is clear that the issue of contact is less pronounced for the leadership. The collaboration between Greg and Qiuhong seems to have been established over the years, and additionally, most meetings are done together. For Avinoam, this is most crucial in the current stage of the company, while future organisational growth will probably require more responsibility of staff: *"But maybe that is not that critical, because if Qiuhong is really 90% of our R&D and Greg is 90% of our commercial activities, then the fact that they are travelling together and meeting those people together could be enough."* (Avinoam, supply chain and manufacturing)

c. *Suppliers, partners and customers are found in personal network*

The company's manufacturing process is reliant on external partners. Especially the final assembly of the tubes requires external know-how and resources. As indicated during the interview, many links to partners stem from Qiuhong's career in science and product development. Thus, his vast network was ad still is a huge asset for Luxbright. Partners are found quickly and due to links to Qiuhong's past, the relationships are often very personal and stable. However, Qiuhong's experience and network do not only play an important role in the manufacturing process and supply chain, but extent to customer contacts. When a first customer for the product was needed, Qiuhong could leverage his contacts in the scientific world.

On the negative side, however, it has to be stated that the dependence on Qiuhong's network contains risks. During the time of the observation, different options for supply were not carefully evaluated and compared in order to find the best possible fit: While such evaluation processes seem much more implemented on the business development side under the more analytic Greg, manufacturing decisions were lacking sound reasoning. The issue of being reliant on Qiuhong's network also trace back to the need of market knowledge. While Qiuhong's network is mostly related to university research and R&D companies, there seems to be less experience in the industry, as pointed out by Avinoam: *"I don't really know very much, but to my understanding Qiuhong brings more knowledge of the research, maybe a little bit of knowledge of the manufacturing side, and not so much of the market. […] There are very strong suppliers who have huge amount of knowledge. And to answer your question specifically, we don't have the knowledge in house. So, the years and years of working with GE or with Phillips or with Toshiba, about what is good and what is bad about a tube, what a customer likes, and what they don't like, where are the pitfalls in the manufacturing? Who makes decisions? There is a mountain of information that our competitors have and we don't."* (Avinoam, supply chain and manufacturing)

d. *Manufacturing decisions are made ad-hoc, verbally and unsystematic*

Stable and reliable manufacturing does require some standardization, clear and complete information. In the transition from being a research company to control manufacturing of a product, Luxbright has not yet separated R&D from production processes. Thus, the more

explorative lab processes still determine the way of working at Luxbright. Together with the huge amount of responsibility and control held by Qiuhong, manufacturing is currently run quite different from what would be anticipated.

On the one side, this allows very flexible processes, manufacturing can react quickly on customer demands or R&D requirements. Additionally, there is no long decision process, as decisions are made by Qiuhong alone.

With this said, it becomes obvious every day that there are issues with such style of manufacturing. Qiuhong's instructions are not given in an organized manner, instructions often lack essential information, and requests are often made last minute. *"No, it is not like that at all. Maybe, when he is here he would just say: "Let's go buy some tungsten". Then after two weeks he might ask me to start electropolishing. That's it. Then I have to ask for the quantity, if he wants SEM pictures of that, when I should send it to him."* (Employee 3)

"As of right now, we only produce in small quantity, mainly prototyping. Those were done verbally, there was no procedure up to know about how are we going to produce one tube. Qiuhong is aware of all the steps and would ad hoc assign tasks to people." (Employee 2)

Last minute and unorganized decisions have also led to largely increased costs for Luxbright. Ordering material on-demand in small quantities is more expansive than ordering based on optimal ordering quantity approaches. External machining resources have been used over weekends in order to finish products according to schedule, however such working hours have led to increased prices.

e. Lack of control on manufacturing processes and quality

At the moment, tubes are produced using an R&D or prototype process. Thus, it is not required to follow rigid structures and processes. Qiuhong's feedback and technical changes can directly flow into the production process. Moreover, he can supervise each step personally, and decide how to move on with the production process.

