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Contrasting similarities and differences between academia and industry: evaluating processes used for product development

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Abstract: The purpose of this paper is to explore the process-based similarities and differences between academia and industry projects engaged in product design and development. The literature discusses similarities and differences between various product development processes but there is little published regarding the methods used, the time spent in different stages, iterations between stages and the nature of the activities that happen in each stage in academia and industry. To investigate this two case studies of product development; one from academia and one from industry were contrasted using the framework of Ulrich and Eppinger's product design and development process, combined with Frayling's research model into, through and for design. This paper visually maps the differences and similarities between academic and industry product development processes used in timber products and construction sectors.

Keywords: Industry; Academia; Product Design and Development Process.

1. Introduction

There have been many attempts by academics to model a satisfactory description of the design process as highlighted by; Wynn and Clarkson (2005); Howard, Culley and Dekoninck, (2008); and Cross (2008). "A key weakness of all the literature reviewed… is the difficulty of application to real design problems" (Wynn & Clarkson, 2005, p.55). There is a lack of comparative studies that measure the similarities and differences between how a design process is used in academia and how the same design process is used in industry. To address this gap, the authors introduce Ulrich and Eppinger's (2012) product design and development process and Frayling's (1993) research into, through and for design model to highlight how these models were used in an academic design-based PhD project. An

Australian SME was interviewed to identify and compare the process used in industry. The industry process and research findings were aligned with Ulrich and Eppinger's (2012) product design and development process and Frayling's (1993) research into, through and for design model to identify obvious discrepancies between the processes used in academia and industry. The purpose of this study is not to detail the product outcomes developed by academia or industry, rather it is to highlight key elements that influence the product design and development process. The importance of this is because the share of basic funding for universities is decreasing, forcing more universities to engage with industry. This is substantiated by data from HERDC where between 1993 and 2013 (20-year period) National Competitive Grant (Category 1) funding for Australian universities increased by 492 per cent (HERDC 1992–2013), however between the same period, the total industry and other funding (Category 3) for Australian universities grew by 685 per cent (HERDC 1992–2013). This data shows the importance of Category 3 income for universities, as while both categories are growing, it is the industry funding that is growing faster. Because of this, more industry-linked projects will be encouraged, making it important to show others how this form of research is conducted within the context of a university.

2. Academic product design process

There are multiple product design and development process models that attempt to illustrate the design process. According to Cross (2008, p.29) the process is heuristic where experience and general guidelines are used to inform design decisions. In its simplest form Cross (2008, p.30) noted the design process follows a four stage sequence: exploration, generation, evaluation and communication where an iterative feedback loop between evaluation and generation exists. Cross (2008, p.30) stated the design process is often presented as flow-diagrams because the design journey is clearly illustrated in this form, demonstrating direction and necessary iterations between process stages informed by feedback or new knowledge. All design process models demonstrate in one way or another the sequence of design activities to develop products. These processes are generic and are used by industry (product manufacturers) and academia (design researchers). For the purpose of this study Ulrich and Eppinger's product design and development process (2012) was chosen to direct and manage the design activities used in an academic PhD project.

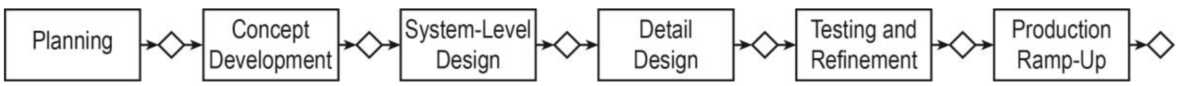

Figure 1 The generic product development process (Ulrich & Eppinger, 2012, p.14).

"A product development process is the sequence of steps or activities that an enterprise employs to conceive, design, and commercialise a product" (Ulrich & Eppinger, 2012, p.12). Ulrich and Eppinger (2012) summaries the generic product design and development process in six phases; planning, concept development, system-level design, detail design, testing and refinement and production ramp-up (p.13-16). These stage descriptions can be summarised as: planning (identify opportunities), concept development (generating ideas), system-level design (define product architecture), detail design (detail product genetics), testing and refinement (preliminary construction and refinement) and production ramp-up (transitioning to full production). Like most design process models the generic stages can be interpreted to suit the project at hand. Ulrich and Eppinger noted their model could take the form of a spiral design process.

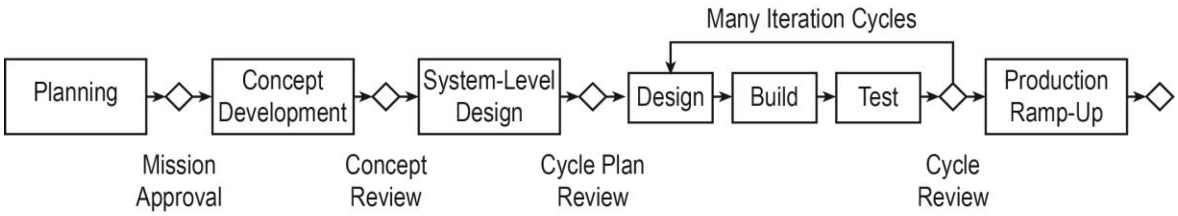

Figure 2 A spiral product development process flow diagram (Ulrich & Eppinger, 2012, p.22).

The spiral product design and development process presented in Figure 2 follows the same stages as presented in Figure 1, however an iterative cycle is highlighted like Cross's (2008) simple design process. The purpose of Ulrich and Eppinger's (2012) design process model used in the academic design-based PhD project was to assist the development of a commercially viable product for industry. The PhD design process also aligned with a design research model. Like the product design process there are multiple examples of research models that exist. Frayling's (1993) research into, through and for design model was chosen in the PhD project because it emphasises the development of a design artefact that is intended to communicate a new contribution to knowledge to its audience. Frayling's (1993) research model is categorised in three areas of design research: into, through and for design.

Figure 3 Frayling's (1993, p.5) research into, through and for design model.

Research into design considers the existing literature and historical evidence of products. Research through design is the use of design skills to practice design to find and embed new knowledge into the product design and development process and research for design is the presentation of the design artefact/outcome to demonstrate the contribution to knowledge. This alignment of the research model and the product design and development process is illustrated in Figure 4.

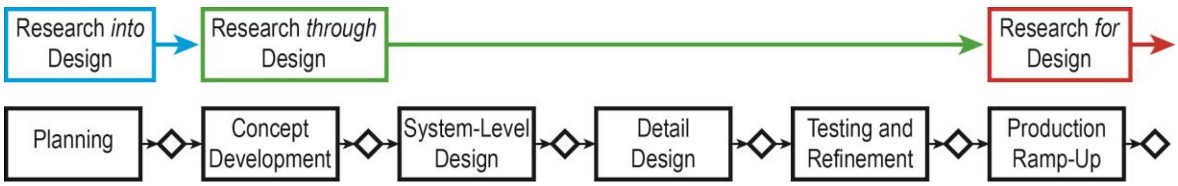

Figure 4 Alignment of Frayling's (1993, p.5) research into, through and for design model with Ulrich and Eppinger's (2012, p.22) spiral product design and development process.

The merging of Ulrich and Eppinger's (2012) product design and development process with Frayling's (1993) design research model was used in the academic project presented in Case Study 1. The following section introduces the background of the two case studies used in this paper.

3. The research framework

Case Study 1 is about product development for the Papua New Guinea (PNG) balsa wood industry. Initial planning and research identified the PNG balsa industry currently has an over-supply of balsa grown by smallholders. The lack of design innovation and product development has led to a lack of international demand for the resource generating financial hardship to smallholders and industry processors in PNG. The objective of the design PhD was delivered through a research question – How can research-led industrial design practice generate and communicate knowledge for PNG balsa? This PhD study was used to develop a commercially viable product for the construction industry to generate international demand for PNG balsa, thus rectifying the current hardship to smallholders and the PNG balsa industry. Research and design methods, reflective practice and feedback loops were used to direct the product design and development process. Similarly, Frayling's (1993) design research model determined the nature of the activities conducted at each design process stage.

The academic project presents the product development process featured in a PhD study, exploring how research-led industrial design practice can lead to new commercially viable applications for PNG balsa and communicate a new contribution to knowledge. The design based PhD followed Ulrich and Eppinger's (2012) product design and development process and Frayling's (1993) research model to demonstrate the use of design skills to identify commercially viable product solutions that are needed to answer the research question. Traditional research methods — external to the design discipline — were used to find information that informs the product design and development process. Design research methods were implemented to source primary information to inform the process and were used to embed and communicate new knowledge into new products to reach a wider audience outside of academia and design. The role of the research model was to help substantiate the use of design to communicate a new contribution to knowledge and to maintain academic research rigor. The role of the product design and development process similarly, was to learn through practice, generate new knowledge and embed that knowledge into commercially viable products that provide solutions to society and associated industries.