As the process is only controlled by Qiuhong, but the actual manufacturing steps are carried out by various people internally and externally. The quality of the manufacturing process cannot be controlled by those carrying out much of the work. Moreover, the fact that clear

guidelines for manufacturing, quality control, and testing are missing has led to confusion and quality issues several times during the observation period. This problem is illustrated by some of the comments made by the employees: *"I would say that that step needs to come into the manufacturing process at one of the last steps before delivering the product. Right now, it seems to be very random: "yes we produced this tube. Qiuhong does this look good to you? Yes, it looks good" Maybe he does one or two tests himself. But again, this has to be documented and planned in a way that ok, this is our quality control procedure."* (Employee 2)

f. Information is not shared, feedback not given

One central observation during the 3 months was again focused around communication. While discussed before that communication within the manufacturing process is difficult due to the large gap in experience and knowledge between the scientist Qiuhong and the rest of the team, as well as due to the limited time Qiuhong actually spends with the manufacturing team inside of the company, it is also a problem that knowledge and experience is not shared. With Qiuhong being responsible for the manufacturing, as well as the technical customer contact, much of the knowledge gained both from manufacturing and customer contact remains with him. In the past, this was alright, as he was the only person responsible for the technical development and the production. With the company growing and Qiuhong's tasks getting more and more complex, sharing of information and collaboration with employees will become crucial to how fast the company can move. As of now, people inside of the company feel restraint due to the lack of information: *"Like for example, I am growing zinc oxide, and I only know the structure looks like. I am doing some research between growth factors and structure. But if we look at the performance, I am not sure yet. So, I need some feedback from him when he integrates it and gets some value. What is good and what is not good? And then I can proceed from that."* (Employee 3)

"But like I said, my knowledge on this, to make sure that this is completely on the record, my knowledge of what is happening behind certain doors is absolutely limited. I am not in the place to say. […] Yes. I have been here since September, and I don't know how many tubes we have produced for instance. I don't know, because that knowledge is not shared." (Employee 1).

This is crucial, because the iterative development process in conversation with both customers and manufacturing partners has been identified as one of the main challenges to the company: *"You have to develop the product to know what is reasonable to propose to the client and then you have to have already some idea of how you can manufacture, so you don't come back two years later and the guy already went to play golf or something like that. These circles are iterative. I don't want to give the message that you should drop everything else not do anything and talk to the clients. Because what do you tell the clients? If you just go to the clients and ask them what they want, that is not and interesting conversation."* (Avinoam, supply chain and manufacturing)

5. Discussion

By setting the analysis performed in the previous chapter in relation to the research questions formulated under Chapter 1.4., the relevance of this study to Luxbright is shown. Moreover, these specific, and company-related outcomes can be seen as a proposal for future research to investigate into the field of young, research driven ventures, which are about to turn towards manufacturing for market. Quite often, the individuals involved might have background in science, research or technology, which they want to leverage into the company's changing situation.

RQ1: What are the main challenges for a scientist when translating scientific knowledge to a value creation process within manufacturing?

It has been discussed by literature (Goethner, Obschonka, Silbereisen, & Cantner, 2012) (Christensen, 1997), (Marvel & Lumpkin, 2007) that young growing companies do often possess one of their most valuable assets in the people involved, their knowledge, experience capabilities and ideas. This is clearly the case for Luxbright, a company with a technology mainly stemming from one man's career as scientist, researcher and developer. However, this comes at a cost for Luxbright at this point in time. The company's technological development, as well as most of the R&D and manufacturing resources, both internal and external, are largely dependent on Qiuhong and his contacts. But that also means that many of the company's processes do not work if not through Qiuhong. When building up a more reliant manufacturing process, a big challenge for Qiuhong and the company is to reduce the dependence on him, which in turn is a personal challenge for the scientist/ entrepreneur as indicated by literature (Goethner & al, Scientists' transition to academic entrepreneurship: economic and psychological determinants, 2012) (Siegel, Waldman, & Link, 2003) and the case study presented.

Related to the first point above is clearly the reliance on supply base, partners and customers, that has been build up through Qiuhong's effort in developing the product quickly and showing the possibilities of the technology, as indicated by literature (Bruderl & Preisendorfer, 1998), (Perkmann & al, 2013). As much as these network benefits have helped the company, and most likely will remain beneficial in the future, the challenge for the researcher is to gradually reduce the dependence on certain, research-based partners and connection, and on

the other hand build up a stronger relationship with the industry, both in terms of supply chain and non-scientific customer base. Thus, likelihood of success of commercialisation can be increased as discussed by (Burgers, Van Den Bosch, & Volberda, 2008), (Leonard-Barton, 1995) (Christensen, 1997) (Chorev & Anderson, 2015). Literature, however, falls short in explaining why the scientist/ entrepreneur is struggling in this process and how he can overcome those problems based on personal habits and beliefs.

Consequently, in order to overcome the challenges above and move the company further in the transition towards manufacturing for demand, the researcher clearly will have to work on various new things. As learned from both the interviews and the observation, time and capacity are already scarce resources for Qiuhong. It is therefore extremely important for him to prioritize tasks, share responsibility and create time in order to bring the development of the manufacturing process forth. As such, literature seems to separate the scientist/ entrepreneur's role as a business leader from his actual operational function within the company, and how those two roles are linked to the progress and success of the venture.