Case Study 2 presents an Australian SME timber product manufacturer and distributer who was interviewed in this study to identify the typical industry product design and development process. The interview was 40 minutes long and conducted at the industry's manufacturing plant. This particular enterprise was sourced as they are experienced timber product manufacturers and suppliers to small-medium post manufacturer enterprises and the construction industry. Interview questions inquired about the typical product development process the company uses when a client delivers a brief. The research participant was not introduced to Ulrich and Eppinger's (2012) design process or Frayling's (1993) research model to avoid influencing the participant's response. The journey from client brief to delivering the product was discussed and documented. Questions about project iterations such as feedback loops and client interactions were also highlighted. The time spent on each stage was discussed and justified to indicate the level of importance of a particular stage. After the interview and without the research participant the interview results were transferred to Ulrich and Eppinger's (2012) product design and development process to directly compare similarities and differences between the same process used in academia and industry. In addition the research findings highlighted the resources consulted, time spent in different stages, iterations between stages, activities that happen in each stage and the type of design research — into, through or for design — conducted at each stage.

4. Case study 1: Academic product development process

Case Study 1 presents the product design and development process used in academia. This process was used by the authors to develop a new product for the PNG balsa industry which was analysed through reflective practice. Figure 5 maps out the process according to Ulrich and Eppinger's (2012) and Frayling's (1993) process models. The activities conducted in each process stage are listed. Process iterations and the general flow of information and product development are highlighted with black arrows. The time spent at each process stage is given as a percentage under the product design and development stages and the overall time spent on the type of research — into, through or for — is highlighted above Frayling's (1993) design research model stages.

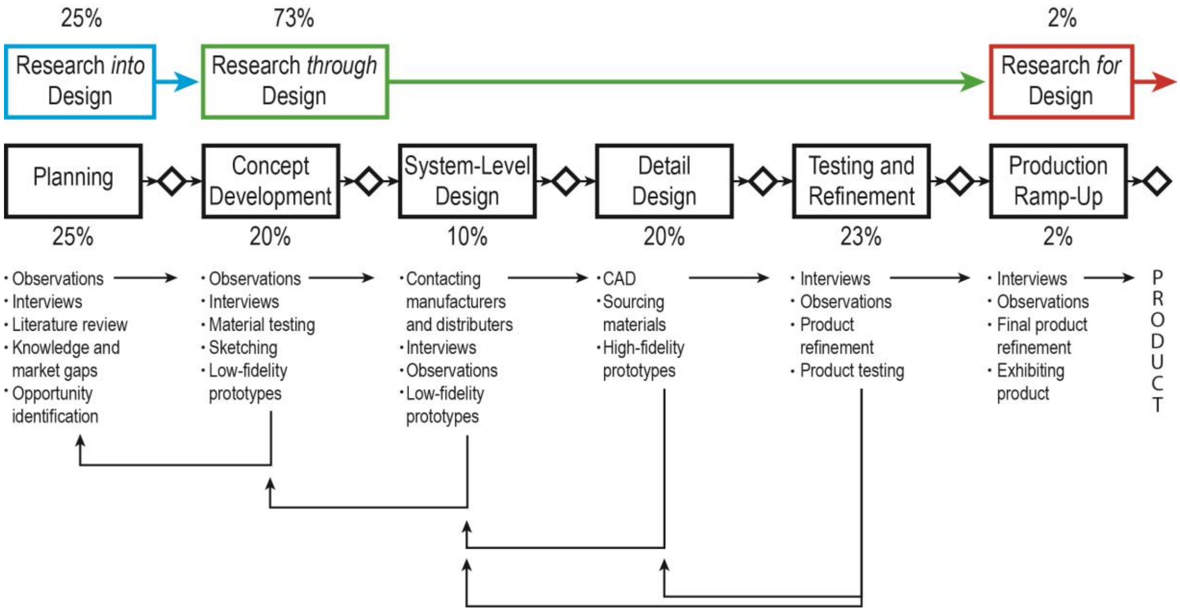

Figure 5 Product design and development process used in academia

Four key research methods were employed in this project: observations, interviews, material testing and prototyping. Observations and interviews were used extensively with industry practitioners to identify opportunities, gather industry tacit knowledge to inform the product design process and for feedback on the product being developed. Material testing was used to determine the properties of PNG balsa and prototyping was used to communicate research findings in product form.

Iterations typically reverted back one stage to reconsider new knowledge attained along the design journey. As previously presented in Ulrich and Eppinger's (2012) spiral design process a larger iteration between testing and refinement to system-level design was necessary to implement product test results into low and high-fidelity prototypes. These prototypes were used to communicate new knowledge to industry practitioners for product feedback in order to assist the product detailing and refinement process. Some iterations involved interviewing participants a second time to review feedback and other iterations were evident to refine product genetics because of newly found research results or product tests.

Figure 5 also demonstrates the process breakdown using Frayling's (1993) research into, through and for design research model. Research into design was the planning stage of the process to identify market gaps and opportunities. A review of the literature, observations and interviews were first used to provide evidence that the research problem existed. The literature highlighted knowledge gaps and informed the need to conduct observations and interviews with industry practitioners to begin identifying project opportunities. The academic product design process heavily invested time in conducting research through design practice to develop new knowledge so it can be embedded into a product outcome. The majority of the design process from concept development to testing and refinement was categorised as research through design – almost three quarters of the project. Design skills such as sketching, low and high-fidelity prototyping, CAD and product testing were used to research through design to communicate new knowledge and ultimately to develop a commercially viable product outcome. Research through design was also used to generate new knowledge through process reflection and product evaluation. The remaining proportion of the project was dedicated to research for design. This area of research was used to promote the new knowledge contribution embedded into the artefact. Less time was spent on research for design because the focus of the PhD was to use industrial design practice to develop new knowledge and embed that knowledge into a commercially viable product. The communication of product manufacturing and detailed product specifications for commercialisation was not the focus of this project as it would be for industry production. The manufacturing process was considered and documented in the production ramp-up stage, however the time spent on research for design was far less than research into and through design.

5. Case study 2: Industry product development process

Case Study 2 presents the product design and development process used by an Australian SME timber products manufacturer and distributor to the construction industry. Figure 6 maps out the process.

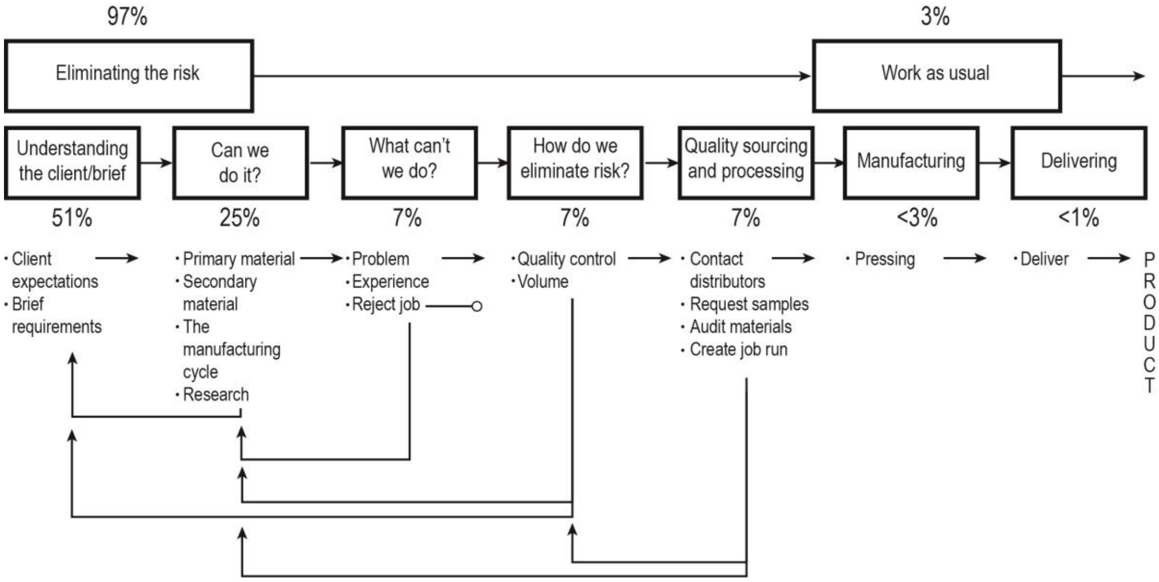

Figure 6 Product design and development process used by an Australian SME.

Ulrich and Eppinger's (2012) design process and Frayling's (1993) research model were deliberately not introduced to the research participant. This allowed the participant to communicate and illustrate the typical process the SME normally uses. The process stages, activities, iterations and time spent on each stage was collected through an in-context interview using design probes to map out the product design and development process used by the SME. This information was then transferred to Ulrich and Eppinger's product development process so a direct comparison could be made with the academic process. The primarily purpose of the above process was to eliminate the risk of damaging company quality reputation and financial losses. The majority of resources are used early in the process to understand client expectations and what is needed to satisfy the brief. The following stages consider the variables which may affect the ability to satisfy the client and brief. Once the project constraints and considerations are addressed and the company is confident that the risk is eliminated the job is created. The remaining stages are work as usual – product manufacture and deliver.