As we have seen from various parts in the interview with Qiuhong, his mentality towards technology, research and manufacturing is quite influenced by his research career, as to be expected (Goethner & al, 2012). Getting over the point of seeing manufacturing as a widely unrelated task, a mere execution of pre-defined processes, he has to develop his understanding in the interconnectedness from manufacturing towards market and customers, back to the development cycles of the technology. This change in mentality cannot be expected from the person alone, but has to be pushed and reinforced by all levels of the organisation, as described by (Hamel & Prahalad, 1991).

Unfortunately, and this has been underlined by Avinoam specifically, it is not possible to focus on one area of the company alone. If the main challenge is customer demand, and then being able to manufacture as described by Avinoam, or if the problem is more in the field of acquiring capital, following Greg's argumentation, is hard to tell. What all this leads to is that building up manufacturing cannot be seen as an isolated task, and thus the responsible people, with Qiuhong in focus, have to be able to plan simultaneously over different parts of the business. This will require a clear vision, profound planning and excellent communication in the existing team and with every new employee added to the team.

RQ2: How is the prior experience and knowledge of the scientist linked to his effectiveness of translating scientific knowledge into a manufacturing process?

As the case shows, the effectiveness of the scientist to design and build up a competitive manufacturing process is reliant on several main points

Firstly, it becomes obvious from the case that the effectiveness of building up the current manufacturing capabilities of Luxbright are strongly linked to how effective the researcher can leverage existing knowledge and networks. In Qiuhong's description, many events seem to have happened coincidentally, but he was quick and flexible enough to react on events and re-combine experience, knowledge and network in a way that benefitted the project. This seems to fit with the traditional explorative role of a scientist (Goethner & al, 2012). However, as much as this explorative and flexible approach has given to Luxbright, such coincident cannot be planned on. Qiuhong's scientific and professional career does not show to many strategically planned decisions, and this is also where his career experience might limit him from being even more effective in building up manufacturing processes and continuously improve quality, cost and lead time. More structured business development is required by the company, mainly triggered by external investors, customers and partners. Literature has not yet sufficiently focused on this gap between required structure and historical scientific exploration within the single scientist/ entrepreneur.

Secondly, the company profited various times from the scientific network of Qiuhong, even if unrelated to the company Luxbright itself. The first ever customer is a contact of Qiuhong he mainly acquired through other research, many of the initial ideas and development stem from scientific discussions, papers, conferences and so forth. This is unsurprising and has been discussed in various publications, e.g. (Bruderl & Preisendorfer, 1998) (Scholten, Hartmann, & Trott, 2015). At the same time, however, as strong as his network is on the scientific side, his industrial knowledge is still quite small in comparison. This is understandable seeing the timeframes he has been in both areas, but it is constantly more difficult for the company to get the foot into the door with industrial players, as long as there is no research connection found. Thus, the positive network effects become at the same time a liability, because the existing network limits the need to create new, complementary networks within the industry.

And finally, a long career in science has also influenced the way that Qiuhong perceives the value created through manufacturing. The different value creation logics, creating value

through knowledge on the one side, and creating value through business transactions on the other, can hardly be considered the same. In both fields there is fierce competition , but being able to understanding the individual positioning is key. Decisions made in research will most like lead to totally different effects if made in a manufacturing environment. Explorative processes are likely to require different reasoning than exploitative ones. However, being in the transition from one logic to the other, and having extensive experience on the research side, is certainly a challenge for the scientist Qiuhong.

RQ3: What general strategies can be found to support the scientist in the process of building up operations with the goals profitably selling goods or services?

As found throughout the study, the company is highly dependent on the scientist, his ideas, knowledge, experience and research network. On the other hand, it becomes obvious that the research needs a team supporting his activities, leveraging his capabilities, and filling the gaps not covered by him. In the following, some main topics will be listed that are in the centre of Luxbright's future development in terms of turning from a research company to a producing company.

a. Build up structure

Explorative processes need flexibility and freedom. Qiuhong has shown throughout his career that he is able to find and pursue new paths in technology and professional approach. This background has allowed Luxbright to be dynamic and flexible over the past years. However, the more the company moves towards a manufacturing focus, the more structure will be needed, both through internal needs (effectivity and efficiency of processes) and through external needs (certifications, funding guidelines, legal demands).

Building up structure in a controlled, but progressive manner will be one main task the team of Luxbright has to perform in order to make sure that Qiuhong's vast knowledge is brought to the product, and finally to the customer. Systematizing and standardising processes will be a team effort across departments and is not limited to manufacturing or R&D only. Therefore, every individual has to help implementing and optimizing these structures.