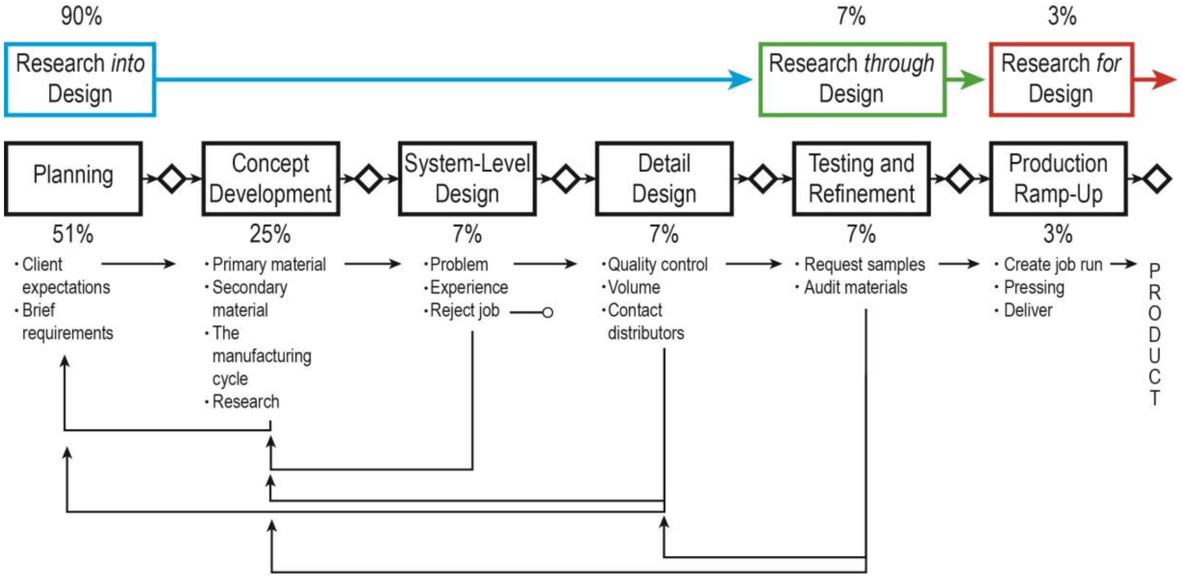

Figure 7 Product design and development process used by an Australian SME aligned with Ulrich and Eppinger's (2012) and Frayling's (1993) process models.

Figure 7 presents the same data however the industry process was mapped using Ulrich and Eppinger's (2012) design process and Frayling's (1993) research model. While the iterations between the stages were unchanged some of the activities in the later process stages were merged or moved to another stage.

Key to the success of the industry job was understanding the client's expectations and the brief deliverables. An exceptional amount of time and resources are spent building a relationship with the client to develop trust between the two parties. The majority of the methods used in this process were used to justify the ability to deliver products to a client that are commercially achievable and economically beneficial to the manufacturer. Once a relationship was established between the client and the manufacturer the process typically proceeded by answering key questions identified as stages in Figure 6; Can we do it? What can't we do? How do we eliminate risk? The concept development stage focused of what the manufacturer could do. The system-level design broke the product down into components to identify what the manufacturer cannot do. If 'what cannot be done' is a significant process block, the manufacturer would go back to the concept development stage to reconsider other ways of satisfying the client brief. It is rare that a job would be rejected after the planning stage due to the amount of time invested in building a relationship with the client, however sometimes solutions cannot be found to solve a problem and the manufacturer must reject the job or they may risk tarnishing their reputation. The detail design stage considers how the manufacturer eliminates the remaining risk. The activities identified in this stage are key to ensuring the product is suitable for manufacturing, high quality products are achievable and the components/materials are reliable. These first four stages of the product design and development process are considered research into design because the level of planning to ensure the manufacturing process runs smoothly is prioritised. The next stage, research through design is significantly smaller. This stage is the final checkpoint prior to manufacturing a client's product. Material tests and pre-production trials are conducted to ensure quality. The final stage – research for design is considered the 'no risk' area. This stage is the procurement documentation of the job and the commitment to full production. The participant noted "this stage is our profession… to us this is easy, we do this every day. The hard part is eliminating the potential 97 per cent risk before you commit to production".

The iterations illustrated in Figure 7 was recognised as constant feedback to the client to ensure the job remained on target. The process of product design and development continues as much as needed to satisfy the client and guarantee the job will be successful and profitable. Unforeseen constraints and considerations need to be rectified prior to committing to full production. If alternatives are available and the client is happy to reconsider their original demands then the job continues. If materials or manufacturing techniques require additional research the process is reverted back to the start to ensure they are incorporated into the job. Once full production is committed the process becomes linear and the job is complete.

6. Discussion

This section directly compares four elements of the product design and development process: the methods used, time allocated to each stage, iterations between stages and the nature of the stage. Each figure presented in this section highlights what was done in academia (top), the process stage (middle) and what was done in industry (bottom).

The results shown differed a great deal when comparing the role of design practice in academia compared to that of industry for product development. Academia uses design practice to create new knowledge and products, where design practice takes on a research role through risk taking. Industry however uses design practice to prove a product can be manufactured, where design practice takes on an engineering role to eliminate risk. In some occasions the use of design can be limited in industry when a client has predetermined the outcome, however it is up to industry practitioners to execute the product to satisfy the client. It is also important for industry practitioners to incorporate controlled risk taking to offer innovative products and outcomes when problems or opportunities arise. Although design is used in industry for its creative nature this is not its only purpose. The case studies presented in this paper are context specific. The industry product design and development process example used in this paper demonstrates the goal of product development in industry, which is ultimately to satisfy a client's brief even if that means the role of design is to engineer a product outcome. Regardless if a product is predetermined by a client the creative capacity of a designer is still required to execute the tangible outcome. Similarly the methods used in the academic product design and development process can take on more of a research role than a design role. This demonstrates the importance of product design, as it can be applied and adapted to either area. Ideally a balance between the two would ensure research informs the need to practice design and through design practice, a well-refined product can be developed.

6.1 Methods

The methods employed by design researchers are used to answer design research questions where the findings fulfil knowledge gaps. The methods used by industry practitioners are used to satisfy a client and their brief. The methods used in the academic project were typical design research methods (sketching, prototyping, CAD and product testing). The purpose of the methods was to generate new knowledge to inform the product design and development process and communicate new knowledge embedded into commercially viable products. Observation and interviews were used in almost every stage of the design process to gather product feedback. Material testing was practiced early in the design process to inform concept development and product testing was conducted later in the design process to justify the performance and competitiveness of the developed product. Prototypes were used to communicate ideas and observe industry interactions with the product. Moreover knowledge was attained through practicing design skills to develop a new balsa product that could not have been identified without physically executing an idea as a tangible prototype. Industry methods were less repetitive and did not seek external feedback to satisfy the clients brief. Industry practitioners contacted clients to reassure them that the planning and concept development would satisfy their brief deliverables. The methods used by industry are safe. Detailed research and material testing has already been conducted by suppliers and clients. The relationship built early in the design process places a level of trust into the client's ability to inform industry of what they want. Industry therefore use their experience to overcome problems, offer alternatives, control the quality of the outcome and produce a quality end result.

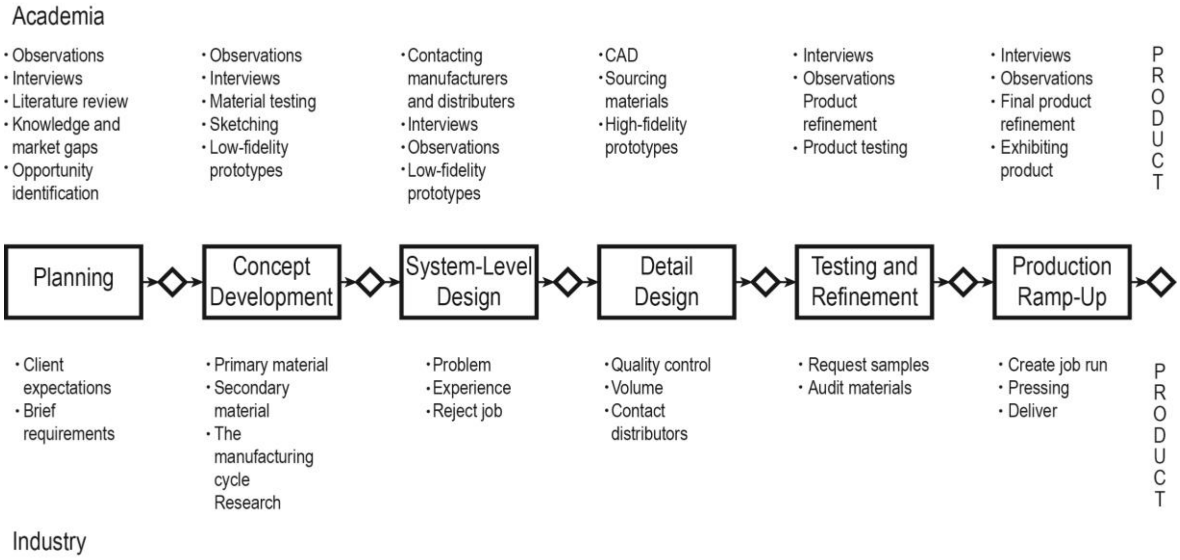

Figure 8 Methods used at each stage of the product design and development stage: Academia (top) vs Industry (bottom).