In a company created around disruptive technology, structure is often seen as risky, due to the possibility of slowing down processes. And indeed, the company needs to stay flexible. So, balancing the disruptive vision with more pragmatic needs for growing operations should be in focus, as discussed by (March, 1991).

b. Strengthen communication

Building structure and helping Qiuhong to focus on the most important tasks will be, as stated early, largely an effort carried out by the whole team. Neither single departments nor leadership alone can define such changes alone. Realizing that this tasks is no one's, also means that this task is everyone's. The team at Luxbright is young, dynamic and growing. So, in essence, a lot of the ingredients for a top-class company are there.

In the phase where the number of employees is constantly rising, and new knowledge is added to the company frequently, communication will be a central topic, especially towards supporting the founder team in their tasks. From the interviews, it can be extracted, that employees often are motivated to help to build success, but lack knowledge or support by the leading team. Improving the way information is shared within the company will thus not only help the employees become more knowledgeable, but it will also allow the founders, and especially Qiuhong, to share responsibility and work load. Using Qiuhong's resources best possible means also to extract his knowledge and disseminate it throughout the company. Vice versa, knowledge from other parts of the company, e.g. from customer interaction or supplier contact, must find its way to the researcher as well.

c. Understand and create demand

In the current situation, the company's main focus is not manufacturing. For a research-driven, young company, this makes absolute sense. Understanding and creating demand should be number one priority, only then can the product be developed and marketed effectively (Hamel & Prahalad, 1991).

In order to understand and create demand, however, new skills will be required. Technical understanding and explanation alone will hardly be enough to convince a wider audience about the product. Much more, the company needs to get into conversation with industrial

customers, but also partners and suppliers. These efforts have not been driven by Qiuhong, due to his lack of industry knowledge. However, an intelligent support structure will try to combine Qiuhong's knowledge and a better way of communicating and learning from customers. The development of the microfocus technology is one example where Luxbright learned from customers and applied internal capabilities to achieve a better fit of the product with customer needs. Ideally, such development cycles with strong customer integration will be more frequent in the future.

d. Separate leadership and management

As a co-founder, Qiuhong combines several roles inside the company. He is responsible for technical development and production, one of the leaders of the company, but at the same time performing various tasks within research and manufacturing himself. He himself clearly states in the interview, that he cannot take all those roles at once, when the company is growing and single tasks get more complex and hard to control.

Thus, clearly separating leadership tasks from management tasks is the first important step towards sharing responsibility for various activities. Becoming a true leader will also mean for Qiuhong, to step out of too many single activities. When talking about implementing structure (see above), it must also be mentioned that this requires a mental change within the founding team. Holding too close to many activities does slow down processes at Luxbright, confirmation cycles take weeks and decisions are not made, creating a backlog of unfinished tasks. However, separating leadership and management also requires fierce integration of structures as mentioned before, to make it easy and also necessary for leaders to give up some responsibility.

e. Facilitate internal learning

It has become obvious during the observation period, that the employees at Luxbright are highly motivated, however, the knowledge gaps between them and Qiuhong remains immense. This is partially due to the short period of time many employees have been with the company, but more importantly due to lack of communication and feedback. It is this communication and feedback, however, that facilitates internal learning. In a start-up

situation where resources are scarce, it is essential to leverage existing resources as effective as possible. Integrating young, motivated employees more into activities and actively guiding them through a learning process thus is a huge opportunity for the company (O'Connor, 1998).

Of course, no HR student will become research specialist in nano physics, however understanding more of what is happening is motivating for the employee and will also make it easier for Qiuhong to share some of the responsibility he is right now carrying himself. Again, this point links back to the previous ones, especially structure and communication.

f. Integrate external knowledge

Internal learning however, can only be part of the process. It can support Qiuhong in gradually transfer knowledge and responsibility to other members of the team, but it cannot create radically new knowledge. Therefore, it will be essential for the company to integrate external knowledge in fields where there is not sufficient knowledge available at the time. This notion is also supported by some literature, including (Larrañeta, Zahra, & González, 2012).

Mainly, this external knowledge stems from two sources. The market on the one side, including customers, partners, suppliers and competitors (O'Connor, 1998) (Scholten, Hartmann, & Trott, 2015). And newly hired staff on the other side (Marvel & Lumpkin, 2007). Both sources require structure and organization in order to benefit from the knowledge available. In case of market knowledge, systematic gathering and dissemination of knowledge within the company is key. And for new employees, a culture and structure that allows them to use their knowledge and share it within the existing organisation.