6.2 Time

A significant difference in the time spent on each stage of the product design and development process is evident in Figure 8. The obvious dedication to planning and relationship building early in the design process was noted in industry. This stage is imperative for industry as it dictates whether or not a job is accepted. By comparison the planning stage was used in the academic project to review the literature and identify opportunities, knowledge and market gaps. This highlights the academic planning stage is used for problem finding whereas industry uses this stage for relationship building and identifying a commercially viable opportunity. The concept development stage has similar goals. In academia the concept development stage required additional research to justify the appropriateness of early concepts, and in industry practitioners begin to consider the elements that are appropriate for concept development to satisfy the client's demand. Similarly, the system-level design stage is used to overcome early problems. Both professions use experience and tacit knowledge to justify the success of early concepts. Due to the level of experience this stage is usually resolved quickly. The detail design stage was prominent to developing high-fidelity prototypes in the academic project. CAD and full-scale prototypes demonstrated the product genetics from materials, tooling, assembly and the quality control. Less time was spent on this stage in industry because of prior experience and existing relationships. The testing and refinement stage again was imperative to proving the product functioned and was competitive for the product development process used in academia. Industry is well aware of what is accepted as 'industry standard' therefore they are aware of what clients/consumers minimum expectations are. For an academic who has less experience in timber products and the construction industry, comparative testing is required to determine the benefits of the new product outcome in order to understand if it is viable. A similar time frame was dedicated to the production ramp-up stage. The academic process focuses on knowledge generation and the communication of that knowledge. While the manufacturing process is imperative to the success of a product developed, less time is dedicated to documenting how a product should be manufactured because industry will typically manufacture a product their way which is determined by available facilities, experience and skills. The process of manufacturing for industry is everyday work and has been proven time and time again. The time spent documenting the production process was less of a concern to the academic project and experienced industry practitioners are already well aware of what works and what fails.

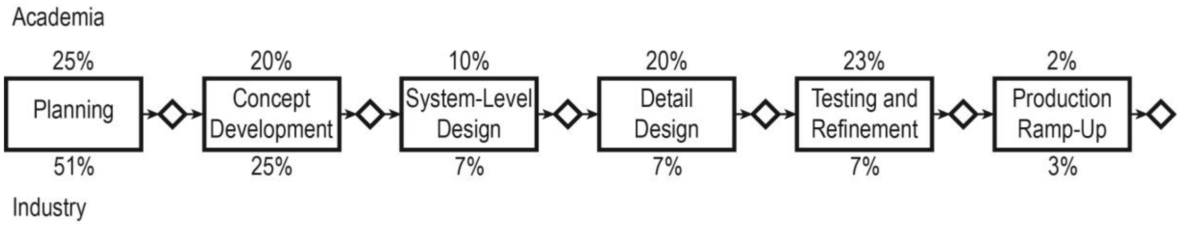

Figure 9 Time spent at each stage of the product design and development stage: Academia (top) vs Industry (bottom).

6.3 Iterations

The iterations presented in academia and industry are repetitive. Figure 10 demonstrates the iterative process flow of each project. The number of iterations is not presented however the transition from a process stage to the other stages is illustrated. Noted in the academic project most of the iterations repeat from the testing and refinement stage back to the system-level design stage. Unlike the industry process the concept development stage is only reverted back to the planning stage during the early stages of the design process. Most of the interactions occur during the product testing, where new knowledge is fed back to the system-level design stage for product refinement until the desired product is achieved and then set up for production ramp-up. The iterations evident in the industry process typically revert back to the concept development stage. This is because this is where industry knows what they can do. The system-level design stage is the problem stage. This is where industry identifies what they cannot do; hence the reject job is denoted with a circle arrow. The detail design stage often reverts back to the planning or concept development stage to offer alternative products to clients or to start the product development process again. Another iteration is from testing and refinement to detail design. This iteration is typically used to finalise product details prior to committing to production ramp-up.

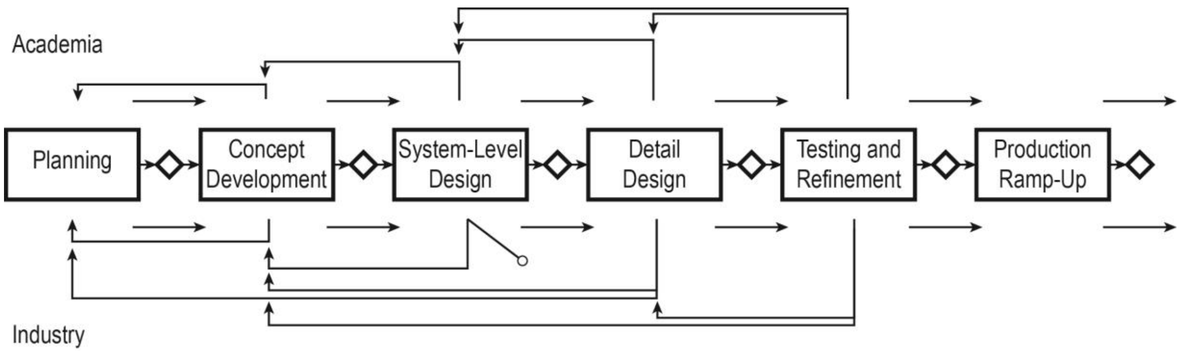

Figure 10 Iterations between each stage of the product design and development stage: Academia (top) vs Industry (bottom).

6.4 Nature of activity

The final variable is the nature of the activities conducted in each process stage. Frayling's (1993) research into, through and for design was used to evaluate what the intentions of the activities at each stage were. The academic process used the planning stage to justify the existence of a research problem and to identify opportunities. Historical product evidence, a review of the literature and preliminary methods were used to research into design to inform the need to practice design skills/methods. Concept development through to testing and refinement where used to practice design to generate new knowledge and embed that knowledge into products. Production ramp-up was therefore used to communicate the embedded knowledge to a wider audience. The nature of the industry process differed as the majority of the design process was used to eliminate risk by better understanding the constraints and considerations of the client and the brief. Only in the testing and refinement stage does industry use practice to research through design to communicate that the job is commercially viable. Different to academia, research for design was used by industry to communicate the production process of the product not to present a new body of knowledge.

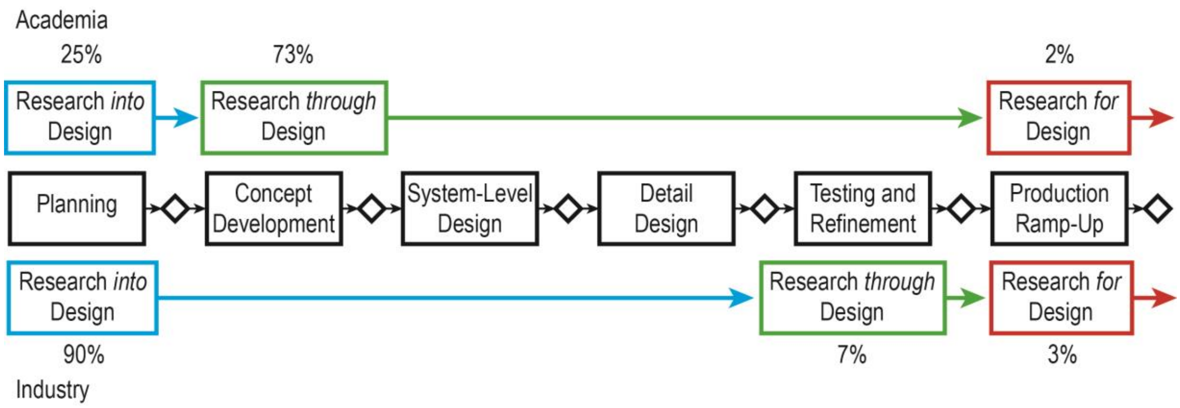

Figure 11 Type of research activity at each stage of the product design and development stage: Academia (top) vs Industry (bottom).

7. Conclusion

The differences and similarities presented in this study are context specific to the case studies presented. Industry relies on relationships and reputation; they play it safe through experience and repetition and prioritise eliminating risk. Academia relies on finding problems worthy of design research, taking innovative risks and developing new knowledge that is embedded into commercially viable products. It is the intention that this study will offer a comparative model that can be used by industry and academia to compare other design processes used for product development.

Further research on other industries and more examples of product development would be useful to defining the obvious similarities and differences between academia and industry. The success of the product and what it means to be successful is also worthy of further research. The difference in design and manufacturing processes would also identify different ways of getting to the same product development goal.

This study measured the similarities and differences between the same product design and development process used in an academic design-based PhD project and an industry product design and manufacturing project. The methods used, time spent on each design process stage, process iterations and the nature of the activities were presented. The academic project presented differs to the industry project by focusing on new knowledge generation where that knowledge is embedded into commercially viable products. Industry focuses on maintaining a quality reputation and building relationships with clients. The majority of time is spent planning, identifying opportunities and eliminating risk in industry projects. Academic design-based projects however spend more time identifying knowledge gaps and generating knowledge through research-led design practice.

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