The personal dimension of integrating external knowledge for Luxbright is evident in two ways. Firstly, the main knowledge assets of the company are focused on Qiuhong and to some degree on Greg. Thus, external knowledge should be targeted to add knowledge to their personal knowledge bases, which also means a close interaction between external knowledge carriers and the person of Qiuhong in particular. Secondly, the existing knowledge gap between staff and leading team as well as the limited availability of the leading team make it especially hard to transfer knowledge through the existing company structure in order to disseminate external knowledge internally.

6. Implications and outlook

The case study performed is limited to the company of Luxbright. All the observations and interviews are specific to the company, the specific circumstances and most importantly the people involved. Therefore, the findings described above cannot be simply generalised for other start-ups in a similar situation. However, the example shows clearly that current research still shows a gap in investigating into the process of building up manufacturing structures from an academic-entrepreneurial point of view, where technological specialists, researchers and scientists ought to step out of their known environment. This is especially important, as the transformation process from research and development focus towards research-driven manufacturing usually happens during a phase where the young company might not have the resources and the knowledge that established manufacturers in the market have. Thus, the success of transforming the organisation is highly dependent on the individual entrepreneur, while on the other hand decisions made early about the supply chain and manufacturing logic might have significant impact on both other areas of the company, as well as on the future structure.

Existing literature, e.g. (Bruderl & Preisendorfer, 1998) (Duchesneau & Gartner, 1990), has often highlighted the importance of prior knowledge on entrepreneurial action. It has also been shown, that both market knowledge and the knowledge of industry networks and processes is crucial when commercialising research outcomes (Scholten, Hartmann, & Trott, 2015). Realising that the manufacturing process is an important part of the picture for the individual entrepreneur as well as for the company, is where this study contributes to the field. This is due to two main points: (a) setting up a competitive manufacturing process falls into a time where there is major organisational change inside of the company in many levels, and (b) the manufacturing process and its extensions into R&D, supply chain and customer contact can and should work as an important link between different organisational areas.

In the case of Luxbright, the current structure of manufacturing could be traced back quite clearly to the scientist/entrepreneur Qiuhong, following the categorization mentioned earlier by (Würmseher, 2017). Although this might be specific to the case, it seems quite natural that the technical development team handles early manufacturing and thus pre-defines later manufacturing processes in such research-driven young ventures. Therefore, the link between

the scientist/entrepreneur and the ventures manufacturing capability should be investigated in more cases. Getting a more complete picture of different companies in different business areas and countries might enhance the knowledge about those arguably interrelated processes of research and manufacturing. Moreover, a more in-depth approach and longer time frames of observation could help to understand not only the links, but also the consequences of the scientist/entrepreneur and the manufacturing capabilities of ventures. More general, this study and the ones following the approach might contribute in understanding how different functions within a venture do influence one another over time, and how does influences are due to single individual actors like Qiuhong in the example of Luxbright.

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Appendix

Appendix 1 Interview Guide

Block 1: personal background

- Where are you coming from (education, experience)?
- How did you get involved with Luxbright and how long have you been here?
- What is your role at Luxbright (on paper/ actual)?

Block 2: Main Challenges for Luxbright

- What are the main challenges for Luxbright in the near future (2 years' timeframe)?
- What capabilities will be important therefore?
- How far is Luxbright on the way to fulfil its near-term goals?
- Which people are most important to fulfil those goals and why?

Block 2: Driving Forces at Luxbright

- Who are the central people at Luxbright and why?
- What exactly do they contribute?
- Are they contributing effectively?
- What do you think is important to make does people deliver, what needs to be done in the organisation?
- Are there any things in the current organisation that might make it difficult for those people to deliver?

Block 3: Involvement in development and manufacturing

- How are you involved in the development process of the product?
    - What is your experience with such development processes?
    - Will you contribute more or less to the development process in future?
- How are you involved in the production process at Luxbright?
    - What is your experience with such processes?
    - Will you contribute more or less to the development process in the future?

Block 4: The current state of development

- How far, in your opinion, is Luxbright with the development of its product?
    - Specify why you think so, what should be done, what are the challenges…
- What are the next steps of development, and when are they achieved?
- How is this reflected in the employee structure (who is responsible, for what, until when)?

Block 5: The current state of production

- How far, in your opinion, is Luxbright with the production process of its product?
    - Specify why you think so, what has to be done, what are the challenges…
- What are the next steps with the production process, and when are they achieved?
- How is this reflected in the employee structure (who is responsible, for what, until when)?